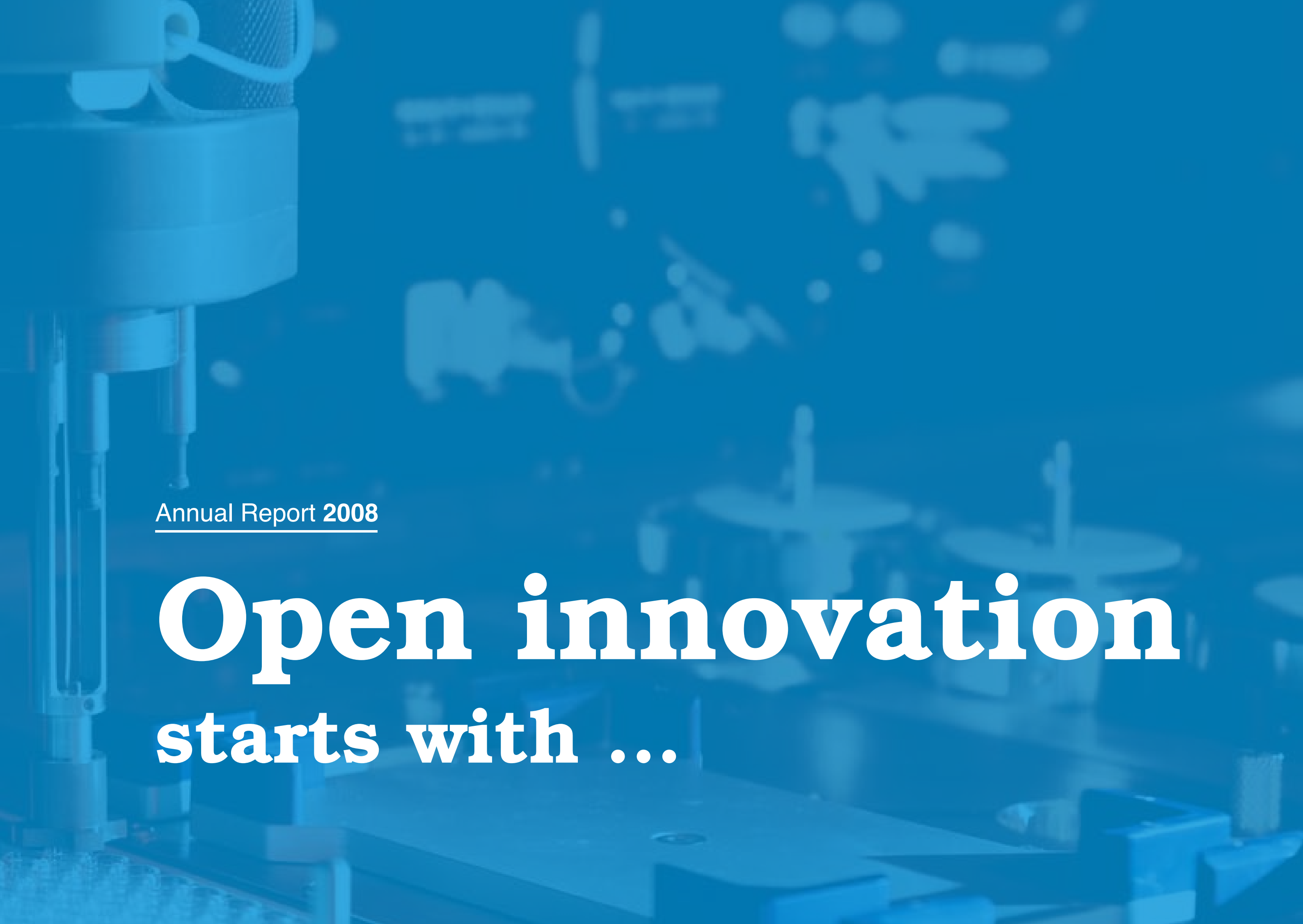
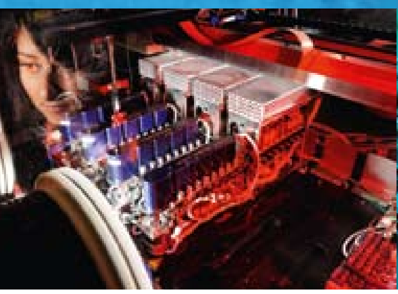
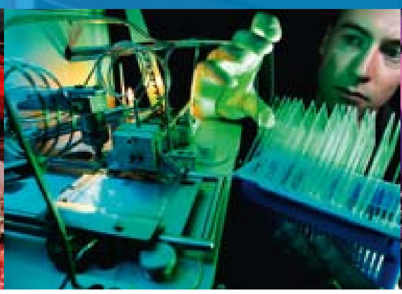
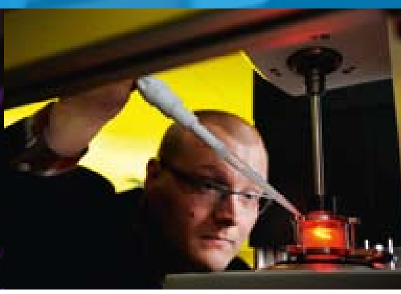


Annual Report **2008**

Open innovation

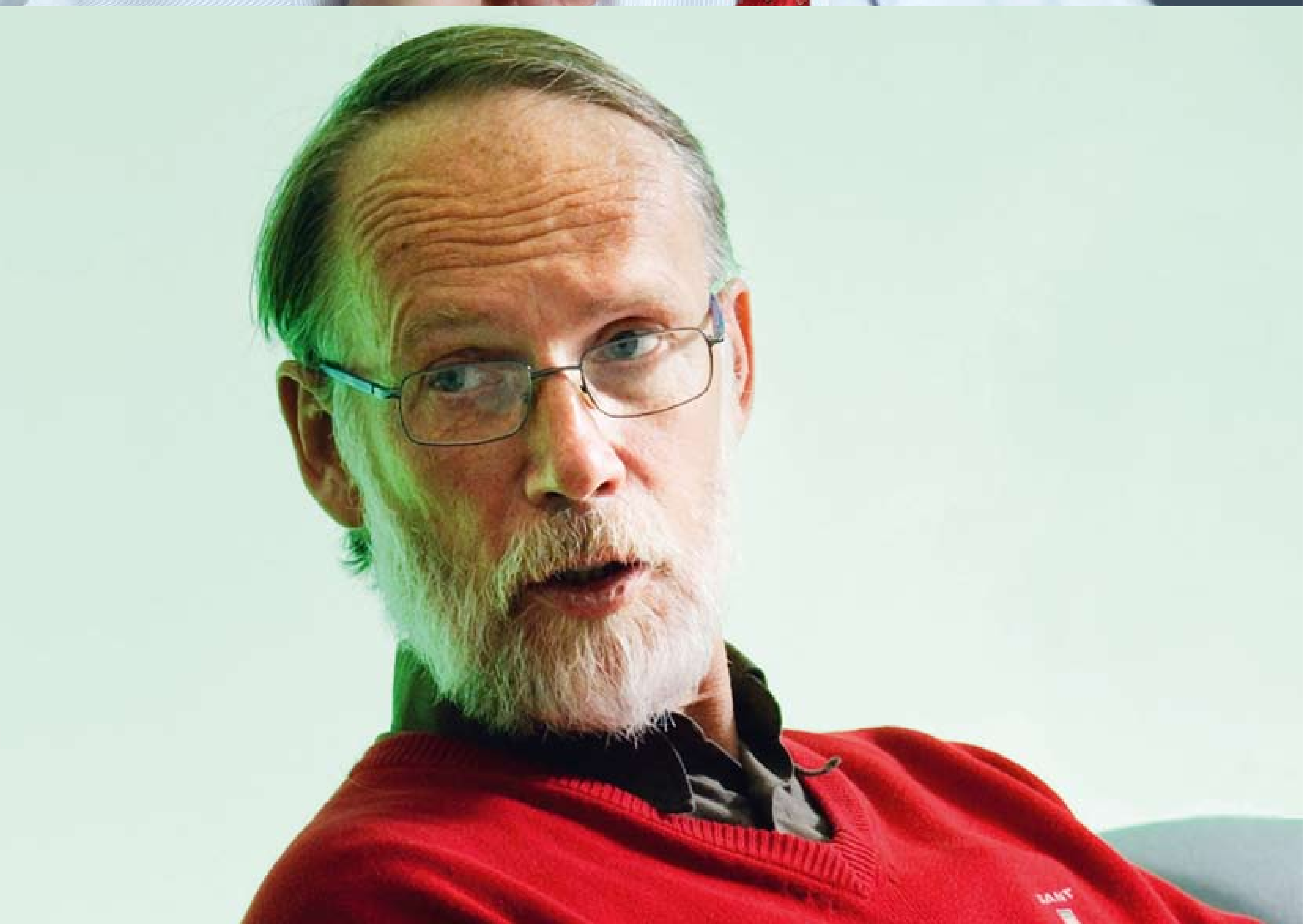
starts with ...



DPI
DUTCH POLYMER INSTITUTE

Inspiration ...



Introduction
Open innovation starts with inspiration

Not a day goes by that does not bring us new sources of inspiration – things we read, things we see around us and especially the thoughts and experiences that other people share with us. This inspiration leads to fresh ideas, which we often get at moments when we are not focused on our work. And these new ideas in turn are the seeds for new innovations. In short, innovation begins with inspiration. This is especially true in the case of open innovation, the theme of this annual report, in which several parties collaborate and inspire each other.

The Dutch Polymer Institute (DPI), founded more than a decade ago, aims to promote high-calibre research in the field of polymers so that more students graduate in polymer subjects and more ideas for polymer processes and polymer products come to fruition. We have already partly achieved these goals, but at the same time we are well aware of the new challenges ahead of us. For example, as a result of the growing need for alternative feedstocks, the interest in (bio)polymers will only grow in the years to come.

Collaboration
Last year we once again proved that it is possible to conduct high-calibre fundamental research based on needs expressed by industry. We also succeeded in breaking down the barriers between the research groups of industrial companies, universities and institutes and initiating collaboration between these groups. But high-quality research alone is not enough. We want this research to have an impact, to lead to new innovative processes and products in both large and small companies. Open innovation can accelerate this process, and the DPI Value Centre can play a key role in this.

> **“Over the last decade DPI has consistently worked towards open innovation.”**

Open innovation
Over the last decade DPI has consistently worked towards open innovation. During the first few years, the process of converting innovations in the ‘proof of principle’ stage to new processes and products mainly took place within large companies. DPI played only a modest role in this process and was primarily responsible for coordinating the pre-competitive scientific research. The foundation of DPI Value Centre in 2007 was a step forward towards open innovation. Using knowledge made available by universities or large companies, new businesses can start up or existing SMEs can expand their activities. Small, medium-sized and large companies mutually benefit from this collaboration; in this sense they might be said to form a kind of eco-system. DPI Value Centre plays an important role in this system in that it brings the various parties into contact with one another and provides practical advice. We have deliberately opted for an

organizational division between DPI and DPI Value Centre, because fundamental research and generating business options have different time horizons and require different people. We are gradually seeing more synergy building up between large and small companies as a result of the activities of DPI Value Centre. The essence of the whole set-up is that DPI coordinates excellent research and DPI Value Centre complements this with initiatives to ensure that this research will have an impact on society. In 2008 both organizations devoted a great deal of effort to the further professionalization of their activities.

Polymer Innovation Programme

A very important initiative in the polymers field is the Polymer Innovation Programme, for which DPI can be said to have laid the basis in the past few years via public-private partnership in polymer research. With this new programme, the Dutch government is showing that it recognizes how important polymers are for sustainable economic growth and that it is willing to provide financial support to stimulate innovation in this field. In early September 2008, Maria van der Hoeven, the Dutch Minister of Economic Affairs, officially launched the programme. She expressed her enthusiasm about the content of the programme and made an appeal to everyone in the polymer sector to help develop polymers based on renewable resources. In this way, the polymer sector can make a major contribution to sustainable economic growth. Mrs. Van der Hoeven's ministry is making available nearly € 50 million euros over a period of four years to fund innovative research and new business development in the field of polymers. A large part of this money has been earmarked for the pre-competitive research to be carried out by DPI. A smaller part will go to projects of DPI Value Centre. So DPI and DPI Value Centre will carry out the programme, in collaboration with SenterNovem, an agency of the Ministry.

"The research carried out by the scientists working for DPI is of an excellent quality."

Accountable

In order to be able to monitor the quality of the implementation of the Polymer Innovation Programme, we will this year carry out an initial evaluation, as a kind of baseline measurement. After two years we will carry out a more comprehensive evaluation, based on key performance indicators, and report the outcome to SenterNovem. In this way, we will be able to account to the government for the implementation of the programme. We have meanwhile reached agreement with SenterNovem about the 'rolling finance model'. From now on, projects carried out in the context of the Polymer Innovation Programme will be evaluated every two years, and on the basis of this evaluation the stakeholders will make a commitment (including a financial commitment) for the next four years. Most of the projects are PhD projects for which universities, companies and now also the government make a four-year commitment. The four-year commitment is a bold and praiseworthy move on the part of the Minister.

Excellent research

According to the Science and Technology Indicators Report 2008 published by the Netherlands Observatory of Science and Technology (NOWT), DPI's scientific research has a citation impact score of 2. This means that the research carried out by the scientists working for DPI is of an excellent quality. On 1 January 2009 Prof. Martien Cohen Stuart became Scientific Director within our Executive Board. He will devote a large part of his energies to the further improvement of the scientific merit of the programmes and the output, among other things by introducing a Fellowship programme. In the autumn of 2009 we will have DPI's research reviewed by the Scientific Referee Committee, an international committee of experts. We will use the results to identify new opportunities and to improve our current activities.

Keeping the innovation momentum going

As a result of the economic crisis, the DPI partners (and definitely potential partners) might be less inclined to make new commitments. At the end of 2008 we anticipated this development. In consultation with a number of large companies we identified a number of highly promising projects that companies are currently forced to put on the backburner or postpone. We are transferring these projects to DPI Value Centre and have dubbed this initiative "From crisis to

"There is a great need for innovation, and innovation starts with inspiration."

opportunity". Via the Polymer Innovation Programme we can assign researchers from universities and knowledge institutes to these projects, and possibly also R&D people from the companies that have transferred their projects to us. The projects are expected to be of a high quality, otherwise the companies would not have selected them for their R&D portfolios in the first place. This means we can make a quick start with them. In this way, the government can provide extra support to industrial innovation, using an existing scheme for which the funds have already been set aside or can be front-loaded. Admittedly, a company that offers knowledge under this programme will have to make concessions in the field of IP if it wants to commercialize this knowledge. But this is a better option than shelving a promising project. In this way, DPI helps keep the Dutch polymer industry's innovation momentum going in these turbulent times.

Economic added value

Thanks to the excellent research, with an increasing business impact, that we carry out in the field of polymers, we are well on our way to meeting part of the objectives for the Chemistry Key Area. New business in the field of polymers is expected to generate €2.5 billion in extra added value for the Dutch economy by the end of the next decade. In addition, novel polymers will account for 30% of the 50% reduction in the use of fossil resources that the chemical sector wants to achieve within 25 years. One of the ways of reducing the use of fossil fuels is by developing polymers based on renewable raw materials. These bio-based polymers form an important new spearhead in DPI's programme.

Young DPI Community

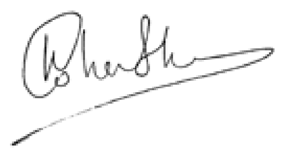
International contacts are very important for the quality of DPI's research. DPI establishes these contacts not only by attracting young graduates for research projects but also by building an international knowledge network. This is greatly facilitated by the fact that DPI is a virtual institute. We do not require top scientists to come to us to carry out research together under one roof; we come to them. This means that it is no problem if one of our scientists, for example a professor, moves to a foreign country. We simply continue the relationship and continue involving them in our research projects, wherever they are in the world. This is what makes the virtual model so powerful. In order to reinforce the relationship with our members and add an extra network, we decided to establish a 'Young DPI Community'. To this end, prior to the annual DPI meeting in 2008 we organized a meeting that was attended by 60 young graduates. Both the participants and the organizers considered it a highly inspiring meeting. Borealis showed itself to be the perfect host for both events. We would like to thank them for this, and compliment them on this success.

Thinking differently

One of our main current challenges is to develop new sustainable materials. There is a great need for innovation, and innovation starts with inspiration. A very powerful source of inspiration is the Cradle to Cradle concept. This represents a paradigm change: instead of thinking 'linearly' in terms of 'from cradle to grave', we might start thinking in terms of closed loops. This approach will give us a new perspective on the use of energy and materials. By viewing these as interrelated issues we can develop new ideas that might lead to breakthroughs. As an internationally renowned institute, DPI can and will make an important contribution in this field. Our position gives us a good insight into developments in the polymers field across Europe. The increasing emphasis on sustainable development will definitely be reflected in our portfolio of research projects. Cradle to Cradle has stimulated thoughts in new directions and towards new solutions. The current economic situation is providing exactly the kind of environment to capture opportunities in this field. We can and must invest in the future, and now is the time to do it.

Jacques Joosten
Managing Director

Martien Cohen Stuart
Scientific Director



Contents

Organization 2008

Supervisory Board

- Dr. H.M.H. van Wechem, *Chairman*
- Prof.dr. M. Dröscher, Evonik Degussa
- Prof.dr.ir. C.J. van Duijn, Eindhoven University of Technology
- Ir. F. Kuijpers, Sabic Europe
- Prof.ir. K.C.A.M. Luyben, Delft University of Technology
- Prof. G. Marrucci, University of Naples
- Prof.dr. J. Put, DSM

Council

- Dr.ir. M. Steijns, Dow Benelux, *Chairman*

Scientific Reference Committee

- Prof. E. Drent, Leiden University (NL), *Chairman*
- Prof.dr. L. Leibler, Ecole Supérieure Physique et Chimie Industrielles (FR)
- Prof.dr. H. Sirringhaus, University of Cambridge (UK)
- Prof.dr. B. Voit, Institut für Polymerforschung (GER)

Executive Board

- Dr.ir. J.G.H. Joosten, Managing Director, *Chairman*
- Prof.dr. M.A. Cohen Stuart, Scientific Director (January 2009)

Programme Area Coordinators

- Dr.ir. M.J. Bruining, Corporate Research
- Dr. H. Gankema, High-Throughput Experimentation, Coating Technology
- Dr. J.A.E.H. van Haare, Functional Polymer Systems, Large-Area Thin-Film Electronics
- Dr.ir. P.M.M. Nossin, Bio-Inspired Polymers
- Dr. J.E. Stamhuis, Polyolefins, Performance Polymers

Scientific Programme Chairmen

- Prof.dr. V. Busico, Polyolefins
- Ir. R.P.A. van den Hof, Performance Polymers (Engineering Plastics)
- Prof.dr.ir. J.W.M. Noordermeer, Performance Polymers (Rubber Technology)
- Prof.dr. D. Haarer, Functional Polymer Systems
- Prof.dr. F. de Schryver, Functional Polymer Systems (January 2009)
- Prof.dr. C.D. Eisenbach, Coating Technology
- Prof.dr. U.S. Schubert, High-Throughput Experimentation
- Prof.dr. M.A. Cohen Stuart, Corporate Research

Organization Staff

- A.F.J. van Asperdt, Financial Administrator
- Dr.ir. M.J. Bruining, Director General Affairs
- I.N.H.M. Hamers, Secretary (left April 2009)
- S.G. Koenders, Project Administration
- P.J.J. Kuppens, AA, Controller
- N. Peek, Communications Manager
- Ir. S.K. de Vries, Intellectual Property and Legal Manager

DPI Value Centre

- Ir.drs. A. Brouwer, Managing Director
- J.J.D. Tesser, Communications Manager
- Dr. L.A.M.J. Jetten, Business Development

Summary of financial data 2008

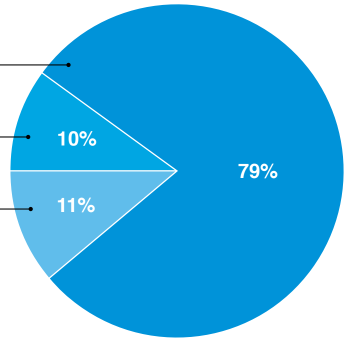
Income

Income	(x EUR million)	%
Contributions from industrial partners	4.81	27%
Revenue DPI Value Centre	0.23	1%
Contributions from knowledge institutes	3.89	22%
Contributions from Ministry of Economic Affairs	9.00	50%
Total income	**17.9**	**100%**

Expenditure (x EUR million)

By nature

Personnel costs	14.08	79%
Depreciation	1.83	10%
Other costs	1.98	11%
Total expenditure	**17.9**	



By Programme Area

Polyolefins	2.24	13%
Performance Polymers	2.64	15%
Functional Polymer Systems	2.89	16%
Coating Technology	1.68	9%
High-Throughput Experimentation	2.80	16%
Bio-Inspired Polymers	1.40	7%
Large-Area Thin-Film Electronics	0.67	4%
Corporate Research	1.81	10%
Knowledge Transfer	0.27	2%
Organization and support	1.26	7%
Support to DPI Value Centre	0.23	1%
Total expenditure	**17.9**	

Key Performance Indicators 2008

Number of industrial partners

2007	36
2008	34

European governmental funding (% of total funding)

2007	0%
2008	0%

Number of partner knowledge institutes
(universities etc.)

2007	40
2008	44

Participation of foreign knowledge institutes
(% of total expenditure)

2007	22,80%
2008	29,30%

Industrial contribution (cash and in-kind)
as % of total expenditure

End 2007	27%	
End 2008	27%	EUR 4.409.949 cash + EUR 377.882 in kind

Overhead costs
as % of total expenditure

2007	8,70%
2008	7,00%

Contribution Ministry of Economic Affairs

End 2007	50%
End 2008	50%

Expenditure for knowledge transfer

2007	EUR 248,000
2008	EUR 358,000

Number of patents filed by DPI

2007	9
2008	12

Number of patents licensed or transferred to industrial partners

2007	0
2008	1

Interest shown by industrial partners	12
Interest shown by third parties	7
In transfer to DPI Value Centre	8
Number of patents to be transferred	**27**

Track record DPI researchers

Left in total	58
Employed by partner knowledge institute	11
Employed by non-partner knowledge institute	7
Employed by partner industrial company	14
Employed by non-partner industrial company or start-up	8
Returned to native or foreign country	12
Unknown	6

Research output

Research output	2007	2008
Scientific publications	152	165
PhD theses	18	27

Partners 2008

Industry

- Accelrys *
- Agrotechnology & Food Innovations
- Akzo Nobel
- AstraZeneca *
- BASF
- Bayer
- Borealis
- Braskem
- Chemspeed Technologies
- Ciba Specialty Chemicals
- Dow Benelux
- DSM
- ECN
- Evonik
- Forschungs Gesellschaft Kunststoffe
- Friesland Foods
- LyondellBasell
- Merck
- Michelin *
- Microdrop Technologies
- Nano Technology Instruments - Europe
- National Petrochemical Company Iran *
- Océ Technologies
- OTB Engineering
- Philips
- Sabic Europe
Sabic Innovative Plastics
- Shell
- SKF
- Symyx
- Teijin Aramid
- Ticona *
- TNO
- Waters Technologies Corporation

Knowledge institutes

- Agrotechnology & Food Innovations
- Bergische Universität Wuppertal
- Delft University of Technology
- Deutsches Kunststoff Institut
- ECN
- Eindhoven University of Technology
- ESCPE

- ESPCI
- Forschungsinstitut für Pigmente und Lacke
- Friedrich-Schiller-Universität Jena
- Imperial College London *
- Innovent
- Leibniz-Institut für Polymerforschung Dresden
- Leiden University
- Loughborough University
- Maastricht University
- Max-Planck Institut für Polymerforschung
- Nanoforce Technology *
- National Technical University of Athens
- NWO
- Polymer Technology Group Eindhoven
- Queen Mary & Westfield College, University of London
- Radboud University Nijmegen
- Stellenbosch University
- TNO
- Universidade do Algarve *
- Università degli Studi di Napoli Federico II
- Università degli Studi di Perugia
- Universität Bayreuth
- Universität Duisburg-Essen
- Universität Ulm
- Universität zu Köln
- Université de Haute Alsace *
- University of Amsterdam
- University of Cambridge
- University of Groningen
- University of Leeds
- University of Liverpool *
- University of Manitoba
- University of Ottawa
- University of Twente
- Utrecht University
- Wageningen University and Research Centre
- Westfälische Wilhelms-Universität Münster

Ministry

Empowered by Ministry of Economic Affairs

* new per 2008

* left in 2009

Intellectual Property (IP)

DPI inventions and patents in 2008

The graph shows that DPI's patent portfolio keeps growing at a steady pace. A total of 15 invention disclosures were submitted in 2008, resulting in 0.8 inventions per million euros spent in 2008. In 2008 a total of 12 patent applications were filed, i.e. 0.7 patent applications per million euros spent. The inventions and patent applications per million euros spent within DPI are comparable to the numbers for other research organizations and industrial R&D units of a similar nature.

Reaping the benefits of our Intellectual Property

A new action plan has been implemented to enhance our awareness of, and focus on, intellectual property with the aim of increasingly capturing IP assets in terms of inventions and patents representing potential economic value for our partners. A significant part of our programme is focused on understanding rather than developing new products and processes. DPI pre-competitive research, by definition, is in an early stage in the process towards commercialization, if any. Nevertheless, it is imperative to keep paying attention to this issue in order to maximize the benefit for our stakeholders.

One of the action lines is to increase awareness regarding patents amongst our research staff. We aim to achieve this in the following ways:

- By introducing the subject of patents to all new research staff on a general level, and more in-depth in a workshop, during the annual Young DPI Community meeting.
- By sponsoring the RPK course "Polymer Innovations" organized by our partner organization PTN, for the benefit of those particularly interested in patents and the commercialization of IP.
- By continuing to pay attention to inventions and possible patents at review meetings of the technology areas, as well as screening all external publications on possibly patentable subject matter.

In order to increase the quality of our research in terms of patents and inventions, we have initiated the following action lines:

- Project proposals are more carefully screened for the inclusion of patents in the description of the state of the art.
- We offer the possibility for an introduction to patent searching, as an addition to a scientific literature search, at the start of a research project.
- If appropriate, we organize project meetings with all partners, both academic and industrial, to discuss possible inventions, patent state of the art and project goals, keeping in mind the interests of all parties.

In order to honour researchers that have made an invention that proved to be of interest for our partners, we grant Certificates of Invention during our Annual Meeting. At our Annual Meeting in November 2008 in Antwerp (Belgium), hosted by partner company Borealis, we granted a total of 45 Certificates of Invention to the inventors of 12 patent applications filed within the academic year 2007-2008. Each Certificate of Invention carries a cash prize of €500.

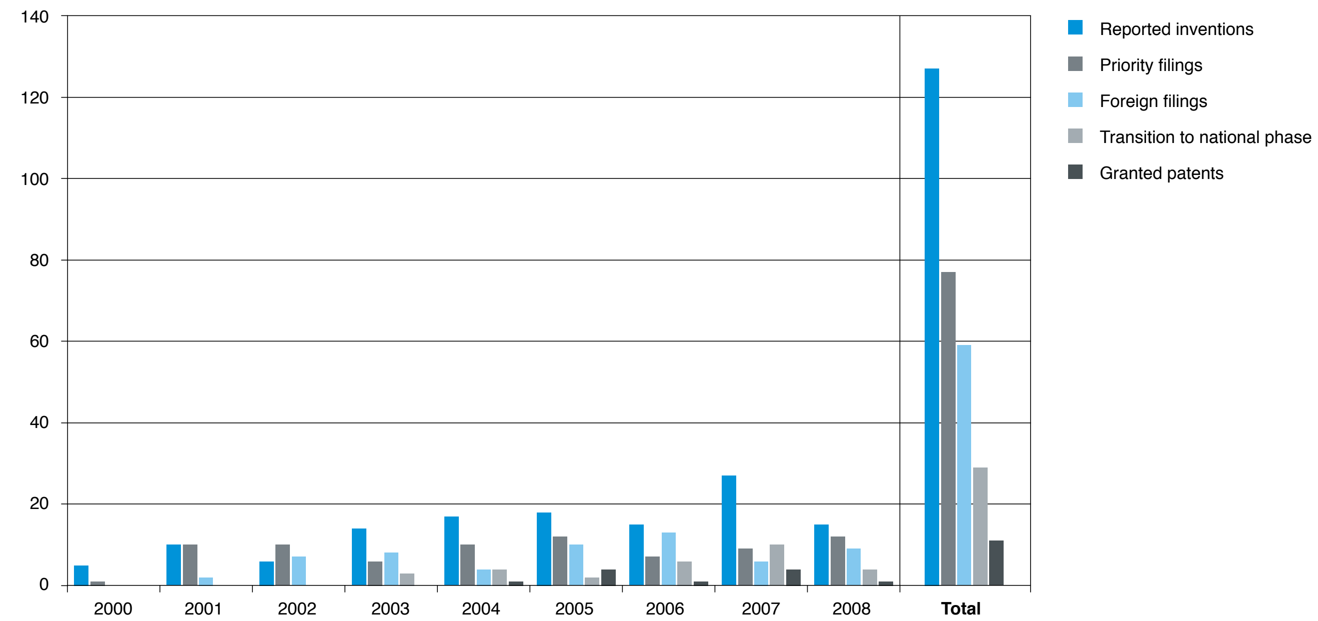
This year's Golden Thesis Award was granted to Dr. Nadia Grossiord. Her research project resulted in a total of three patent applications that are currently under discussion to be transferred to one of the partner companies.

Towards valorization of Intellectual Property

In 2008 we gave special attention to the valorization of the results of our DPI projects. In this context, the distribution of our Intellectual Property assets plays a prominent role. Even though our DPI programme is pre-competitive in character, we are collecting a significant patent portfolio, which we are making available to our partners.

In order to safeguard the rights of our partners and to ensure fair play for all participants we have revised our procedures for Intellectual Property transfer. DPI patent applications are offered for transfer to the partner companies eighteen months after first filing. In 2008 11 new cases were offered to the partners of DPI and quite a few negotiations with

DPI patents 2000 - 2008



Statistics per area 2008

	PO	PP	FPS	CT	HTE	BIO	LATFE	Corp	Total
Reported inventions		4	2	2	7				**15**
Priority filings		1,5	4	1	5	0,5			**12**
Foreign filings	1	2	2,5	2	0,5			1	**9**
Transition to national phase		2			2				**4**
Granted patents		1							**1**

partner companies took place. Some of these negotiations resulted in a loss of interest on the part of a partner and abandonment of the patent application, whereas other cases are still under discussion. Achieving a fair estimate of the potential business value resulting from our patents is one of the main points of interest in these discussions.

Furthermore, we have made arrangements with our partner DPI Value Centre regarding the transfer of patents to third parties (other than the industrial and academic partners of DPI). DPI Value Centre has shown an interest in 8 patent applications, and is currently investigating new business opportunities that can be generated from the technology developed withing the DPI research programme.

The American start-up company ImagineOptix has taken out a licence on a Dutch Polymer Institute patent application in order to commercially introduce affordable high-quality small projectors. The technology was developed in a DPI project under the supervision of Cees Bastiaansen and Dick Broer at Eindhoven University of Technology (Netherlands). The American start-up wants to develop the best quality projection image possible in the smallest possible devices, like PDAs, cell phones, handheld games and digital home cinema systems.

DPI Value Centre

"DPI Value Centre can look back on a successful first year, in which we have been able to help many customers, such as existing innovative small and medium enterprises (SMEs) and start-ups. The new funding scheme for polymer research projects was also successful, even though it was open for a relatively short period in 2008. Furthermore, we received approval for our very first large consortium project between a multinational and fifteen innovative SMEs, and this has inspired other large companies to start similar projects," says Arie Brouwer, Managing Director of DPI Value Centre.

Funding scheme

The funding scheme for polymer research project came into effect in July 2008. DPI Value Centre and SenterNovem had jointly designed the set-up of the scheme. The aim is to enable SMEs that want to innovate in the field of polymers to make the required investments, as part of the Polymer Innovation Programme (PIP). The Ministry of Economic Affairs made available € 1.9 million in 2008 for feasibility studies and SME innovation projects. At the end of 2008 around 20 projects had been approved and initiated. "In order to qualify for the funding scheme, companies have to collaborate with a knowledge institute or another company in their innovation projects. We can help them find partners, reach mutual agreement or fine-tune the innovation project," says Arie Brouwer.

Consortia projects

"Since 2007 we have been building consortia of large and small companies around technologies that are of interest to large and smaller companies alike." These are the words of Steven Meun, who coordinates the Perkalite® project that was initiated by AkzoNobel. It is quite a step to organize collaboration between companies that would normally have no relationship with each other. "The typical pattern is that a large company – in this case AkzoNobel – wants to invest in the further development of a product and seeks the help of smaller companies that we have been able to attract for the project. Each of the partners does its own part of the research, in its own organization, and the questions that come up during this work are pooled in the partnership. This enables the partners to build up more knowledge together than they would have been able to generate on their own. It's a good thing that we have been able to finance part of the investment using an existing scheme. We are now working on two similar projects, one of which concerns DSM's chain extender Allinco® and the other a liquid colouring method developed by Evonik Degussa. All these companies are partners of the Dutch Polymer Institute (DPI)."

"We can help them find partners, reach mutual agreement or fine-tune the innovation project."

Support for start-ups

DPI Value Centre supports various start-ups that want to conquer the market with an innovative idea. "These starting entrepreneurs, who have the guts to start their own company at their own risk and who believe in its success, all have a tremendous drive". In the first year of its existence, the Value Centre supported more than 15 start-ups. What these start-ups have in common is that they are doing innovative things in the field of polymers. "Each of them works from a different perspective, which means each of them needs a different kind of help. There is a great need for tailored support and a central point of contact. Clearly, the Value Centre is fulfilling this hitherto unmet need,'' says Arie Brouwer. "We can provide a start-up with expertise on the purchasing process, for example, or help them develop a prototype or gain access to seed capital. We don't have a big bag of cash available, but we do have a team of people with business experience and a network of experts in relevant fields. Our clients find that we are an engaged partner, that we really help them make the next step."

From left to right: Christiaan Bolck, Karin Molenveld, Judith Tesser, Vincent Sendra de Jongste, Caroline de Ruijter, Arie Brouwer, Steven Meun, Lonneke de Graaff, Louis Jetten.

Themes

In 2008 DPI Value Centre focused on a number of common themes that were identified in close consultation with NRK (the sector organization for the plastics and rubber industry):

- **Recycling**
  The "orange plastic man" campaign has put plastics recycling back on the map in the Netherlands. "This will boost the collection of plastics waste, but in order to recycle this waste we will need to reduce it to mono-streams. We have been partially successful in this, but there are still challenges to overcome," says Louis Jetten, focal point for companies in the field of recycling.
- **Biopolymers**
  The replacement of fossil resources (oil) by biological raw materials is one of the spearheads of the Polymer Innovation Programme. Dutch industry is interested in the application potential. Christiaan Bolck from Wageningen University/Research Centre has been posted to the Value Centre, where he uses his expertise to provide immediate support to companies that have information needs in this field.
- **Sustainability**
  The polymer sector still uses a lot of eco-unfriendly additives and products in its production processes. "When it comes to this theme, the SME sector is our direct sparring partner. We are looking for alternatives that have a lower environmental impact and can be used straightaway without of course raising costs," says theme coordinator Steven Meun.

- **Cradle to Cradle**
  The Cradle to Cradle philosophy introduced by Braungart and McDonough is having its effects on the Value Centre's customer base. Lonneke de Graaff specializes in polymers and Cradle to Cradle. "Our challenge is to reach the point where plastic products are suitable for the technical or biological cycle. There are synergies with the other themes. In the coming year we want to launch a network for knowledge exchange between companies in the polymer sector that are putting the Cradle to Cradle concept into practice. This network will enable companies to collaborate and to give concrete shape to their ideas. We have only just begun with this initiative and are already getting a lot of response."

"This enables the partners to build up more knowledge together than they would have been able to generate on their own."

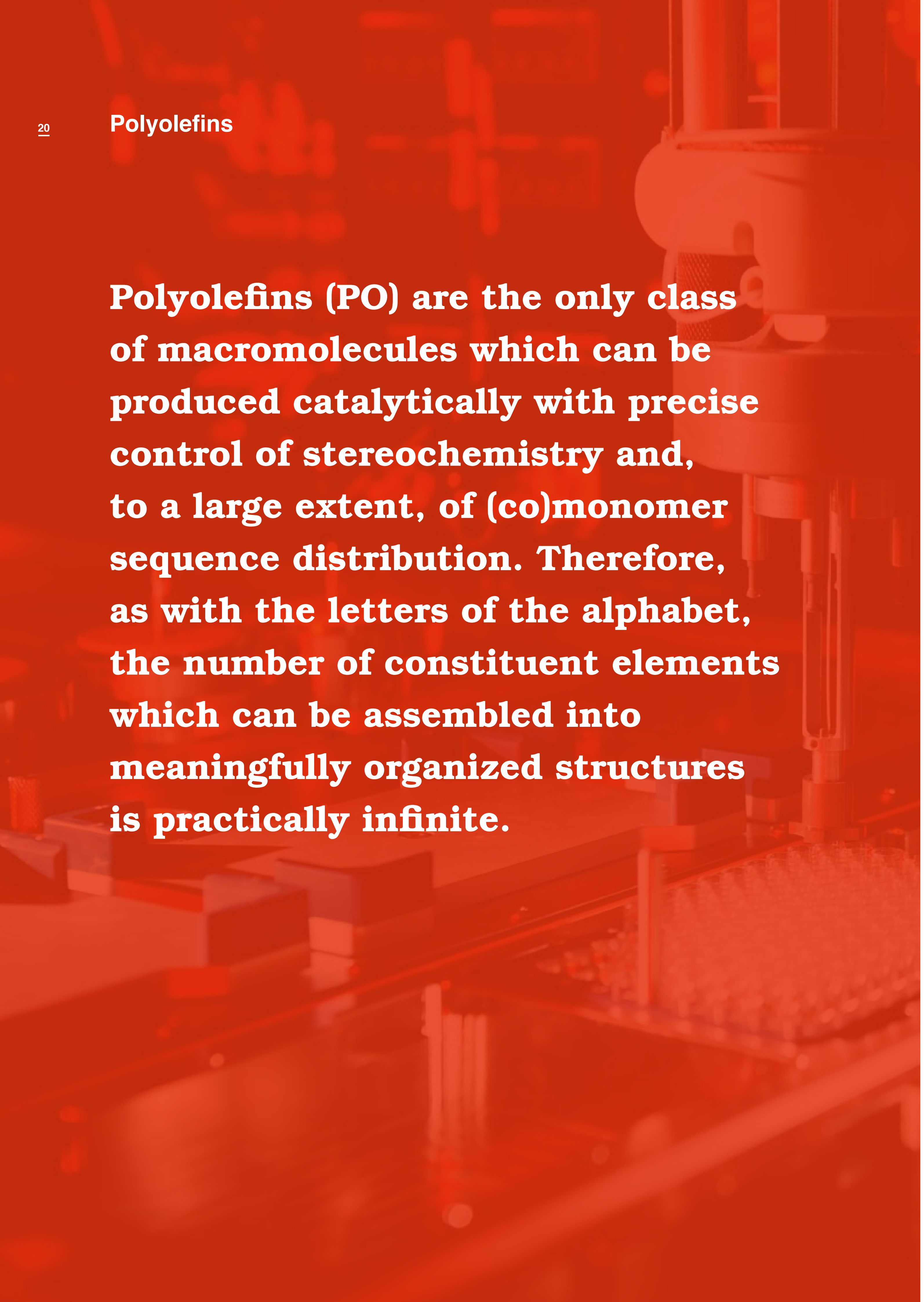
Opportunities

For 2009 and beyond, various activities are in the pipeline. Research is being carried out into potential new opportunities for polymers in the building construction sector, the automotive industry and the packaging sector. A number of patents that are going to be released from the DPI portfolio represent opportunities for DPI Value Centre's customers. The challenge for the Value Centre is to link these patents to the right entrepreneurs. Besides this, twenty workshops have been planned around the spearhead themes. Questions from entrepreneurs are being answered. Where necessary, these questions will be pooled and meetings will be organized with partners to discuss them in more depth. Collaboration with Syntens, NRK (Dutch Association for the rubber ans plastics industry) and organizations outside the Netherlands will be intensified. And in 2009, the funding scheme for polymer research projects will continue to apply.

Arie Brouwer: "We therefore expect a lot of interest from companies that we can help via our network. In addition, we will open an office at the Centre for Open Chemical Innovation (COCI) at the Chemelot campus in Sittard-Geleen, from where we can provide direct support to companies in the region. We are further expanding our polymer network. The foundations are already there, thanks in part to the infrastructure built up by DPI."

Annual Meeting 2008

The annual DPI meeting 2008 took place in Antwerp and was hosted by Borealis. During two days the participants visited several presentations and workshops. We granted a total of 45 Certificates of Invention to the inventors of 12 patent applications filed within the academic year 2007-2008.



Polyolefins (PO) are the only class of macromolecules which can be produced catalytically with precise control of stereochemistry and, to a large extent, of (co)monomer sequence distribution. Therefore, as with the letters of the alphabet, the number of constituent elements which can be assembled into meaningfully organized structures is practically infinite.

Understanding polyolefins: how does it work?

Although the polyolefins industry is often regarded as a mature sector, polyolefin production processes still have not reached their full potential in terms of selectivity and process control levels. A better insight into basic chemical mechanisms might lead to optimized catalyst design, which in turn would lead to better polymers and plastics based materials. The academic world and industry are jointly working on this common goal.

Sandro Gambarotta is professor of Inorganic Chemistry of Transition Metal Complexes at the University of Ottawa (Canada). He has been involved in the DPI public/private partnership for a couple of years now, via two catalyst related DPI projects. “I try to strike a compromise between academic and industrial interests. In the academic world, you can just make a new material, describe it and you have a decent scientific publication. That is interesting, but why should anyone care when this material has no real added value? Now we perform industrially relevant research, we develop solutions that are really in demand. This adds spice to research.”

And it is quite fundamental research. Gambarotta: “The first project for instance focuses on how molecules are activated. This calls for a fundamental understanding of the mechanism of oligomerization. The second project is aimed at creating a more competitive process to produce 1-octene from natural sources and to make a catalyst for this process. Eventually, we may be able to find things that make a real difference; the research might lead to a profitable process for the industry. I like the idea of contributing to that.”

There is already a process for the production of 1-octene, an important feedstock for polymeric materials. “But this research targets one of the key issues in catalysis: selectivity”, says Nic Friederichs, Research Chemist at SABIC Europe in Sittard-Geleen (Netherlands). “Polyolefin production has not reached perfection yet. We have to clean up the conventional 1-octene production process and think of ways to use the side products. A new conceptual approach to increased selectivity could result in ways to make it more efficient and to obtain new products with better characteristics.”

Tim Kidd, Competence Manager UH polymerization Chemistry & Catalysis at DSM: “Apart from selectivity, there is process control. When we know what really happens during the process, we are able to design polymer structures down to their carbon-carbon structure. We still aren’t able to use the true potential of the material. To reach that, we need exact control over our process. Academia can help us on the way towards gaining this control. That is our synergistic aim.”

Shock therapy

“The one question we keep asking ourselves every day is: how does it work?” says Itzel Guerrero-Rios, a postdoc in Molecular Inorganic Chemistry at Groningen University (Netherlands). “My dream is to go to the reactor in the lab and find the desired immobilized single sited catalyst. It’s not like that, though. In fact, the step from PhD to postdoc is quite frustrating. From being an expert

> **“The synergistic effect of DPI was like shock therapy to me.”**
>
> **Sandro Gambarotta** – professor of Inorganic Chemistry of Transition Metal Complexes, University of Ottawa (Canada)

in your PhD subject, you get into a situation where you have to start all over again: get into elemental analysis, learn new techniques in synthesizing and testing. At the same time, new knowledge is always a stimulus."

As far as this is concerned, academia and industry are in the same position, Kidd stresses. "We want to enlarge our understanding and in this we share the same goal." Of course there is already some understanding of the research topic. "The search for a new catalyst isn't a shot in the dark", Gambarotta remarks. "It is idea-driven and this enhances the chances of success." Adding up the 'worlds of knowledge' from academia and industry is a good thing, he thinks. "Industry has a wealth of hidden knowledge. In the past two years of collaboration with industry I have learned more than during the previous twenty years. The synergistic effect of DPI was like shock therapy to me. Industry provides inspiration on what to do and where to look. Also, the industrial way of tackling problems was an eye-opener."

Guerrero-Rios agrees: "The collaboration broadens the scope to a lot of applications and has shown me that

"It is quite customary among industrial competitors to brag to each other about their successes, but in open innovation this will get you nowhere."

Nic Friederichs – research chemist at SABIC Europe

I should not linger in this one area of organo-metallic materials. It brings you closer to society and shows the relevance of what you are doing. My project is aimed at developing more efficient processes, which not only reduce costs, but also generate less waste."

Opening up

Conversely, access to academic brains is very valuable to industry, Friederichs and Kidd agree. Friederichs: "We know the value of what the research projects can deliver. We have a lot of in-house research, but you can't develop everything by yourself; you have to collaborate. The hardest thing is that you have to open up about the areas where you lack essential knowledge, in other words display your own weaknesses. This requires a cultural change; it is quite customary among industrial competitors to brag to each other about their successes, but in open innovation this will get you nowhere. You sometimes have to admit that although a process works, you in fact don't understand why. Admitting this is vital for optimization." Guerrero sees this in her project: "The more partners open up, the better the results. And when the various participants notice this, communication will improve even further."

Academia, too, needs to open up, Friederichs says. "The challenge is openness. It only works if both sides open up and discuss opportunities and weaknesses. DPI brings parties together and creates the atmosphere for open discussion. But we still have a way to go in open innovation. In one-to-one situations, we open up. But to be open to a larger group remains difficult. You can push openness across boundaries, but you also have to ask yourself how much openness is wise."

"Co-operation with industry brings you closer to society and shows you the relevance of what you are doing."

Itzel Guerrero-Rios – postdoc in Molecular Inorganic Chemistry at Groningen University

Sustainability

Guerrero-Rios already hinted at the impact of research. What effects does it have in the areas of economic growth, sustainability and quality of life? Kidd, Gambarotta and Friederichs

stress that optimizing catalysis and selectivity, leading to higher process efficiency and better materials, gives benefits in all three of these fields. Kidd: "It would be wrong to think that profit is the only driver of industry." Friederichs: "A proposal wouldn't make it if it didn't at least cover two of these three areas. In fact, sustainability is nowadays more of a prerequisite than economic growth. Industry is an integral part of society."

Another thing is that a commercially-driven project does not fit into the fundamental, pre-competitive DPI programme. What strikes Gambarotta about the DPI concept is its pragmatism: "DPI is showing a rare open-mindedness in shopping internationally for industrially relevant knowledge." The DPI participants, too, come from around the globe nowadays. Gambarotta: "That's not surprising because, for any single company, creating genuine innovation is a luxury and a necessity at the same time. DPI brings this within reach." Kidd: "And, very importantly, it gives companies access to a lot of people and a great network. For DSM, gaining access to people with the right knowledge is essential."

"For DSM, access to people with the right knowledge is essential."

Tim Kidd – competence manager UH polymerization Chemistry & Catalysis at DSM

Tim Kidd, Sandro Gambarotta, Itzel Guerrero-Rios and Nic Friederichs

Roberta Pellecchia
A high-tech lab and age-old Vesuvius

Post-doctoral researcher Roberta Pellecchia gets her inspiration from the places where she works and lives. A sophisticated high-tech laboratory and a city offering beautiful vistas and tremendous opportunities for spending one's free time make for a stimulating environment. Whether she is reading, enjoying the view of mount Vesuvius or sailing, Pellecchia's research is always with her: "Right here, you can get new ideas everywhere."

Pellecchia works at the Federico II University of Naples (Italy). She has two main sources of inspiration, she says: "First of all, I work in one of the most scientifically and technologically advanced labs in Europe. It is very stimulating to work in an environment that's at the cutting edge of catalyst and polymer research." The second thing that inspires Pellecchia is the city of Naples, where she grew up and where she works: "There are places from where the views of the bay, the islands and mount Vesuvius are breath-taking. When I look at those great views and enjoy the sunshine and the blue sky, my mind feels open.

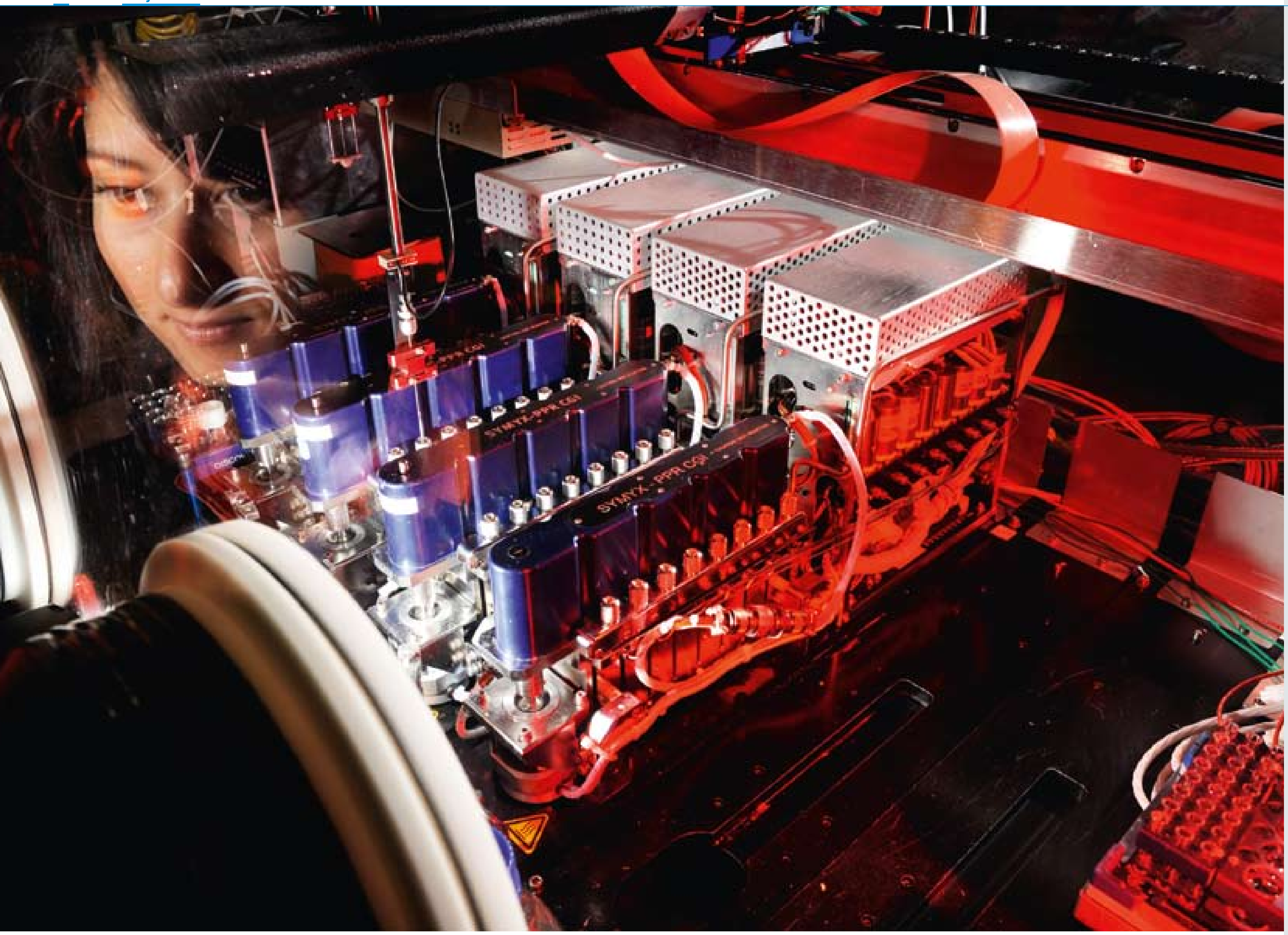
"When I look at the beauty of nature under the Neapolitan sun, my mind feels open."

Roberta Pellecchia – post-doctoral researcher at the Federico II University of Naples (Italy)

It is a great way to feel inspired and to get new ideas. We have over 250 sunny days per year, and almost all the year round I can decide if I want to sail or ski in the weekend. I know the city isn't perfect, but I am not aware of many other places where high-tech science, history and natural beauty go together so well."

Endless combinations

Pellecchia's research focuses on the development and application of High Throughput Screening methods in catalysis of alpha-polyolefins. Pellecchia: "Polyolefins have improved our lives dramatically. They are ubiquitous and make it possible to save energy and materials to the benefit of our environment. I am amazed by how well catalytic chemists, including myself, can synthesize gigantic polyolefin molecules yielding an enormous range of useful materials. As with the letters of the alphabet, the number of combinations that we can make is endless. My supervisor once noted that poetry, music and polyolefins will never get mature; I tend to agree and this feeling only makes me more enthusiastic about my job."



“You can get new ideas and insights everywhere, at any time.”

New ideas

Although Pellecchia spends a lot of time on leisure activities, her work is always with her: “I like to read a lot, from fiction to travel stories to science books. I’m a regular visitor to the cinema as well. My favourite movie is *Le fabuleux destin d’Amélie Poulain*. Whenever possible I spend my weekends skiing or sailing. When everything around me is white or blue I have the feeling that I’m breathing freedom. However, even when I’m doing that I often think about my research. Being a researcher implies that your work is always with you; this can be tough at times, but it’s always challenging and often a great joy. You can get new ideas and insights everywhere, at any time.”

Another way to get fresh ideas, says Pellecchia, is by talking to people: “Of course I have conversations with my colleagues, but I also like to talk with my friends about my research. It’s surprising how often inspiration can come from unbiased remarks by non-specialists. And Neapolitans are among the most unbiased people I can think of.”

Objectives

Polyolefins are the only class of macromolecules which can be produced catalytically with precise control of stereochemistry and, to a large extent, of (co)monomer sequence distribution. Therefore the number of constituent elements which can be assembled into meaningfully organized structures is practically infinite.

In fact, polyolefin-based materials can be tailor-made for a wide range of applications: from ultra-rigid thermoplastics to high-performance elastomers. This vastly different performance is achieved by a variety of polyolefin molecular structures, whose common features are full atom economy in their synthesis, low cost, excellence in performance, long life cycle and ease of recycling.

The research programme of the Polyolefins Technology Area addresses the complete chain of knowledge in full width and depth, aiming at proficiency in the ever expanding applications of the polyolefin polymers. Although polyolefins represent one of the oldest (if not the oldest) thermoplastic polymer families, they are still very much characterized by innovations that provide new applications through stepwise and continuous technology renewal and that reduce the eco-footprint during manufacture and use.

Subprogrammes

Catalysis
Investigation, screening and development of novel homogeneous and heterogeneous catalyst systems, new approaches for the immobilization and activation of hetero-geneous and single site catalysts for polefins (co)polymerization.

Polymer structure, properties and processing
Understanding, modelling and predicting structure-processing-property relation-ships of polyolefin polymer systems.

Polymer reactor engineering
Studies on various reactor and technology unit operations to produce a quantitative description and acquire a thorough understanding of the crucial aspects of polymerization processes.

New methods and exploratory research
New characterization and polymerization methods, high-throughput screening and experimentation, embryonic research and concept development.

Facts and figures

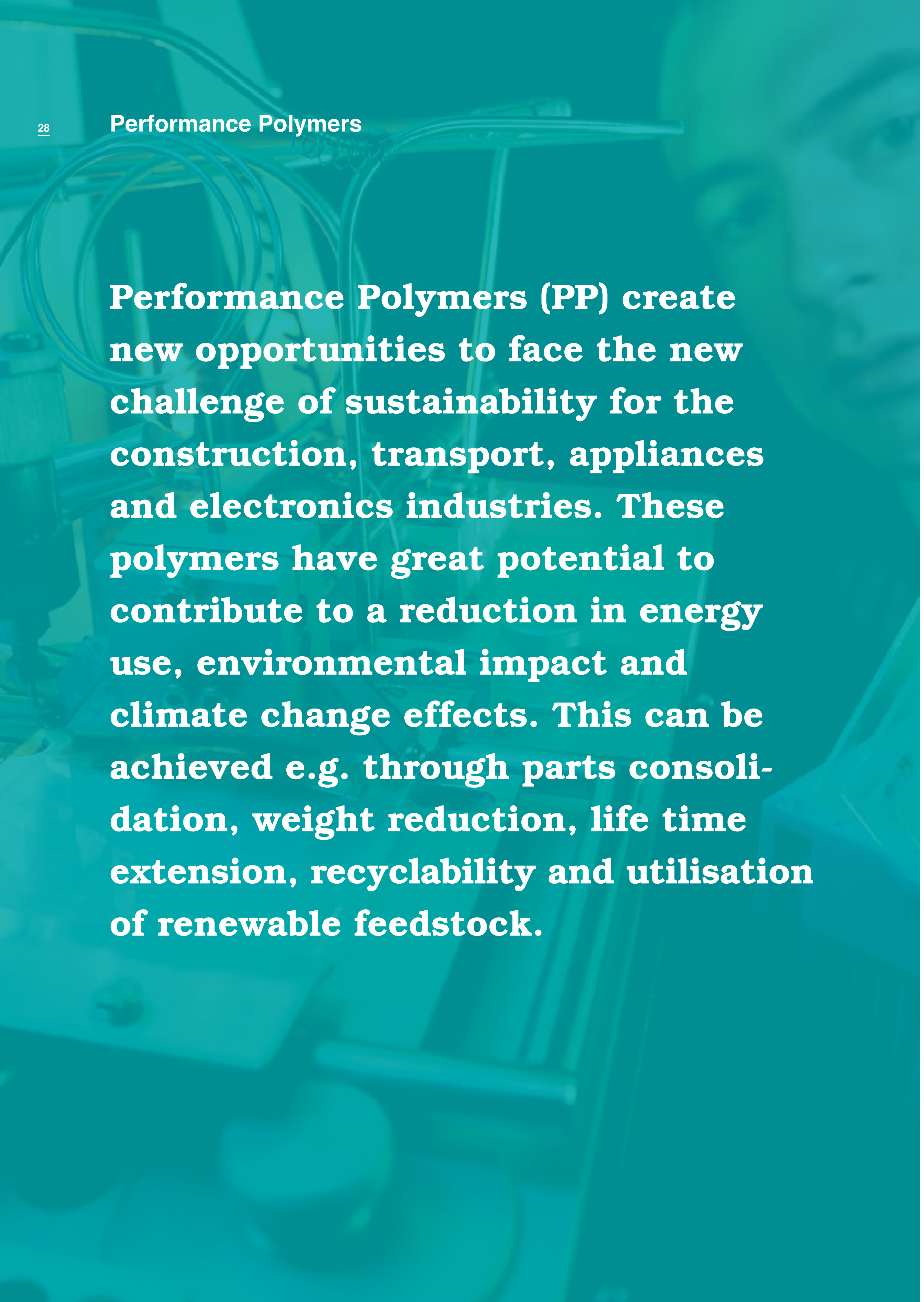
Partners from industry
Borealis, Braskem, Dow, DSM, LyondelBasell, Sabic, Shell, Symyx and Teijin Aramid. Ticona joined in November 2008.

Partners from the research world
The Netherlands: Delft University of Technology, Eindhoven University of Technology, University of Groningen, University of Twente, University of Amsterdam.
Italy: University of Naples Federico II and University of Perugia.
France: ESPCE Lyon.
UK: University of Loughborough.
Germany: Deutsches Kunststoff Institut.
Canada: University of Ottawa and University of Manitoba.

Budget and organization
Overall expenditure in 2008 was € 2.25 million (budget: € 2.82 million). Expenditure on equipment was limited to € 75k; the total number of FTEs allocated at the end of 2008 was 20 (31 researchers). Professor Dr. Vincenzo Busico is Scientific Chairman of the Technology Area and Dr. Jan Stamhuis is Programme Area Coordinator.

Publications and inventions
In 2008 18 reviewed papers and 4 theses were published in this Technology Area.

Detailed information on page 84.



Performance Polymers (PP) create new opportunities to face the new challenge of sustainability for the construction, transport, appliances and electronics industries. These polymers have great potential to contribute to a reduction in energy use, environmental impact and climate change effects. This can be achieved e.g. through parts consolidation, weight reduction, life time extension, recyclability and utilisation of renewable feedstock.

The DPI experience helps to get corporate cultures in the open innovation mode

Open innovation is a necessity nowadays and DPI provides a platform for it, say Rabin Datta of Teijin and Hans-Erich Gasche of Bayer Technology Services. That is probably why many large companies in the performance materials field are already represented in DPI. Datta: "The DPI experience helps to get corporate cultures in the open innovation mode."

Wilco Wennekes, R&D Engineer at membrane manufacturer Norit X-flow in Enschede (Netherlands) received his PhD on a DPI project in 2008: "Direct contact with industry was a strong motivation for me during my research, supervised by Rabin Datta, Business Manager Tires at Teijin Aramid. I wrote my thesis on adhesion between the tire cord and the rubber compound in a tire. The so-called Resorcinol-Formaldehyde-Latex (RFL) treatment to create adhesion was invented in 1938, but it remained poorly understood. The notorious incidents in the United States caused by adhesion failure underline the importance of gaining a better understanding. I tried to unravel what really happens mechanically and chemically at the interface between rigid fibre and flexible compound."

Hans-Erich Gasche, Head of PT-Reaction & Polymer Technology at Bayer Technology Services in Leverkusen (Germany) and member of the Programme Committee: "Did you in this industrial research encounter the problem of not being able to publish results?" Not at all, Wennekes explains: "Because of the fundamental nature and the fact that the RFL treatment isn't really Teijin technology, I could be open about my research." Datta adds: "It was really pre-competitive, as it uses recipes from the public domain."

Implicit knowledge

Richard Schaake, Team Leader Polymers at SKF in Nieuwegein (Netherlands) had the same experience in his PhD research on friction and wear of polymers: "This research is so far away from the actual product, that publication is no issue. It can only become a problem when innovation is directly involved. A colleague of mine had this problem. His sponsored PhD research was on such a touchy subject that he had to omit essential parts from his thesis eventually. In the DPI context such a disaster is prevented by screening beforehand. The industrial partners know the subject and they know it will be published."

Like Wennekes, Schaake too enjoyed working with the industry, in his case Teijin, TNO and DSM: "Industry has a lot of implicit knowledge, the kind you won't find in literature. Coming from an academic environment, it's fascinating to plug into this. The goal of my research was to isolate the role of the polymer material, for instance molecular weight distribution. Friction and wear are caused by a whole system of parameters. You have to know the role of the polymer itself in order to make better materials."

Steering effort

That is what it is all about: no matter how fundamental the problem, in DPI the focus will ultimately always be on the application. Datta: "I like the 'sandwich' of fundamental and applied, driven by industry. There is a real connection between academia and industry. The downside of this could be

"There is a real connection between academia and industry."

Rabin Datta – business manager tires, Teijin Aramid that academia is lured away from fundamental science. But the assurance that all research has real relevance outweighs this." Gasche: "I agree; even if there is initially not enough relevance in an idea, the programme committee will adjust the course. Relevance doesn't pop up after three years by surprise; it is result of a steering effort." Gasche notices other positive aspects as well: "The network is a real asset. It is neutral ground for pre-competitive discussion, which I really appreciate. Another thing is the geographical spread. DPI is not only Eindhoven, but involves research all over Europe. During cluster meetings you witness such a diversity of international talent. That is important to us, because we strive for a broad diversity of talent within Bayer."

Eco-efficiency

In the DPI strategy, quality of life, economic growth and sustainability play an important role. How does this impact on the researchers in their daily work? "It's funny, but when you start as a PhD student you hardly think of that; you are too preoccupied with technology. But friction is directly linked to sustainability," Schaake says. "The more power gets lost into friction, the more energy is wasted and the more CO_2 is emitted. Furthermore, worn products need to be replaced. This means that the more wear you have, the more waste you get. With regard to quality of life the connection is likewise direct:

> **"Coming from an academic environment, it's fascinating to plug into implicit industrial knowledge."**
>
> **Richard Schaake** – team leader Polymers, SKF

as a result of wear processes in implants, particles of ultra high molecular weight PE can end up in the body and cause inflammatory reactions. So by addressing wear, we contribute to health."

Wennekes: "When tire cord and rubber compound delaminate, the life of passengers is at stake. Clarifying this 'black box process' from the past and building up knowledge on why adhesion can fail contributes to quality of life. There's also an economic growth aspect: I found cheaper materials that outperformed the latex in the RFL treatment." Datta: "Might I add the sustainability aspect to that? We are presently working on a less toxic replacement for the formaldehyde in the treatment."

In general, eco-efficiency has become a big issue in recent years, according to Datta, the aim being to bring down total energy consumption during the product lifecycle. Gasche: "In companies operating large-scale assets this is really an issue. It is the context of our daily life. We have to be sustainable in the long term in order to remain profitable. Sustainability is perfectly compatible with business models based on profitability. Therefore it isn't hard to integrate sustainability into research; neither at DPI nor in an industrial company."

Open mind

Open innovation might even speed up the spread of sustainability research. Datta: "DPI is a wonderful platform for innovation. The interaction makes it easier to find out-of-the-box solutions. Without open innovation, research groups tend to remain in their own traditional area. Our Twaron fibre was originally developed for tires, but now we have also found applications in ballistics, composites, optical cables, etcetera. Twaron combined with nanotubes, as investigated at Delft and Eindhoven in the Netherlands, might get us into other new areas. Tires nowadays account for no more than twenty per cent of sales. Open innovation opens your mind for other things. The DPI experience helps to get corporate cultures in the open innovation mode."

Gasche agrees: "I notice that it broadens my colleagues' mindset. You need a platform like DPI for open innovation, which has become a necessity both cost-wise and knowledge-wise. Take for instance organic photovoltaics. As a materials producer, you provide the polymer but not necessarily the cell.

> **"DPI is not only Eindhoven, but research all over Europe."**
>
> **Hans-Erich Gasche** – head of PT-Reaction & Polymer Technology, Bayer

Wilco Wennekes, Hans-Erich Gasche, Richard Schaake and Rabin Datta

System integration is key; you need a system of overlapping capabilities. In Europe, companies that have all necessary disciplines in-house are rare. That is why we need open innovation. It's important to include partner companies who have complementary skill sets to improve solar cell technology and who can tell us what material properties they need for that." Schaake: "The polymer industry is of course represented widely within DPI, but SKF as a polymer user also sees this interest. It is peculiar that there are not many end users involved, as we are dependent on our suppliers. Our participation in DPI helps us to understand the suppliers. It enables us to ask the right questions."

Norit is not a DPI participant, although the company is looking for new, sustainable and preferably cheaper polymers for its membranes.

> **"I was one of the few PhD students to perform my research at the industry partner in a project."**
>
> **Wilco Wennekes** – R&D engineer Norit X-flow

Wennekes: "The membrane part itself, as our core business, will remain closed, but it would be good to be present at the forefront of polymer research." Wennekes feels his DPI background gave him a head start in his current role: "I was one of the few PhD students to perform my research at the industry partner in a project. This gave me the opportunity to learn the industrial way of thinking, in which all activity is directly linked to business potential." Datta: "I came from academia and remember I was amazed that cost could be an issue. My views have changed since then, and ongoing interaction with industry will probably change them it further."

Bridging the gap

Gasche notes that most large polymer manufacturers are already represented in DPI, but that the participation by SMEs leaves room for improvement. "That is what the DPI Value Centre is aiming for now, in response to the notion that smaller companies by their nature always work closer to applications. The Value Centre might prove to be the step needed to bridge the last gap in the chain from universities over large companies to SMEs."

Roy l'Abee
From toothbrushes to submicron particles

Roy l'Abee is a lucky guy. He gets his inspiration from his daily life. Even a simple object like a toothbrush inspires him. "There is much more to a toothbrush than people tend to think," he says. "Multiple technologies and a number of materials have been combined into a smart product everybody uses everyday. I find that inspiring."

In his doctoral research Roy answers the question of whether the particle size of the rubber dispersion affects the properties of the thermoplastic vulcanizate.

"This is indeed the case: the smaller the dispersed particles, the better the mechanical properties of the thermoplastic vulcanizate," he concludes. "Unfortunately, the minimum size of the rubber dispersion of commercial thermoplastic vulcanizates is one micron. In my research I also worked on a new method to obtain smaller – submicron – rubber dispersions."

> "I get inspired by smart products in daily life for which various technologies and materials have been combined in a clever way."
>
> **Roy l'Abee** – Eindhoven University of Technology

By taking the entire chain of technology into account, Roy succeeded in further miniaturizing the dispersions. "I applied different disciplines such as chemistry, physics and mechanics. This combination of different theories and technologies made the work extremely inspiring."

Smart products

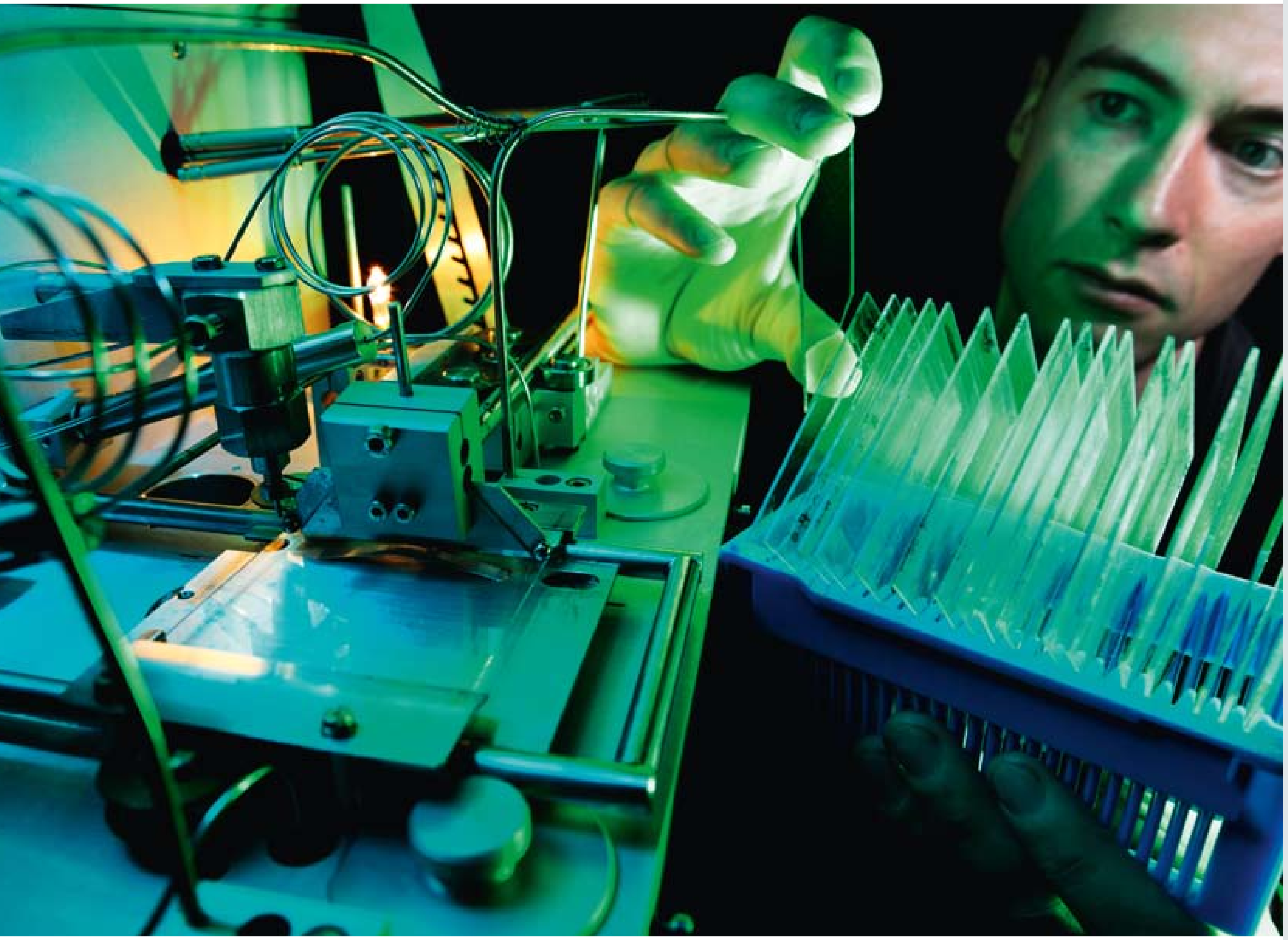
His daily life is full of inspiring items, he says. "There are so many smart products that you use in daily life, products for which various materials and technologies have been combined in a clever way. From relatively simple products such as a milk carton or my crash helmet that I use during mountain biking to more complex products such as a car tire or an LCD screen. All of them are great examples of clever thinking, where the specific properties of different materials like polymers, ceramics and metals have been combined with a proper design to form a useful product."

New applications

The examples show that successful projects require a combination of fundamental research and an open eye for new applications. Roy l'Abee really enjoys it when he sees research translated into applications. "I hope my doctoral research will contribute to new applications too," he says.

He had a great time during his PhD project. "Only one thing made it a little difficult at times. Although you work together with your colleagues and industrial contact persons, you often work on your own. For the future, I think I would prefer a job in a team." That future is now, for he received his doctoral degree at the end of April 2009.

"I hope my doctoral research will contribute to new applications too."



Objectives

Performance Polymers (PP) create new opportunities to face the new challenge of sustainability for the construction, transport, appliances and electronics industries. These polymers have great potential to contribute to a reduction in energy use, environmental impact and climate change effects. This can be achieved e.g. through parts consolidation, weight reduction, life time extension, recyclability and utilisation of renewable feedstock.

Furthermore, the complex part and assembly performance requirements necessitate a close technological cooperation between polymer supplier, converter and end-user. This calls for a thorough understanding of polymerization, polymer modification as well as polymer processing, properties and design.

These themes are reflected in the strategy and objectives of the Performance Polymers Technology Area, which includes investigations related to fundamental issues in the value chain using a 'chain of knowledge' approach in the context of energy saving, durability, ultimate performance and sustainablility.

Subprogrammes

Polymer and network chemistry and modification
Studies focusing on an increase in the use of bio-based materials on the one hand and cost and energy reductions in polymerization and network formation on the other. New concepts for monomer and polymer molecular structure to achieve step changes in the balance of flow, static and dynamic mechanical and other functional properties.

Processing for properties
Understanding of the relationship between the molecular structure, processing and properties of polymers. Studies of the processing effects of intermolecular interactions, e.g. hydrogen bonding. Processing, modification and vulcanization studies of elastomer blends.

Advanced reinforced thermoplastics and synthetic fibres
Studies on interface effects in fibre-reinforced composite systems, effects of nano-reinforcement on polymer material properties on macroscopic and microscopic scale, friction and wear of fibre-reinforced thermoplastics and elastomers.

Stability and long-term performance
Investigations of the chemical and physical ageing mechanisms and their interplay with the ultimate objective of predicting lifetime and realizing fit-for-use design over the entire life cycle.

Facts and figures

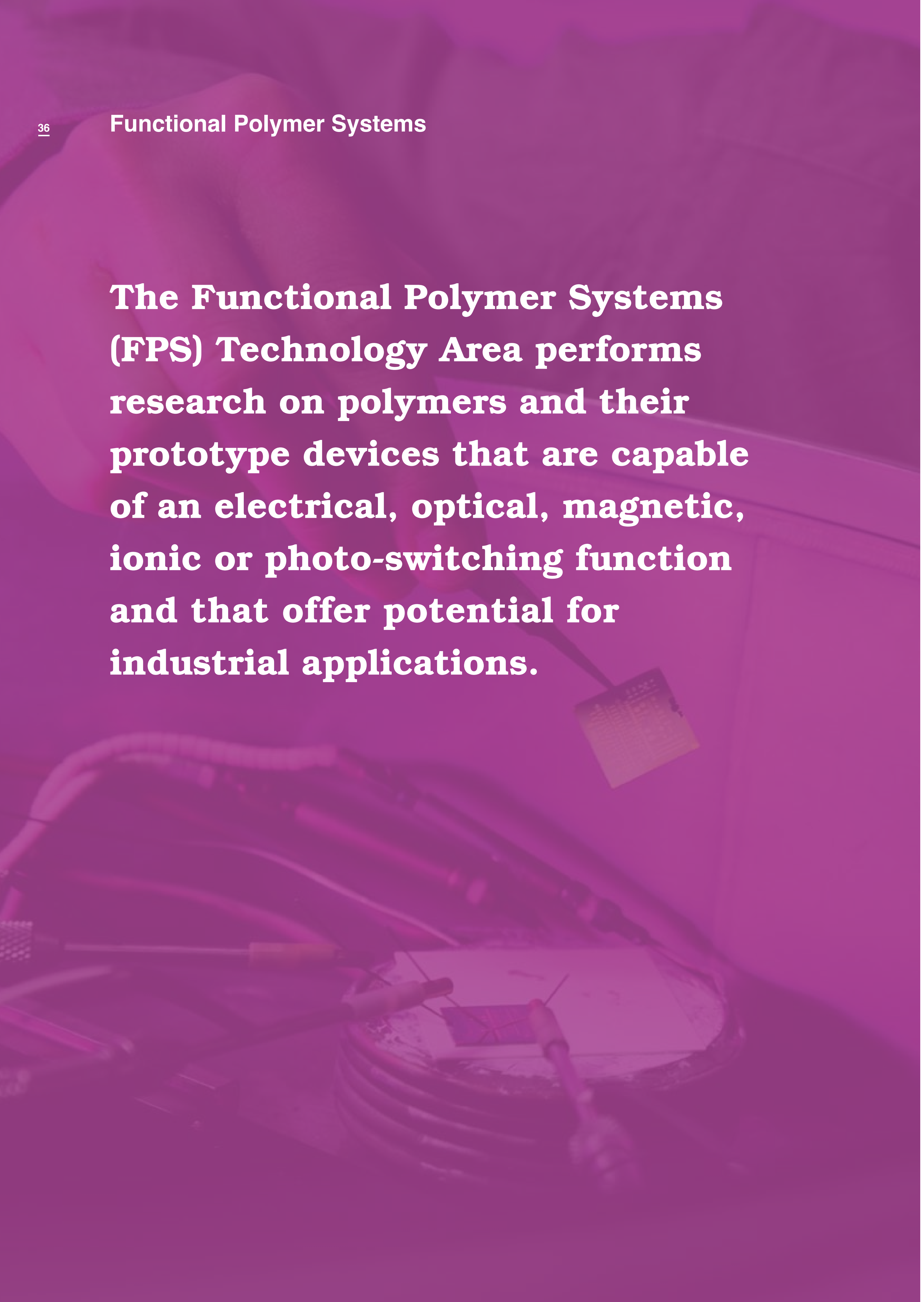
Partners from industry
BASF, Bayer, Dow, DSM, Evonik-Degussa, LyondellBasell, Océ Technologies, Sabic-IP, SKF, Teijin Aramid.

Partners from the research world
The Netherlands: Delft University of Technology, Eindhoven University of Technology, University of Groningen, University of Twente .
France: ESPCI Paris.
Germany: Deutsches Kunststoff Institut DKI (), Institut fuer Polymerforschung at University of Dresden.
UK: Queen Mary College, University of London.

Budget and organization
Expenditure in 2008 totalled € 2.64 million (budget: € 3.05 million). A total of € 111k was spent on equipment; the total number of FTEs allocated at year-end 2008 was 26 (44 researchers). Ir. Richard van den Hof and Professor.dr.ir Jacques Noordermeer acted as Scientific Chairmen of the Performance Polymers Technology Area and Dr. Jan Stamhuis as Programme Area Coordinator.

Publications and inventions
A total of 24 reviewed papers and 4 theses were published in the Technology Area. Four inventions were reported and two patent applications were filed.

Detailed information on page 85.



The Functional Polymer Systems (FPS) Technology Area performs research on polymers and their prototype devices that are capable of an electrical, optical, magnetic, ionic or photo-switching function and that offer potential for industrial applications.

A roadmap to sensible packaging

The multi-disciplinary research field of functional polymers shows a lot of promise for future applications. For example, printable sensors that monitor food quality, contaminants and hazardous gases. Two research groups from Eindhoven University of Technology (TU/e) in the Netherlands and two companies are collaborating closely on these functional polymers and their applications. In the very competitive chemical industry, this kind of collaboration is still quite rare.

DPI's Functional Polymer Systems (FPS) framework focuses on the development and application of polymers with advanced optical or electrical properties. Dr. Cees Bastiaansen, associate professor of Polymer Technology at Eindhoven University of Technology (TU/e) and part-time professor at Queen Mary, University of London: "Our aim is to construct cheap, printable sensors that can detect multiple environmental parameters like humidity, temperature and gases. For instance, we have created chiral dopants that are sensitive to external stimuli and respond with an optical signal: a visible colour change." Bastiaansen collaborates in this project with Rint Sijbesma, professor of supramolecular chemistry at TU/e, and Dick Broer, part-time professor of polymer chemistry and polymer technology at TU/e, who is also a part-time senior researcher at Philips Research.

Future food packaging

Rint Sijbesma synthesized the new chiral dopant to create CO_2 and O_2 sensors. These can potentially be used for food packaging. Bastiaansen: "Foodstuffs are very often packaged in a CO_2 environment. Once that environment is gone, O_2 gets in and the food starts to deteriorate. That process is something you want to monitor and measure." The collaboration between the two research groups was a natural match, says Bastiaansen: "We have knowledge about printing technology and self-organization of liquid crystals, but the group of Dick Broer and myself lacks expertise in the kind of sophisticated chemistry that is needed for this project. Sijbesma's group has that expertise. What we have in common is an interest in self-organization. We combine concepts of self-organization and liquid crystals with supramolecular chemistry." Sijbesma: "We have the expertise to design and make molecules. So we bring in the molecular approach introducing functionality in these materials. Neither of us can create functional materials on our own, but by combining our expertise we make it possible."

Dirk Sjoerdsma is programme manager at DSM Specialty Packaging, part of the company's Innovation Center. He is responsible for Specialty Packaging R&D, which supports the sensor research project. Sjoerdsma: "We have two technology platforms. The first is controlled atmosphere, about creating and maintaining an atmosphere in a food packaging that keeps the contents fresh and tasty. That's an old product/market combination, and we know how to play that game. The second platform is intelligent packaging that tells something about the actual freshness of the food contents and their conservation history. We believe this to be the future of food packaging. Any sensoring for systems like this is interesting to us."

> **"I think DPI is the only organization in Europe that has so many chemical companies working together."**
>
> **Owain Parri** – senior scientist at Merck

Chemical company Merck is also involved in the project. Senior scientist Owain Parri: "We know nothing about sensors, but we do have lots of expertise in materials. We consider ourselves to be a potential material supplier for intelligent food packaging."

"We believe intelligent packaging to be the future of food packaging."

Dirk Sjoerdsma – programme manager at DSM Specialty Packaging

Naive

The sensor project started a year ago. The researchers have made quite some progress, says Bastiaansen: "For a number of sensors, for instance temperature, O2, CO2, pH, amines and humidity, we have proof of principle and we know that we can print them. Right now, selecting a specific application and developing something for it is high on our wish list. We are looking for markets, but each market has its own peculiarities. The food market has large volumes, but price is an issue. With medical devices, price is less important, but volumes are much smaller. We will conduct a market study to select a market and in the near future we will start with development and applications in a specific area."

The researchers should not, however, focus too much on the food packaging application alone, says Broer: "This sensor technology is generic and suitable for far more applications. Take for instance wallpaper that senses humidity or dangerous gases such as formaldehyde. In many parts of the world, water needs to be filtered before it's drinkable. These filters sometimes don't function because of certain minerals in the water. It would be nice to be able to detect these minerals before filtering the water."

Applying the technology to food packaging is less easy than initially expected, Sjoerdsma experienced: "We were a bit naive at the beginning. We wanted to go to market in one or two years. That's just impossible. There are regulatory problems because the application is in contact with food, and there will be legal problems when something goes wrong. Then there's the discussion on value. We used to think that functional packagings would be worth a lot of money because they save lives. But what if you do it wrong? What will happen and who will be responsible? We know now that because of these hurdles it will take at least three years to get from proof of principle to a market-ready product." For Merck to actively participate in the project, an application needs to be in sight, says Parri: "Because we're not experts, we need to be convinced that this will lead to industrial applications. We also need to know on what time scale. We would like to have some sort of development roadmap."

"Our aim is to construct cheap, printable sensors that can detect multiple environmental parameters."

Cees Bastiaansen – associate professor in polymer technology at TU/e and project leader of the FPS project

Exception to the rule

DPI projects are always based on generic, applied research with multiple industrial partners. For Merck, this approach is unusual, says Parri: "We are a conservative company and we consider IP protection to be important. In an ideal world, we would get the necessary knowledge on our own terms. Open innovation is not something we do often, we prefer to work bilaterally. And when we collaborate in projects, we always ask ourselves how we can protect ourselves and our knowledge."

The reason behind Merck's participation in this particular project is the long-standing collaboration between TU/e and Merck, which dates back 25 years. Bastiaansen: "We know and trust each other. We have an open relationship without secrets, everything can be discussed." Parri: "TU/e is the exception to the rule, we usually want all the paperwork to be in place when collaborating with universities." Sjoerdsma: "For Specialty Packaging, all we have is customer intimacy. We don't develop or produce products ourselves, but we do know who's who in the market and we know market demands. The only way we can make use of that is by open innovation."

The chemical industry is very competitive, says Sjoerdsma: "We are part of DSM's Innovation Center, but DSM as a whole is much more secretive. Competition is fierce, so companies don't want to share anything." Parri admits that Merck would get somewhat nervous if it had to participate in a research program with some of its direct competitors: "We only collaborate with other companies if they have expertise that doesn't conflict with ours."

That makes DPI all the more unique. Parri: "I think it's the only organization in Europe that has so many different chemical companies working together." DSM as well as Merck would like to have interns from universities to carry out DPI research at the company for a few months. Sjoerdsma: "Given the right disclosure agreements, I don't see a problem with that. As long as research is pre-competitive. Sharing knowledge on research in the competitive phase is an entirely different story."

"Sensor technology is generic and suitable for far more applications."

Dick Broer – professor of polymer chemistry and polymer technology at TU/e and senior researcher at Philips Research

Dirk Sjoerdsma, Dick Broer, Rint Sybesma and Cees Bastiaansen

Edsger Smits
Making circuitry by letting the dots connect

Edsger Smits researched ways to let semiconductors self-assemble into electronic circuits. While in theory this sounds simple enough, several complicating factors make it a daunting task, requiring researchers to regularly revise their methods and ideas. Smits clears his mind by cycling or hiking, allowing himself to get the occasional eureka moment.

Edsger Smits is an inquisitive person. He wants to know how things work and why they do what they do: "Asking questions, pursuing inquiries and ultimately getting results gives a lot of satisfaction. Curiosity is my main driver." Recently, Smits received his doctorate (cum laude) for research on self-assembling electronics. Smits: "I researched molecules that had the capability to self-assemble and that had a semiconducting core at one end and a small 'anchor' binding to SiO2 on the other. We constructed an electronic circuit by allowing these molecules to self-assemble on a SiO2 substrate." This method, if successful, could become a cheaper alternative to lithography, the current technique for constructing electronic circuits. Smits: "Our way is a bottom-up approach, meaning that we design the circuit by starting with the smallest part. Basically, you define a circuit by fabricating predefined gold lines on a substrate, put the substrate in a solution of the molecules and wait until they have assembled into the circuit."

"I like to walk or cycle through the forest or in the fields. It clears the mind."

Edsger Smits – researcher TNO/Holst Centre

Electronic circuits

In reality there are complications. Smits: "If you want to make an electronic circuit, you have to make sure that all molecules in the circuit are connected to each other. If one molecule does not connect, the circuit won't conduct any electricity. That and the fact that the molecules have to anchor to the substrate makes it difficult to create molecules that can assemble to form an electronic circuit. There are dozens of molecules that are more or less suitable for the job. During my doctorate, I tried to find out why some molecules work well while others don't. Also, we looked whether our electronic circuits were suitable to be used in sensors. The circuits we produced are very sensitive to disturbances. In theory, this makes them very useful for gas sensors: a trace amount of gas can change the conductivity of the molecules." Since his doctorate, Smits has been working for TNO/Holst Centre research institute: "There, I am also researching sensors. Which sensors are interesting? How could they work? How can we improve them? These questions I try to answer."

Cycling and hiking

In his spare time, Smits likes to go cycling and hiking in the densely forested Veluwe region of the Netherlands, where he also grew up: "There is some beautiful nature there. I like to walk or cycle through the forest or in the fields. It clears the mind. It enables me to look at things from a different perspective. Like every researcher, every now and then I get stuck. While hiking or cycling I sometimes come up with an idea for an entirely new approach. You could say that these events are my eureka moments."

"Asking questions, pursuing inquiries and ultimately getting results gives a lot of satisfaction. Curiosity is my main driver."

Objectives

The Functional Polymer Systems (FPS) Technology Area performs research on polymers and their prototype devices that are capable of an electrical, optical, magnetic, ionic or photo-switching function and that offer potential for industrial applications. Therefore the FPS research programme is structured along application lines in the following subprogrammes: polymer lighting and field effect transistors, polymers for information and communication technology, solar cells (photovoltaics), and responsive materials, sensors and actuators. At the beginning of 2009 the Technology Area renewed its research strategy, providing openings for other industrial applications.

Subprogrammes

Polymer lighting and field-effect transistors
The aim of this theme is to gain a thorough fundamental understanding of materials behaviour under operational device conditions. Based on this fundamental knowledge breakthroughs in device performance are anticipated. Additionally new materials are explored for significant improvement of efficiency (lm/W) in polymer lighting applications. The research focuses on understanding materials and device performance, photo-physics and charge transport of white emitting polymer blends, mobility improvements, and the influence of self-assembled monolayers on device performance. This theme strongly supports interdisciplinary research projects between materials scientists, photo-physicists and device physicists.

Polymers for information and communication technology
The objective of the sub-area is the structuring of polymers on the nano- and micro-scale via 'top-down' approaches combined with 'bottom-up' techniques based on e.g. self-assembly or supra-molecular chemistry. In this way new or strongly enhanced properties for optical, electrical and biomedical applications should be generated.

Photovoltaics
The aim of this theme is to explore new materials and develop a fundamental understanding of all (photo-)physical processes occurring in the third generation photovoltaic (PV) technology, namely polymer bulk heterojunction PV. Besides many other PV technologies, polymer PV holds strong potential for large area cost effective PV for sustainable energy production on the long term. The research focuses on novel low band-gap materials, non-radiative decay processes, efficient charge separation, morphology control and thorough fundamental understanding of materials behaviour under operational device conditions. The ultimate goal of this theme is the significant improvement of polymer PV devices up to the level ready for commercialisation, at first instance for powering small consumer applications.

Responsive materials, sensors and actuators
The aim of this theme is to develop new materials and processes that result in a response and/or large displacements upon an external electrical, magnetic, optical and/or chemical trigger. Furthermore, new materials and devices for selective sensoring gases, time-temperature, bio fluids, etc. are targeted and, last but not least, actuating principles of rubber-like materials and corresponding devices are explored.

Facts and figures

Partners from industry
The Netherlands: DSM, ECN, TNO Océ Technologies, Philips, Shell.
Germany: BASF SE, Evonik Degussa GmbH, Merck.
Switzerland: Ciba.

Partners from the research world
The Netherlands: Universities of Wageningen, Groningen, Delft, Eindhoven, ECN, TNO.
Germany: Universities of Cologne, Bayreuth, Münster, Wuppertal, Duisburg-Essen, Ulm, Max Planck Institute für Polymerforschung Mainz.
UK: Imperial College London.
Belgium: Catholic University of Leuven.

Budget and Organization
Total expenditure in 2008 amounted to € 2.88 million (budget € 3.31 million). The total number of FTEs allocated at the end of 2008 was 29 (47 researchers). Total expenditure on equipment, expensive consumables and special analysis time amounted to € 107k. Prof. Dietrich Haarer acted as Scientific Chairman and was actively engaged in scientific developments alongside the Programme Area Coordinator (PAC) Dr. John van Haare, whose focus was more on operations.

Publications and inventions
The research programme of the Technology Area generated 5 theses and 38 scientific publications. Almost the full FPS research programme was renewed during 2007 and 2008. About 80% of the current projects are now fully staffed and the output of high level refereed papers can be expected soon. A total of 2 inventions were reported and 4 patents filed.

Detailed information on page 86.

Within the Coating Technology (CT) research area frontier research in the general field of organic coatings is performed. The aim is to develop fundamental insights that will lead to innovative coating technologies. The research is pre-competitive and is focussed at achieving sustainability and quality of life improvements and economic growth, preparing the coatings industry for future challenges.

Universities and industry need each other

Open innovation is a source of inspiration to both industry and academia. This is perfectly illustrated by a recently started project on the possible partial shift from UV cured coatings to daylight cured coatings.

Society is moving away from coatings with a high solvent content. Solvents might cause several health, safety and environmental problems, such as deteriorating working conditions, fire hazard and the breakdown of the ozone layer. UV cured coatings need less volatile solvents and the energy need for curing is reduced in comparison to thermally cured coatings. Unfortunately, UV curing technology has certain drawbacks too, which is the reason why UV technology is not in use in all possible applications.

At the Département de Photochimie Générale of the Université de Haute-Alsace in Mulhouse, France, professor Céline Croutxé-Barghorn recently started a research project on a possible shift from UV cured coatings to daylight cured coatings. This could open new application fields for UV coatings. The project meets DPI goals of sustainability, economic growth and quality of life and receives DPI funding. “If daylight could be a source of photo-hardening, there will be no need for short UV irradiation,” Croutxé-Barghorn says. “This is better from an industrial and environmental point of view and it also reduces the risk of health problems.” Daylight cured coatings could for instance be applied in varnishes and paints, for metal coatings, in the building and construction sector or in the furniture industry.

Daylight curing

Leo van der Ven is Group leader Expertise Group at AkzoNobel Car Refinishes and industrial fellow at the Eindhoven University of Technology in the Netherlands. “The shift from short-wave UV to daylight curing could be very important,” he stresses. “It is a classic example of Triple P: people, planet and profit could benefit from it. Daylight is a lot less dangerous, especially when it comes to home decoration coatings, where circumstances are less well controlled than in a factory. It also is less expensive and energy consuming, so the development is favourable from the viewpoint of sustainability. And, finally, some objects are simply too large for UV curing: it is impossible to contour an entire airplane with UV lamps.” Dr. Stephan Nowak, coatings physicist at Bayer MaterialScience (Leverkusen) adds: “UV curing light sources are often quite bulky. It is therefore difficult to reach all spots. Daylight curing may also be a solution for objects with a complex surface structure, as smaller and less heavy light sources are easily available for the visible spectral range.”

However, the shift from UV curing to daylight curing is not easily made, professor Croutxé-Barghorn tells us: “In order for daylight curing to become acceptable to the industry, it is imperative to shorten the current curing time significantly. This requires a thorough understanding of the photochemical process.” Professor Xavier Allonas is head of the Département de Photochimie Générale at the UHA. “Photochemistry is not trivial at all,” he confirms, “and we need to develop a completely new photo-initiating system.”

Collaboration

Prof.Dr. Claus Eisenbach, Scientific Chairman of Coatings Technology at DPI, is interested in the collaboration between industry and academia in this and other projects. Van der Ven: “The communication between both

> **“Open innovation helps to bring forward new ideas quickly to a broad research community.”**
>
> **Stephan Nowak** – coatings physicist at Bayer MaterialScience (Germany)

Stephan Nowak, Céline Croutxé-Barghorn, Leo van der Ven and Xavier Allonas

parties within the DPI framework helps in defining a project." Allonas: "Review meetings, lectures and discussions help us to define possible future applications. Also, we discuss what directions towards a solution are unlikely options. An open discussion within the DPI framework allows us to see the limitations of a project."

But the phase in which a project is defined is not the only moment industry and academia can reach synergy. Nowak: "For every project there are industry contact persons in the companies who have some interest in the research subject. They appreciate being contacted by the researchers to give further assistance in specific questions. They can act as a sounding board to the researchers: we would invite the researchers to appeal to them as much as possible." Van der Ven adds: "We can also supply the researchers with specific paints or resin systems for testing purposes. And professors Croutxé-Barghorn and Allonas are always welcome to test their systems in our laboratories, using our equipment."

"The communication between parties within the DPI framework helps in defining a project."

Leo van der Ven – group leader Expertise Group at AkzoNobel Car Refinishes and industrial fellow at the Eindhoven University of Technology

Value of open innovation

Over the past few years, industry has been cutting down on fundamental research. The importance of university research is growing: industry needs the universities for the development of basic knowledge. In return, industry can assist the researchers with input or facilities. Industrial partners can help to define the scope of the research, and focus it towards solutions that, in the long term, may be beneficial to society. If carried out in a setting of open innovation, a lot of parties may profit from it. Not only in terms of research results, but also in terms of fresh ideas and knowledge about future trends. Nowak says: "In several fields of pre-competitive research, Bayer MaterialScience is in favour of the concept of open innovation. It helps to bring forward new ideas quickly to a broad research community. Open innovation has, in this sense, a 'pilot' or

"We are all aware of the fact that fundamental research is very time consuming."

Céline Croutxé-Barghorn – Université de Haute-Alsace in Mulhouse (France)

'guidance' function, which helps us focus on future trends and topics at an early stage, and orient our in-house R&D respectively."

Also, PhD students get to know both sides of the table and can make a well-funded choice for their future careers. And, Van der Ven adds: "Open innovation creates powerful networks. This may lead to new business opportunities, which is an important reason for taking part in open innovation." Nowak agrees: "Open innovation helps you find partners for joint development."

No threat

Open innovation is no threat. Van der Ven: "Of course, 'open innovation' also means 'open' to our competitors. It refers to research that is relevant to more parties and to which many partners contribute. Sometimes partners A and B benefit most, sometimes partners C and D: one cannot plan the results of fundamental research. But this is all in the game. It is clear that we need each other, and benefit from each other."

But, says Nowak: "In pre-competitive research, we are in favor of the concept of open innovation. It helps bringing forward new ideas quickly and to a broad research community. Open innovation has, in this sense, a "pilot" or "guidance" function, which helps us finding and focusing on future trends and topics soon and to orient our in-house R&D respectively. Open innovation is also important in view of building up networks, and eventually find partners for joint developments. On the other hand - when it comes to more product related research, IP becomes very important, and everyone needs to draw a line between the pre-competitive part of innovation which is more "open", and the "private" part, which is the IP-based one necessary to ensure the capital of every company. When this distinction is not clearly made, there is the danger that only research and information of minor importance are exchanged in open innovation programmes."

In the DPI community, IP rights are well managed, Van der Ven says. And when it comes to company-specific research, this is done on a bilateral basis. Nowak: "Bayer MaterialScience is active in several pre-competitive research groups. The research is relevant to us, but not directly on a product-related basis. Maybe our company researchers can use the results to develop company-specific solutions. Or we interact bilaterally with academic groups to further develop certain technologies. In the latter case we enter into an agreement with the knowledge institution on IP ownership."

Time scale

Open innovation may be beneficial to both universities and industry, but admittedly the nature of both parties brings along some complications. Croutxé-Barghorn: "There is the time problem. We are all aware of the fact that fundamental research is very time consuming. Still, industry needs to operate fast. It is difficult for us to operate in the same time scale." Allonas: "The time gap is undeniable. But I must add, that it is not only industry that focuses on fast results. Politicians and university boards also put pressure on academia. They require a high output in terms of scientific results and publications. Perhaps the pressure from inside the universities is even higher than from industry."

Open innovation may help relieve the pressure: a fruitful cooperation between universities and industry offers possibilities to speed up the process and direct it towards knowledge that, in the long term, may benefit society.

"We need to develop a completely new photo-initiating system."

Xavier Allonas – head of the Département de Photochimie Générale at the Université de Haute-Alsace in Mulhouse (France)

Joris Sprakel

The unexpected may be the missing piece of the puzzle

Joris Sprakel was watching a TV programme on earthquakes in San Francisco. It was about the statistical laws behind earthquakes and how they can be used to construct earthquake-proof buildings. "The next day I applied these laws to one of my own experiments and, somewhat to my surprise, it worked! Isn't it fascinating how the unexpected can turn out to be the missing piece of the puzzle?"

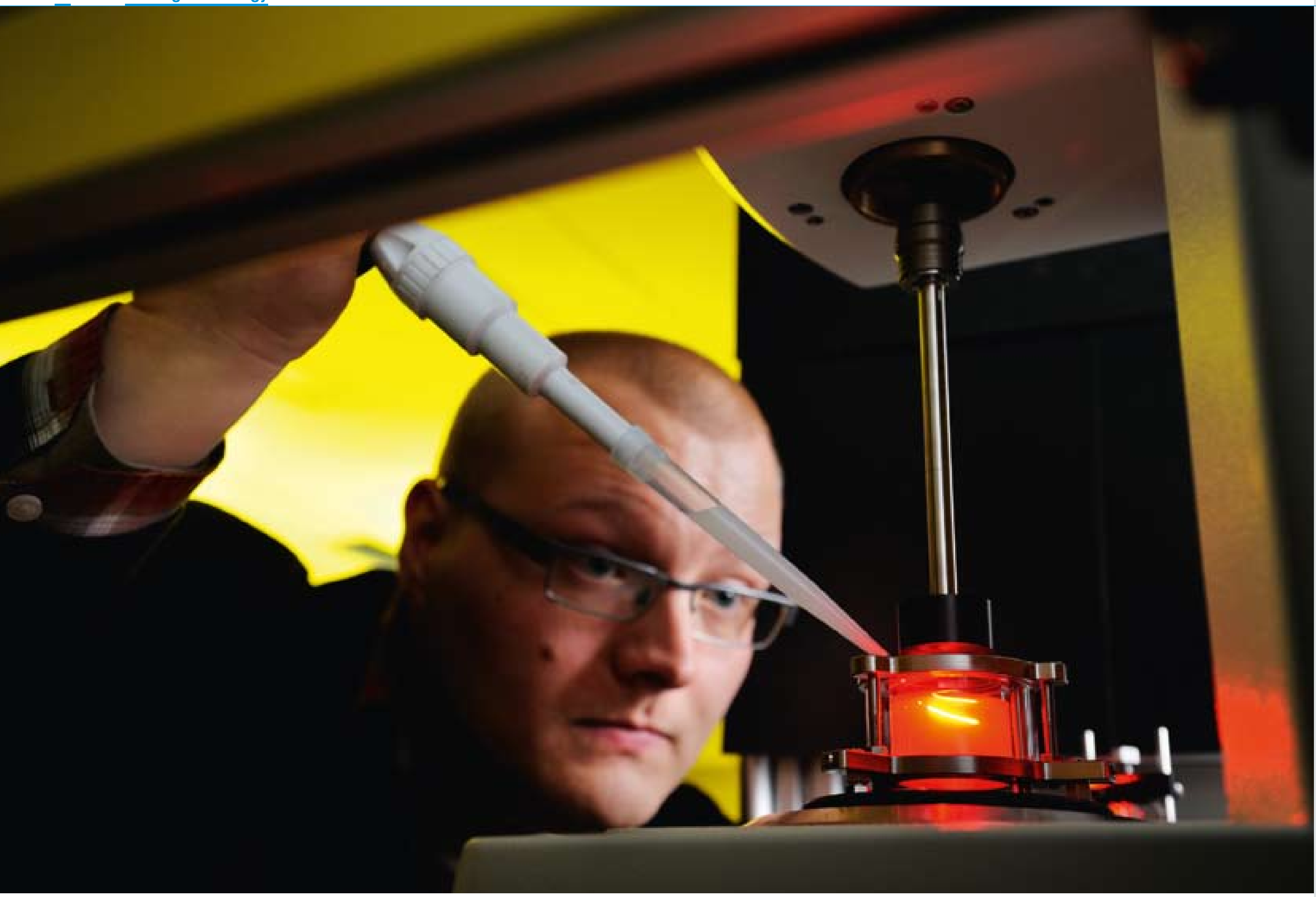
Joris Sprakel isn't afraid of the unexpected and the creative. He is curious by nature and always open to new ideas. "Often they don't lead to anything," he says, "but when they do they help you make a great leap forward." He likes to explore new horizons, also from an artistic point of view. "I have been drawing and painting for as long as I can remember," he says. "I also love making music with my band, Funkoplast." The cover band consists of friends from Wageningen University (Netherlands). Sprakel is the only physicist among them. "It's fun to relate to people who come from different backgrounds and have different interests. It prevents you from getting rusty." In his doctoral research too he likes to spar with colleagues, professors and other partners. "Everybody approaches a problem from a different angle. That stimulates us to come up with new concepts."

"I love making music with my band, Funkoplast. It prevents you from getting rusty."

Joris Sprakel – Laboratory of Physical Chemistry and Colloid Science at Wageningen University

Water-based coatings

His doctoral research focuses on water-based coatings. "Coatings containing volatile organic compounds damage both the environment and the health of the people using them," he says. "Therefore, the European Union has decided to phase out these products, eventually banning them altogether. But it is not easy at all to design water-based coatings with the same quality as traditional coatings. The thickening agents applied in modern water-based paints pose a major problem. On the one hand thickeners are necessary to prevent the paint from dripping from the wall under the influence of gravity, but on the other hand they often cause the paint to become unstable. The thickeners are, in fact, associating polymers. When dissolved in water they form small objects consisting of a number of polymer molecules in a process called 'self association'. In my doctoral research I studied this self association process in detail. I applied computer based modelling as well as molecular models. The result was a set of rules that can be used to cleverly design new thickeners."



“The fact that a melting pot of ideas and techniques has led to new fundamental knowledge is very satisfying to me.”

Part two of his research focused on the interaction of thickeners and surfaces. “We suspected that thickeners might generate forces of attraction between the particles in the paint, leading them to lump together instead of spreading homogeneously through the paint. I found two different mechanisms causing this attraction. I also succeeded in measuring these forces with an atomic force microscope. It’s important to understand these mechanisms, because they may teach us how to prevent this lumping.” The third part of his research concentrated on the flow behaviour of thickeners. “Unexpected patterns occur that remind us of weak earthquakes. The research proved that these flow patterns are much more common than we expected them to be and are applicable to numerous materials.”

Discovery Channel

Sprakel is enthusiastic about his doctoral research. “I have applied numerous techniques and sparred with a lot of people. My ideas for the third part of the study even came from a programme on Discovery Channel. The fact that a melting pot of ideas and techniques has led to new fundamental knowledge is very satisfying to me.”

Objectives

Within the Coating Technology research area frontier research in the general field of organic coatings is performed. The aim is to develop fundamental insights that will lead to innovative coating technologies. The research is pre-competitive and is focussed at achieving sustainability and quality of life improvements and economic growth (DPI business plan 2008-2015), preparing the coatings industry for future challenges.

Subprogrammes

Renewable raw materials, formulation and powder coatings

- Investigating the feasibility of the use of sustainable, renewable resources for the development of alternative monomers and co-monomers for the production of coating resins, without compromising the final coating (film) properties.
- Gaining a fundamental understanding of the colloidal stability of waterborne coatings as a basis for increasing their shelf-life and the number of applications.
- With a view to extending the application field (wood, MDF, plastics) for powder coatings, finding innovative solutions to meet the stringent demands on the cure window with respect to both rheology (levelling) and reactivity (cure).
- A new project started in 2008 and is directed towards the development of daylight / sunlight photoinitiating systems to the polymerization of organic resins and characterization of the coatings. Structure-property relationships will be thoroughly investigated with the goal of understanding the relations between the actinic light and its irradiance, the chemical structure of the polymer network and the mechanical properties of the cured materials.

Functional (smart) coatings

The objective is to develop new coatings with additional functional properties at the surface as well as in the bulk apart from protecting underlying layers and decorating effects, which are the functionalities normally associated with coatings. Preferably, these additional functional properties should be demonstrated using fewer sequential coating layers. Therefore structure-property relationships are extensively studied in the research field. Examples of functions which are explored in this area are: self-healing properties of coatings, antimicrobial activity, increased adherence between polymers and metal by surface modification of the metal substrate and the development of super-hydrophobic coatings by incorporation of hydrophobic monomers in the resin system.

Durability and testing of industrial coatings

The aim of this sub-cluster is to create fundamental understanding of the degradation mechanisms of coatings used in outdoor exposure. Furthermore, the program aims to develop new testing and analysis methods for coatings, such as adhesion, gloss, drying and scratch resistance. Typical examples of research topics are: investigation towards the physical-chemical relationship during coating degradation, systematic study on the molecular aspects of scratch resistance, a fundamental study towards the mobility of water and charge carriers in polymer/oxide/Aluminum alloys in relation to corrosion protection of the metal surface (project in cooperation with M2i) and investigation of the drying mechanism of coatings using 3D imaging techniques.

Facts and figures

Partners from industry
AkzoNobel, DSM, Océ Technologies, Shell, Bayer MaterialScience, Evonik Degussa, Dow Europe.

Partners from the research world
The Netherlands: University of Amsterdam, University of Groningen, University of Wageningen, Technical University of Eindhoven, Agro Technology & Food Innovations.
South Africa: University of Stellenbosch.
France: University of Mulhouse.
Germany: Forschungsinstitut für Pigmente und Lacke.

Budget and organization
The total expenditure of the Coatings Technology cluster in 2008 was € 1.68 million (budget € 1.75 million). The total number of FTEs allocated at the end of 2008 was 18, distributed over 27 researchers. The total expenditure on equipment was € 224k. In 2008, Professor Dr. Claus Eisenbach was Scientific Chairman of the Technology Area. Until September 1st Dr. John van Haare acted as Program Area Coordinator. Hereafter this role was taken over by Dr. Harold Gankema.

Publications and inventions
The research program of the Technology Area generated 5 theses and 13 refereed scientific publications. Moreover, there were a significant number of contributions to scientific symposia in the form of posters and presentations, which reflects that the Technology Area contributed considerably to the international science in this area. Two inventions were reported and one patend application was filed.

Detailed information on page 88.

High-Throughput Experimentation (HTE) and combinatorial materials research open the way to the rapid construction of libraries of polymers, blends and materials with a systematic variation of composition. Detailed characterization of such libraries will help to develop in-depth understanding of structure-property relationships.

Keep thinking while the machine keeps running

Within the DPI portfolio, the Programme Area of High-Throughput Experimentation (HTE) stands out. While most other Programme Areas focus on materials, HTE also aims at speeding up research and discovering new approaches as well as technologies. Therefore, the name of the cluster could well be High-Output Experimentation or New Technologies.

Scientific Chairman professor Ulrich Schubert states: "This is very important in the present global competition. In Europe, unlike China, we do not have dozens of researchers available to put on a project. But we need to get fundamental research to the market in two years all the same." The answer lies in clever automation.
Schubert is also Chairman of the Laboratory of Macromolecular Chemistry and Nanoscience at the Eindhoven University of Technology (Netherlands) and the Laboratory of Organic and Macromolecular Chemistry at the Friedrich-Schiller-University Jena (Germany). He explains what is special about the projects: "The whole knowledge chain is involved in a project. It begins with fundamental science. Ideas in this field are screened by industry at the other end of the table. Industry considers whether these ideas can lead to worthwhile applications. This is, for instance, the way in which we got started with rapid prototyping by ink jet printing."

Faster and better

The approach includes several key aspects: the Design of Experiments (DoE) precedes physical prototyping. The creation of new properties or colours is based on existing monomers or additives that are combined in a new way. Furthermore, research is highly automated, for instance by using robots for fast characterization. Schubert: "Yet another aspect is building a fundamental understanding of the relationship between structure, function and properties of the polymer. This enables a faster design of new variations: less experimentation and better design. Our vision for the long term is to introduce a wish list to the computer, which responds with the right product formulation."

There is still a long way to go, but the approach has already led to increased output within HTE: 16% of DPI researchers account for 25% of the publications. With patents the figures are similar. Dr. Manfred Stickler, Senior Vice President Innovation Management Chemicals at Evonik Industries in Darmstadt (Germany) and Chairman of the board of DKI notes: "In addition to the 'high throughput' aspect there is also a 'high output'."

He has observed this not only in the projects, but also in DPI management: "We had a project application running somewhere. Huge amounts of documentation were requested. After two years we found that we would not get any funding. So professor Schubert invited us to Eindhoven. One page proved to be enough to become partner of DPI and a project was up and running within a couple of weeks. We were impressed by the way in which the DPI was managed."

Systematic insight

Matthias Rehahn is professor for Polymer Science at the Technical

> **"In Europe we have to approach the value chain by co-operation and open innovation."**
>
> **Manfred Stickler** – senior vice president Innovation Management Chemicals at Evonik Industries

University of Darmstadt and head of the private institute within this university, the Deutsches Kunststoff Institut (DKI) in Darmstadt. He says DKI is a scientific member and industrial partner of DPI at the same time. "In our research, we are complementary to Eindhoven and Jena. Whereas professor Schubert focuses on specialty polymers, we mainly look at classical polymers like PP and PE. It is part of our mission to understand more thoroughly how they work. With this knowledge we support the industry to make better products in a cheaper way. This research is still mainly based on trial and error; we think our involvement in DPI might bring us closer to systematic insight into processes. To bridge the gap between fundamental science and application we use fundamental chemistry and physics alongside analysis and engineering. However, our work has lately expanded to include more polymer types: from membranes for proton transportation in fuel cells to polymers for transportation inside lithium-ion batteries. And for us, too, high throughput and high output are two sides of the same coin."

Staying ahead

Schubert: "All efforts within HTE revolve around new methods and approaches for better, smarter, faster research, regardless of whether the application is solar cells or lighting. We strive to create platforms; not for a single system, but for several systems at once. We are not smarter than the Chinese and they have got the numbers. We have to be better in different ways. Therefore, we invested heavily in high-tech equipment. Another aspect is the organization into large projects. In an individual small research project you can synthesize something but still be lost. We learnt that a multi-disciplinary approach and critical mass are necessary to get to the market with competitive new applications."

Stickler comments: "Global competition is all about knowledge. HTE is not new, but it is getting more important. It comes down to shortening time to market. You have to keep thinking while the machine keeps running." Schubert links this approach to the current crisis: "It offers us an opportunity to come out faster and better. Nobody gives us decades anymore to develop something and then throw it over the fence to see if someone likes it. Those were the old days. You have to go from fundamental knowledge to a genuine product in a few years." Stickler adds: "And at the same time the chemical industry is entering new areas. Innovations mainly occur at the boundaries of biotechnology, energy and electronics. This means we have to understand the materials and the applications as well. This is no choice; it is our opportunity for success. Materials can be produced everywhere. And where Japan and Korea have vertically integrated companies, covering entire complex product-market combinations, in Europe we do not have that. We have to go about it differently: by co-operation and open innovation. For that, we need clustering. Preferably, DPI should grow further into a real European Polymer Institute."

"We think our involvement in DPI might bring us closer to systematic insight into processes."

Matthias Rehahn – head of the Deutsches Kunststoff Institut (DKI) and professor for Polymer Science at the Technical University of Darmstadt

He welcomes Michelin as the first French participant. "Its people are now experiencing that new findings in, say, drug delivery might be applied in tires. Companies are getting into contact with new ideas that they would not have thought of trying in a 'closed shop' situation." Rehahn: "DPI should not run the risk of becoming a closed shop itself and should expand to France, Britain and Spain also." And, says Stickler, "Although ten per cent of Evonik employees are Chinese and most industry participants work world-wide, their home is still Europe. I think the Netherlands should be very proud to have started the DPI initiative."

A strong driver

Apart from growth throughout Europe, the DPI strategy also addresses current topics such as quality of life, economic growth and sustainability. The broadened scope of chemical companies affects these areas, says Stickler: "In Evonik we have three 'blood types', so to speak: chemistry, energy and housing. And all of them are all about sustainability. Quality of life also means sustainable growth, for instance through bio-based chemistry. We have many projects on chemicals

Roy Wäber, Manfred Stickler, Ulrich Schubert and Matthias Rehahn

from bio-renewable sources like sugar cane or wood." Rehahn stresses that sustainability is a key driver: "It was a reason for us to build a combinatorial compounding line. In the end, European law will force us to ban all poisonous additives – and with good reason, as nobody knows how all ingredients in a mixture of additives interact. Systematic research into the use of non-additive alternatives is driven by sustainability."

That is exactly Schubert's experience: "Research at the University of Liverpool on novel polymers for hydrogen storage and release for fuel cell applications is one example. Another one is DKI research into a formulation of polyoxymethylene (POM) that can prevent the formation of formaldehyde when it heats up. A third example are water-soluble, non-toxic polyethers that can be produced with less waste. The beauty of it is that a significant part of this HTE research can be applied generically: different fields of application and different partners, using the same research strategy."

Multiple benefits

Already, a lot of parties have found each other in DPI, says Schubert: "From multi-billion companies to SMEs and from private research institutes to universities, everyone can contribute and benefit." SMEs often wonder where their benefit might lie. Schubert has a nice example: "Chemspeed from Basel in Switzerland is a small firm. Before entering DPI, it produced 90% of its machinery for the pharmaceutical industry. In DPI projects they listen to the partners' wishes and come up with machinery that satisfies these wishes. Now they get a large portion of turnover from the material sciences market." Stickler further explains this success: "DPI researchers work with these machines. Once they transfer to industry they want the equipment to be there also." Dr. Roy Wäber, Head of the Service Department at DKI: "It is excellent marketing for the SME, but it is also an answer to the industrial need. Both sides benefit."

Schubert: "And let us not forget the researchers who benefit. Our PhD students are in high demand. At the moment, with this crisis, they stay longer in DPI research. There is a beneficial effect in that too. DPI benefits from the input of these experienced people. Once this crisis is over, they will be able transfer their knowledge to industry. There is no 'black hole' here like in the USA, where both industry and universities are laying off people. In Europe, the infrastructure remains intact. That is why we could come out favourably. As soon as there is ground under our feet again, we can leap ahead."

Jolke Perelaer
What printing has to do with coffee and microwaves

Dr. Jolke Perelaer likes to use everyday objects and situations to illustrate and explain his research. Be it a vegetable or a microwave dinner, anything can trigger a sudden idea. The important thing is that your mind is open.

Perelaer sees research overlapping in many ways with everyday things. “For my dissertation I took my camera to take pictures that would make my research comprehensible. A picture of a Romanesco cauliflower illustrates the lotus effect, in which nanoscale structures minimize adhesion of water drops. I came up with that during dinner, when I looked at the cauliflower on my plate.” Research isn’t a nine-to-five job, says Perelaer: “You don’t get ideas on demand. Your mind has to be in the right mode. I like to ride my motorbike and to hike in nature. These activities help me relax. And when you’re relaxed, ideas can suddenly pop up.”

Coffee rings

Perelaer’s research area is inkjet printing. One of the subjects he researched as a PhD student at the Eindhoven University of technology (TU/e) in the Netherlands was the drying of inkjet-printed droplets. Perelaer: “The solvent evaporates faster at the rim than in the middle of the droplet. Therefore, the solute material precipitates at the edge of the droplet and leaves a ring of solute material. This is the same reason why stains left by a coffee cup are always ring-shaped, hence the *coffee-ring effect*. I decided this was relevant to my research at the coffee table.”
For many industrial applications, including inkjet printing, inhomogeneous droplet drying is a major problem.

> **“You don’t get ideas on demand. Your mind has to be in the right mode.”**
>
> **Jolke Perelaer** – researcher at DPI

RFID chips

The main focus of Perelaer’s research is printable RFID chips. Perelaer: “These small chips can communicate wirelessly. They show great promise as successors to the bar code. They’re produced using lithography, a time-consuming, costly method. Inkjet technology would be cheaper and more efficient. Also, it would enable us to print electronics on flexible surfaces.” Conducting materials for electronics, like silver and gold, are solid at room temperature. But in the form of nanoparticles, they can be treated as a ‘liquid’. Perelaer: “To prevent agglomeration of the particles, you have to pack them in polymers. However, if you want to print electronics with them, you need to remove the polymers after printing. Most polymer substrate foils can’t resist the 200 to 300 degree temperatures you need to remove the polymers on the particles. It’s a Catch-22.”

Microwave

Perelaer's idea for a solution came from an everyday situation: "When I come home after a day's work, I sometimes heat up my dinner in the microwave. I asked myself if we could use microwave technology to remove the polymers." He discovered that the polymer around the nanoparticles can be burnt off with microwave energy. The foil remains intact. Perelaer already used this method to make antennas for RFID chips. "However," he says, "the chip has more components, and some are still too complex to print. For the moment, RFID is still too expensive to replace barcodes in the supermarket." He expects that inkjet printing will bring cheap RFID chips within reach. And not only that, says Perelaer, who received his doctorate in March 2009: "Most people don't realize the potential of inkjet printing. In the coming years, inkjet technology will change the world in many ways."

"Most people don't realize the potential of inkjet printing. In the coming years, inkjet technology will change the world in many ways."

Objectives

High-Throughput Experimentation (HTE) and combinatorial materials research (CMR) open the way to the rapid construction of libraries of polymers, blends and materials with a systematic variation of composition. Detailed characterization of such libraries will help to develop in-depth understanding of structure-property relationships. In the long term, a kind of 'materials informatics' is envisioned that will allow the design and preparation of tailor-made materials and devices with predetermined properties based on previously established structure-property relationships.

The main focus will be on creating and applying full workflows, covering the design of experiments, automated and parallel synthesis, fast structural characterization, preparation of thin-film libraries, fast and efficient investigation of macroscopic polymer and material properties, formulation, up-scaling, combinatorial compounding, processing and complete data-handling, data-mining and modelling. DPI's unique combination of leading industries and academic partners provides an excellent basis for successful output. It also guarantees speed in the pre-competitive evaluation of the new (platform) technologies and rapid transfer into commercial R&D programmes of the industrial partners. At the same time, considerable efforts will be made to educate students and post-doctorate graduates in the use of HTE and CMR approaches in polymer and materials science.

Subprogrammes

Synthesis, Catalysis & Formulation

The research in this sub-cluster focuses on the preparation of libraries of (co)polymers and formulations as a basis for the determination of structure-property relationships. The polymer synthesis within the cluster focuses on living and controlled polymerizations that allow the preparation of well-defined polymers with systematic structural variation. Besides fundamental research on the use of microwave irradiation, feasibility studies are performed on up-scaling microwave-assisted polymerization procedures. In addition to fast synthesis and formulation platforms, the incorporation of high-throughput screening techniques for e.g. molar mass, polymerization kinetics and thermal and surface properties is investigated. The current high-throughput experimentation workflow is used for the optimization of polymerization methods and the synthesis of libraries of (co)polymers based on 2-oxazolines, (meth)acrylates, styrenics, cyclic esters and, in collaboration with the Polyolefin Technology Area, the synthesis of polyolefins. There is a strong emphasis on the development of a complete high-throughput workflow including parallel synthesis and high-throughput screening using for example automated high-temperature size exclusion chromatography. The existing high-throughput workflow has been further expanded to include capabilities for polymer water-uptake screening and polymer solubility screening. Therefore, the synthesis efforts have been intensified in the direction of water-soluble polymers.

Facts and figures

Partners from industry

Accelrys, AstraZeneca , Chemspeed Technologies, Dow Benelux, Evonik Degussa, Forschungs-gesellschaft Kunststoffe, Lyondell Basell Industries, Michelin, Microdrop Technologies, Nano Technology Instruments Europe, Océ Technologies and Waters Technologies.

Partners from the research world

The Netherlands: Eindhoven University of Technology, University of Amsterdam, Technical University of Twente.
Germany: Deutsches Kunststoff Institut, Friedrich-Schiller-Universität Jena.
UK: University of Cambridge, University of Liverpool.

Budget and organization

The total expenditure for the High-Throughput Experimentation Technology Area in 2008 amounted to € 2.80 million (budget € 3.06 million). About € 561k was spent on equipment. The remaining budget was allocated to 57 researchers (25 FTE). In 2008, Professor Dr. Ulrich S. Schubert was Scientific Chairman of the Technology Area and acted as interim Programme Area Coordinator until this role was taken over by Dr. Harold Gankema on 1 September.

Publications and inventions

The research programme of the Technology Area generated two theses and 48 scientific publications. Seven inventions were reported and five patent applications were filed.

Detailed information on page 88.

Thin-Film Library Preparation & Screening

This sub-cluster mainly focuses on gaining a detailed understanding of thin-film preparation technologies (mainly inkjet printing), on the application of these technologies and on the screening of thin-film materials properties by automated atomic force microscopy and nano-indentation technologies. Fields of research are the processing of polymer inks (coatings and light-emitting materials) and homogeneous drop and film formation on different substrates (including polymeric ones). Application fields include the processing of light-emitting materials, surface patterning and the preparation of conductive tracks on polymeric substrates. In the area of AFM, the investigations (in collaboration with the Functional Polymer Systems Technology Area) cover photo-embossed relief structures. Now, combinations of inkjet printing and other structuring techniques, such as hot embossing, are explored to further decrease the size of printed features.

Combinatorial Compounding

The programme of the combinatorial compounding sub-cluster is executed at the Deutsches Kunststoff Institut (DKI) in Darmstadt (Germany). The central objective of the programme is the development of a process, closely related to technical production processes, that facilitates the acceleration (by up to 100%) of the preparation, characterization and optimization of plastic formulations. The combinatorial extrusion line used for this purpose will be supported by in-line and on-line screening techniques (e.g. IR, UV/Vis, rheometry, ultrasonic spectroscopy) as well as data acquisition, analysis and visualization systems. In addition, new screening facilities have been set up.

Materials Informatics & Modelling

This programme concerns data handling, database construction and the build-up of integrated knowledge capture systems for combinatorial materials and polymer research as well as experimental design, hard and soft modelling tools and tools for deriving quantitative structure-property relationships, supporting mainly the programme on Synthesis, Catalysis and Formulation, Thin-Film Library Preparation & Screening and Combinatorial Compounding. A model is being developed for the screening of MALDI matrices to facilitate faster screening of molar mass. In addition, activities for the installation of a cluster-wide inventory system as well as the first steps into an e-notebook system have been initiated.

Detailed Characterization Techniques

The sub-cluster on detailed characterization techniques focuses on the development of detailed characterization methodologies, mainly microscopic and chromatographic techniques, for specific applications. One aspect is the combination of different measurement techniques (high-resolution TEM and AFM in combination with SAXS/WAXS measurements) with the aim of characterizing multi-phase (amorphous/crystalline) or multi-component materials (rubber-reinforced polymers or nano composites) on macro, micro and nanoscales. A further focus of interest is the analysis of branched polymers by means of two-dimensional liquid chromatography. Unique results have been achieved regarding the fractionation of high molar mass branched polymers. This has significant implications, e.g. in the polyolefins field. Moreover, the development of tools and models for the nano-scale characterization of interfaces using AFM technology has been continued. In combination with the Synthesis sub-cluster, projects are running to develop and evaluate high-throughput screening methods for polymer solubility, including phase transitions such as lower and upper critical solution temperatures, dispersion formation and micellation.

Young DPI Community Meeting 2008

Jacques Joosten, managing director of DPI: “Innovation is not only about ideas, but especially about people. To reinforce the relationship with the many young scientists who work on DPI-projects we have established the ‘Young DPI Community’. In November 2008 we organized a meeting that was attended by 60 young graduates. Both the participants and the organizers considered it a highly inspiring meeting. We will continue this way and have already planned a second meeting for the ‘Young DPI Community’ in 2009 prior to our Annual Meeting.”



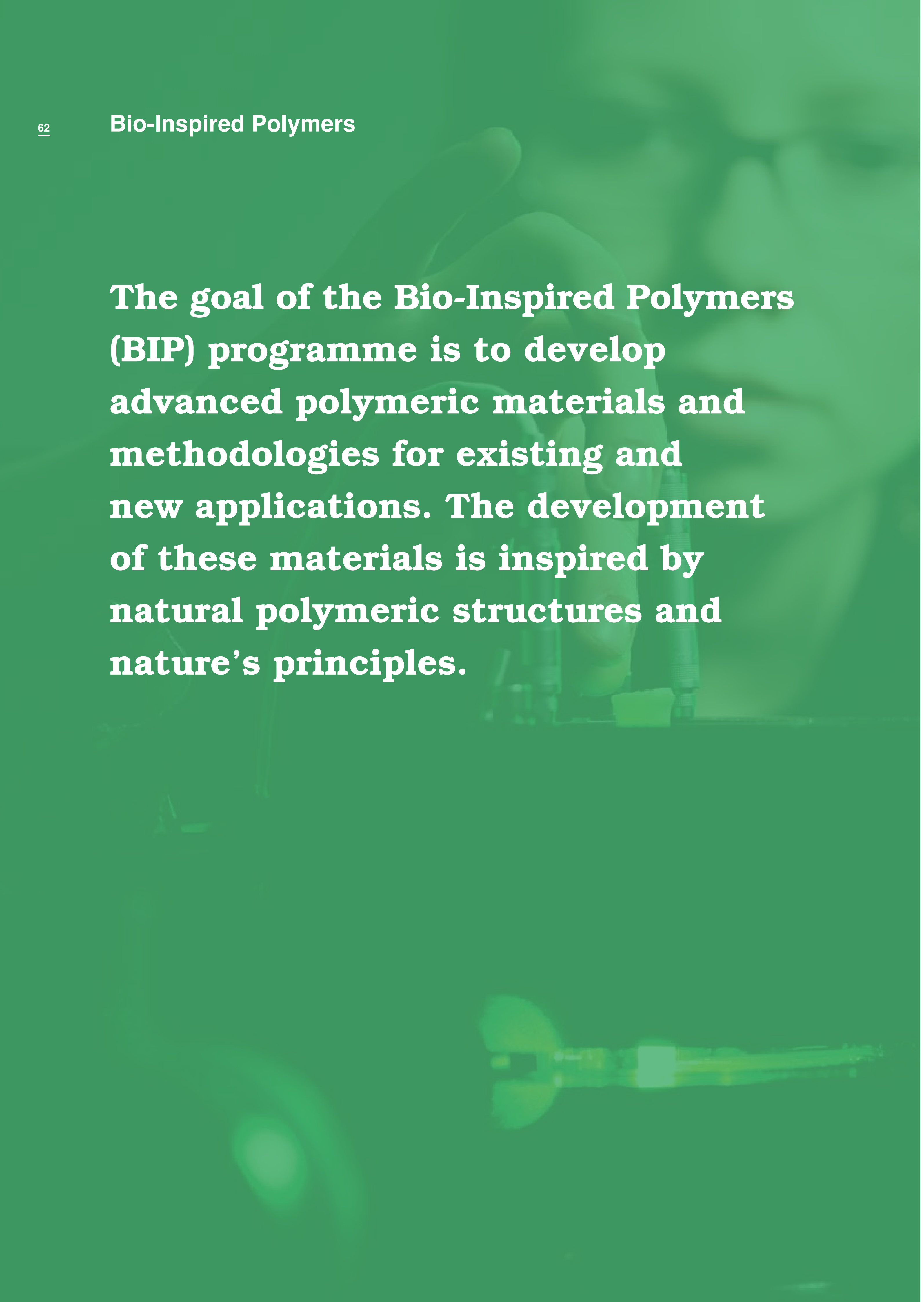










The goal of the Bio-Inspired Polymers (BIP) programme is to develop advanced polymeric materials and methodologies for existing and new applications. The development of these materials is inspired by natural polymeric structures and nature's principles.

Robustness is also an aspect of sustainability

The Japanese company Teijin is putting a lot of effort into the development of commodity polymers from bio-renewable sources, and Wageningen University (Netherlands) has a considerable track record in bio-based polymer development. Still, both agree that robust fossil-based polymers can score high on sustainability. And both regard the Dutch situation of collaboration between companies and knowledge institutions as beneficial for research and development.

This development could go in the direction of bio-inspired production mechanisms or head towards bio-based polymers produced by micro-organism like yeasts or bacteria. Now that proper end-to-end eco-efficiency analyses are becoming available, the focus on sustainable solutions will only increase.

Like other major chemical companies, Teijin is involved in the development and use of polymers from bio-based feedstock. The company for instance aims to develop stereocomplex polylactic acid (PLA) as a bio-based alternative for polyester. Jan Roos, director Research & Technology, Teijin Aramid (Arnhem): "SC-PLA stands out for its high glass transition and melting point and its excellent dye characteristics. This makes the material highly interesting for automotive applications like car seat covers. We already supply SC-PLA fibres for this application to a car manufacturer in order to contribute to completely biodegradable car interiors."

This choice for bio-renewable raw material fits in with the long-term philosophy of the Japan-based multinational. Roos: "The company is very responsive to societal issues. It has had an environmental charter for a long time and is putting a lot of effort into recycling by de-polymerization. This reflects our corporate motto of 'Human Chemistry, Human Solutions'."

Martien Cohen Stuart, professor of Physical Chemistry and Colloid Science, department of Agrotechnology and Food Sciences at Wageningen University and recently appointed scientific director at DPI: "This fits in with the tradition of Wageningen University. We have thirty years of experience in close co-operation with the business world. As a university with agrarian roots, we have always focused on making the best use of everything that grows. Nowadays, raw material management has become a major factor worldwide. But at Wageningen quality of life and sustainable development have always been at the forefront, for instance in relation to the valorization of waste flows in the agro industry. In order to get more added value from these flows, the trend is towards increasingly high-tech solutions. Against this background it is not surprising that we can look back on at least twenty years of biodegradable polymer research. The impact of this subject has greatly increased lately."

Roos too notes that polymers from bio-renewables are at the centre of attention. "Market demand, however, still lags behind. The market is enthusiastic about the advantages of bio-based materials, but is often not willing to pay more for them." Cohen Stuart drops in: "And governments? Do they stimulate the use of bio-renewable raw materials?" Roos: "They sometimes do, but there is

> **"Co-development of applications with partners in the supply chain is so much 'business as usual' to us that we hardly regard this as open innovation."**
>
> **Jan Roos** – director Research & Technology, Teijin Aramid

Jan Roos, Martien Cohen Stuart and Jurriaan van den Heuvel

hardly ever a really stable course towards sustainability. Regretfully, there often is a tendency to honour trends and hypes for a limited period of time."

Eco-efficiency

Furthermore, Jurriaan van den Heuvel states, sustainability is a complex theme that goes beyond the use of bio-renewable raw material. Van den Heuvel is group head of Fiber Physics at Teijin Aramid: "We are unlikely to find a bio-renewable successor to Twaron in the near future; bio-renewables are more suitable for bulk fibre applications. For instance cellulose or protein-based fibres and of course PLA."

But fossil-based Twaron fibre is so robust, he remarks, that the use of a kilo of it often saves dozens of kilos of other materials, simply because of its long lifecycle. Less wear means less replacement, which is a contribution to sustainability. Also, Twaron is an alternative to harmful materials like asbestos in brakes for cars and trucks. After use it is recycled wherever possible for re-use in downgraded applications. This recycling stream is currently small, but growing." A new Teijin Aramid product is Sulfron. Van den Heuvel: "This additive to tire compounds diminishes rolling resistance and extends tire life."

Proper calculations of the environmental footprint during a product lifecycle throughout the whole chain are highly complex - and they are becoming available just now. On this issue, there is a debate going on between the Eco-Efficiency Analysis used by BASF and the cradle-to-cradle principle of Braungart. Cohen Stuart: "Closing raw material cycles can in practice turn out to be very energy-inefficient. It is therefore not always the best option. Furthermore, there is a natural but invisible flow of material to the biosphere. It cannot always be measured, but it exists. So sometimes it might be more sustainable overall to discard something rather than to recycle everything." Roos: "To use a polymer for twenty years and subsequently burn it for its energy content might not be a bad solution."

Cohen Stuart: "But isn't there an issue of dwindling sales when the product lifecycle is too long? When the quality is too high, you just don't sell new products anymore..." Roos: "That is what has been said about light bulbs for years on end, but look at the present situation. LEDs last for 50,000 hours. Competition – especially in rational business-to-business environments – will ensure that the supplier with the best performance wins: a sustainable product with less wear and minimized maintenance costs. "

Internal-external

In developing new products with such an overall competitive performance, open innovation is a possible strategy. Roos: "We always have to prove the added value of our fibres to customers. Co-development of applications with partners in the supply chain is so much 'business as usual' to us that we hardly regard this as open innovation. But it is, because it goes much further than a normal supplier-customer relationship."

Van den Heuvel: "Open innovation is essential nowadays. In the past, companies had large corporate research departments. There were internal specialists to answer any problem you could think of. At present, in-depth knowledge is limited to core business. For other issues we consult our extensive network of third parties. This might not be full-fledged open innovation, but it illustrates how the choice between internal and external crops up in every discussion on research and development. Take for instance the investment in a TEM (Transmission Electron Microscope), an issue we recently discussed. We decided not to buy it ourselves as yet, but to outsource the research. For NMR (Nuclear Magnetic Resonance) spectroscopy research on the other hand we were accustomed to hiring external parties. Now that this technology has become vital to us we have decided to do this by ourselves."

Split

Cohen Stuart understands this policy: "Companies have to constantly adapt to dynamic market conditions; they need to be agile. Therefore it is not always useful or possible to maintain all sorts of rare specializations. Although ivory towers have long gone, universities still can maintain specializations. They can support several market parties with rare knowledge. This provides the very basis for fruitful collaboration between companies and universities. It works out nicely, provided that publication and IP issues are addressed. "

Roos: "From a corporate perspective, you must have a keen eye for the academic interest. You should settle IP issues beforehand and see to it that there is solid commitment from both sides. That is a condition for added-value open innovation. It demands special types of people, who are able to work 'with one foot in a company and the other in a university'. Not everyone is able to do that. I think that Dutch universities deserve a compliment for their willingness and ability to co-operate, to find mutual advantages and to look for creative IP solutions. In a global perspective, this is quite rare." Cohen Stuart: "It is probably a consequence of size. The Dutch academic world is too small to maintain a lively competition between regions or universities. We are therefore inclined to collaborate. Furthermore, the government stimulates public private partnerships. This certainly helps; this government funding is a nice bonus to stimulate long-term developments."

Bio-inspi(de)red

In the long run, apart from PLA, Cohen Stuart also sees possibilities for amino acids produced by yeasts and bacteria. "The challenge lies in creating the proper structure-function relations." As to literally 'bio-inspired' polymers, Van den Heuvel points to the mechanism that spiders use for prevention of hydrogen bridges. "This could be relevant for the development of super-strong nylon fibres. It is the raison d'être and the added value of DPI that ideas like that can emerge."

Roos: "Even in this time of crisis this added value continues to be a strong asset. Every company is looking at the consequences of the crisis and trying to cut costs. But they know that innovation is vital to survival and that open innovation is an effective and efficient way to do it."

> **"Closing raw material cycles can in practice turn out to be very energy-inefficient. It is therefore is not always the best option."**
>
> **Martien Cohen Stuart** – professor of Physical Chemistry and Colloid Science, department of Agrotechnology and Food Sciences at Wageningen University and scientific director at DPI

Paulina Skrzeszewska

As a kid I dreamed of discovering the world

Wherever Paulina Skrzeszewska goes, she takes a map of the world with her. "I have always known that I would travel the world, for work as well as for fun. I love discovering new territories."

The research of Paulina Skrzeszewska focuses on the physical characterization of transient networks formed by telechelic polypeptides, with collagen-like end blocks and a random coil, hydrophilic middle block. The protein copolymers are produced by modified yeasts. "Using genetic engineering, well defined, monodispersed molecules can be created," she says. "We know the exact length, sequence and composition of the polypeptides. By changing the design of the underlying DNA template, we can easily vary the precise molecular design."

Swiss watch

At temperatures above 50°C, solutions of the polypeptides investigated are viscous with no elastic response. When the solution is cooled down to 20°C, the collagen-like end blocks form triple helixes. These in their turn form a physical gel. "Well-defined network multiplicity allows us to carry out calculations which link results obtained from linear rheology with the internal gel structure. That knowledge is crucial from an application point of view, where controllability and the tenability of the system are essential," says Skrzeszewska. In addition to physical properties the biological properties of the system can be modified by changing the composition of amino acids in the middle block.

"After two years of research, I am now halfway," says Paulina. "My plan is to learn as much as possible about the architecture and physical properties of our system. I have always been curious about the way nature works, and now I am working with biotechnologically produced polypeptides, a system inspired by collagen. Very often I am so amazed by nature, I think it's incredible how everything fits together! Like a Swiss watch, everything works perfectly."

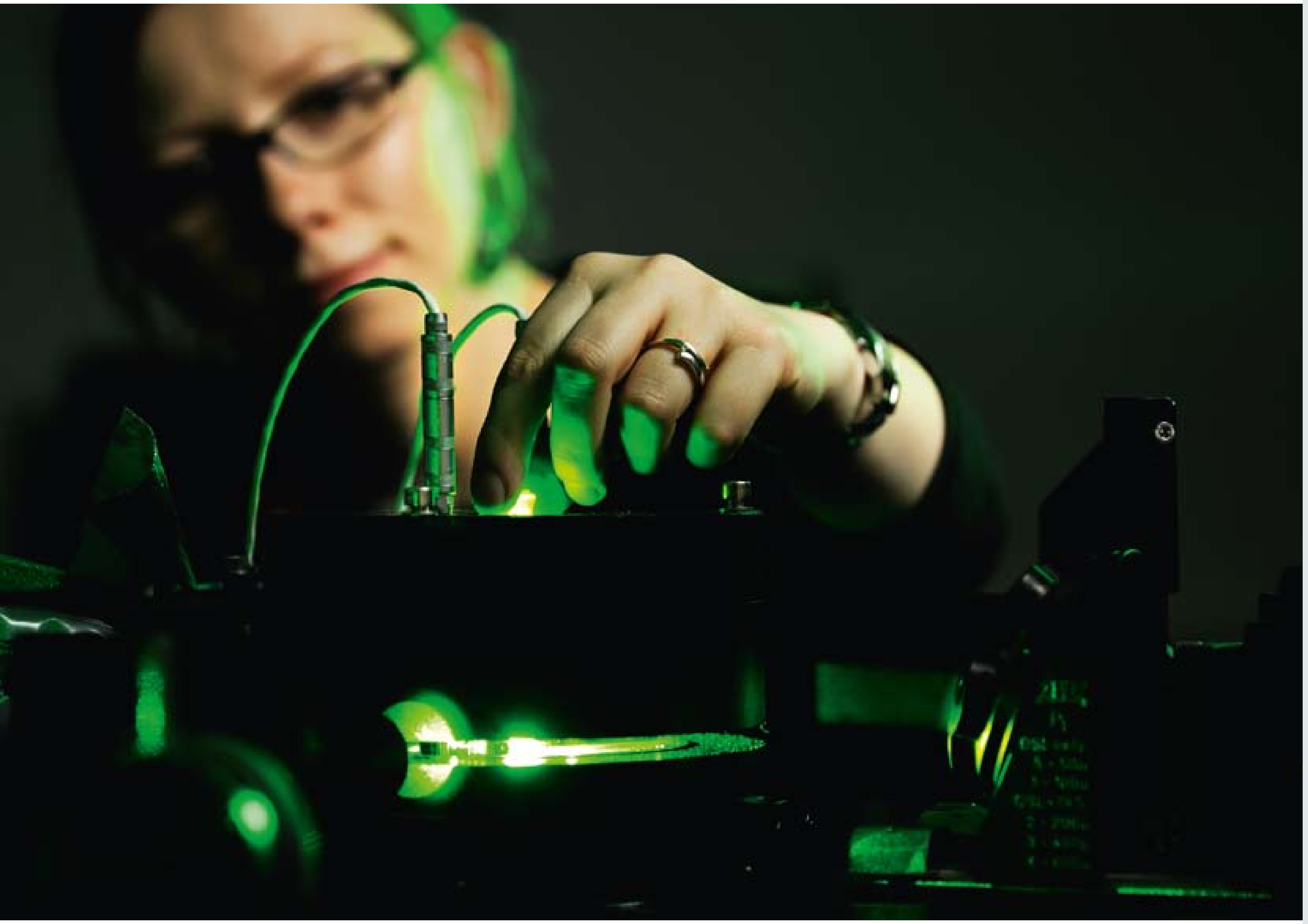
> "I always knew that I would go far to find answers, both for work and to satisfy my own curiosity."

Paulina Skrzeszewska – PhD student at the Laboratory of Physical Chemistry and Colloid Science at Wageningen University

Challenges

The work is challenging, but that only adds to its attraction, Skrzeszewska finds. “My work is a source of inspiration to me, it makes me happy. There is great satisfaction in finding answers to complex puzzles.” Her search for knowledge and answers never stops. “In my free time I like reading books on sciences not directly related to my work. But I also like to travel the world, gathering as many impressions as possible. I grew up in Poland, and as a kid I had a world map in my room. I always knew that I would go far to find answers, both for work and to satisfy my own curiosity. Of course I didn’t know my work would bring me to Wageningen, but I like it here. I like the direct approach of the Dutch, the urge to be clear. It suits my character.”

“There is great satisfaction in finding answers to complex puzzles.”



Objectives

The goal of the programme is to develop advanced bio-inspired polymeric materials and methodologies for existing and new applications. The development of these materials is inspired by natural polymeric structures and nature’s principles (such as self-assembly and biocatalysis).

These polymers can be produced from natural or synthetic resources and by using (chemo)enzymatic and microbial catalysis. The structure-property relationships of the novel materials are to be studied in order to elucidate why they exhibit these unique properties. The scale of the synthesis is to be developed to such an extent that tangible amounts of materials will become available for testing. The aim is to demonstrate scale-up potential as well.

Facts and figures

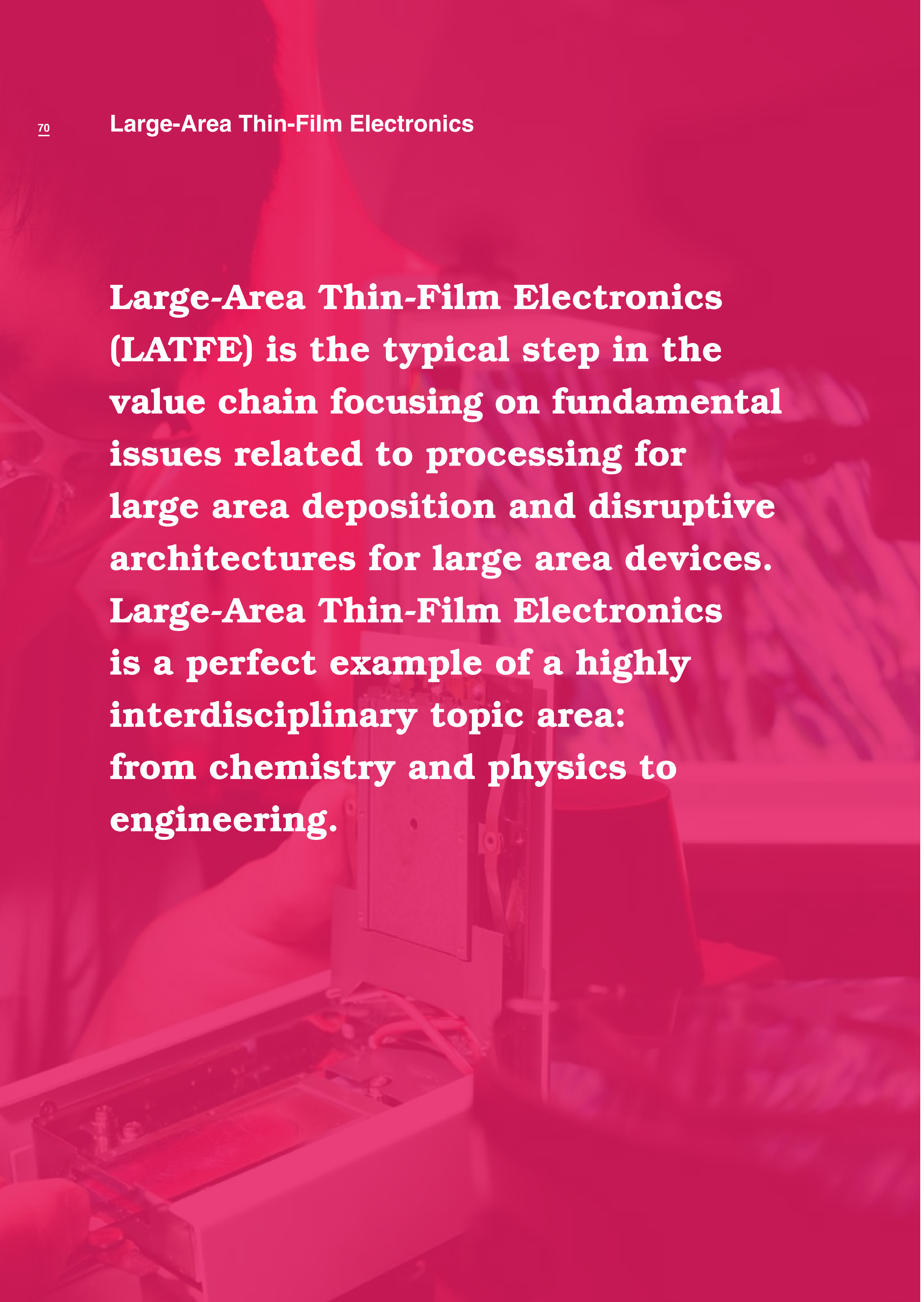
Partners from industry
Dow Benelux, DSM, Océ Technologies, Agrotechnology & Food Innovations, Evonik Degussa, FrieslandCampina, Teijin Aramid

Partners from the research world
The Netherlands: the universities of Eindhoven, Maastricht and Wageningen, PTG Eindhoven, Agrotechnology and Food Innovations.
UK: the universities of Leeds and Loughborough.
Germany: Max Planck Institut and Friedrich-Schiller-Universität Jena.

Budget and organization
Total expenditure in 2008 was € 1.40 million (budget € 1.53 million). About € 24k was spent on equipment. The total number of FTEs allocated at the end of 2008 was 14 (21 researchers), but not all vacant positions have been fulfilled. In 2008 Dr.ir. Peter Nossin took over the responsibilities of Programme Area Coordinator from Ir. Richard van den Hof.

Publications and inventions
The research programme of the Technology Area generated three scientific publications in 2008. There were no reported inventions. One patent application was filed.

Detailed information on page 91.



Large-Area Thin-Film Electronics (LATFE) is the typical step in the value chain focusing on fundamental issues related to processing for large area deposition and disruptive architectures for large area devices. Large-Area Thin-Film Electronics is a perfect example of a highly interdisciplinary topic area: from chemistry and physics to engineering.

Open Innovation is imperative to survive

In the DPI field of Large-Area Thin-Film Electronics there is a clear-cut division of roles between a limited number of research partners. This aspect is highly valued, as it provides focus to a small team. Contacts could be more intense, but the partners are confident they will meet more often as projects evolve. In collaboration projects between academia and industry there is always the intellectual propery (IP) versus publication issue. Participants think that DPI has struck the right balance between these two.

Imagine a ceiling emitting soft, warm light. A button on the wall enables the user to change the colour of the light. He or she could go for a warmer, romantic atmosphere or rather a brighter, more businesslike feel. Other promising applications of this solid state lighting with Organic LEDs (OLEDs) are signage systems, light emitting windows and interior car lighting.

Participants in the Large-Area Thin-Film Electronics (LATFE) Technology Area are trying hard to move towards applications, but some technological problems have to be solved before the market can be penetrated. Holst Centre is now working on a near product scale pilot line for the deposition of conductive polymers. Researchers from Eindhoven University of Technology (TU/e) in the Netherlands support this with ‘fundamental-applied’ knowledge in the shape of proof-of-principle studies and model systems.

The ultimate goal of Philips, the main industrial participant, is a cost effective reel-to-reel process for OLED lighting products.

Peter van de Weijer, Principal Scientist Photonic Materials and Devices at Philips Research and LATFE Programme Committee Member: “The end product has to compete with fluorescent tubes and the present inorganic LEDs in terms of comfort, sustainability and economic value. The wallpaper-like application stands for comfort. OLEDs are a very energy-efficient light source, which covers sustainability. As to economic value, the technology will have to compete price-wise. This will start in high-value niche markets on the basis of unique characteristics like flexibility and freedom of shape. Later on, gradual penetration of the general lighting market will become relevant.”

Fundamental understanding

According to Van de Weijer, the fundamental-applied research effort is worthwhile. “Universities are shifting from long-term to mid-term development and companies focus on the short term. But in our line of work understanding the fundamental phenomena at work is vital. Gaining a systematic understanding at an early stage will speed up research later on.” Professor Anton Darhuber and his group at the TU/e Department of Applied Physics in Mesoscopic Transport Phenomena provide this fundamental input. One of the focal points is control of drying of wet films on a substrate. This involves research into small-scale fluid mechanics, with control of surface tension, heat and mass transfer aspects.

Ike de Vries, Senior Researcher Reel-to-Reel processes at Holst Centre, gives an example of how collaboration works: “Some samples show an

> **“To me, open innovation is co-operation.”**
>
> **Peter van de Weijer** – Principal Scientist Photonic Materials and Devices at Philips Research

inhomogeneous conductive coating and some don't, although the coating solution and the process conditions were the same. Only the substrate was different. TU/e can help to understand these phenomena and to model them. The fundamental input enables a better selection of raw materials and processes."

TU/e researcher Jorge Vieyra Salas works on the simulation of drying. He likes the applied angle in his fundamental research on evaporation of a droplet: "Half of my research consists of simulations, and the other half is spent on experiments. Although the research is fundamental it also supports a concrete goal. I like the co-operation with industry and the connection with a real-life application. It makes an abstract subject come alive."

Closer co-operation

Therefore Vieyra Salas would welcome even closer co-operation. Van de Weijer, Darhuber and De Vries agree. De Vries: "It would be useful to consult with each other more frequently, preferably not only have formal contacts, but just drop in whenever we feel like it. We all work in close range of each other, so that is no problem." Van de Weijer: "To start with, we could learn more about each other's facilities. The DPI project environment already provides focus to a small team working on one subject. More frequent contacts would only strengthen this." De Vries thinks that contacts will intensify automatically since on the one hand a pilot production line is up and running at the Holst Centre and on the other hand the research programme of Prof. Darhuber is progressing. It becomes easier to link application-related topics to more fundamental ones. All parties involved really co-operate.

> **"The fundamental input enables the right choices in raw material and processes."**
>
> **Ike de Vries** – senior researcher Reel-to-Reel Processes at Holst Centre

Van de Weijer: "You can look upon open innovation as a one way street: research by academia is financed and absorbed by industry. But to me open innovation is co-operation. We like to participate in joint research projects. In this way we can integrate the effort even further than we are doing now."

Philips is open to this, he says, for good reasons. "The open innovation concept has become a matter of survival. An innovation chain is far too expensive for a single company to sustain." Therefore Philips even co-operates with direct competitors in close-to-market research. Van de Weijer: "But that kind of co-operation is sometimes limited to sharing expensive equipment. It is better to include parties with different roles in the value chain, like material suppliers and machine builders. This really boosts progress." De Vries sees a problem ahead: "I wouldn't know how to do that, as these parties have a similar place in the value chain as we have."

Van de Weijer sees the point and also stresses that the number of project partners should not become too large. "Three or four, maximum five partners should be involved. Collaboration in a small team is fun. When the number of partners grows beyond that, co-ordination and communication get harder and politics come into the picture."

Intellectual Property

No such problems are to be expected from the academic partners, Darhuber states: "I'm an enthusiast of open innovation. Beyond sharing resources it is also: more people, more ideas, more knowledge. I only slightly hesitate when it comes to IP, which might close

> **"I'm an enthusiast of open innovation, as long as IP issues don't close the door to publication."**
>
> **Professor Anton Darhuber** – TU/e Department of Applied Physics, Mesoscopic Transport Phenomena group

Peter van de Weijer, Anton Darhuber, Ike de Vries and Jorge Vieyra Salas

the door to publications." This touches an important issue in the collaboration between industry and academia. Therefore DPI has mechanisms in place to limit the delay for publication because of patenting. A publication draft is delayed for at most three weeks when the content causes no IP issues. If there are IP implications, this content is covered in a patent within a couple of months. The resulting IP is owned by all industrial members of the Technology Area.

This, in turn, is also a matter for consideration. De Vries: "The key issue is what partners regard as their core business. Core business and sharing or licensing patents can be conflicting. But there is a grey area in which sharing or licensing patents is advantageous for all parties involved." According toVieyra Salas IP is all part of the game. "I work with models for ideal liquids and do experiments, but I don't know about the PEDOT formulation we use. The data on material properties would be welcome, but isn't available. It doesn't hamper research, but it can slow it down." Unlike some scientists Vieyra finds it hard to choose between publication and patent. "I like the application side; therefore I do understand the importance of patents."

> **"The connection with a real-life application makes an abstract subject come alive."**
>
> **Jorge Vieyra Salas** – PhD, TU/e department of Applied Physics, MTP group

Darhuber however chooses publications. "That is how the academic arena judges our work." But in the Netherlands, IP issues are not as restrive as in the USA, he says: "Some US universities have very strict IP regulations, which impede collaboration with industry. I prefer the open and co-operative atmosphere here."

Vieyra now has Mexican, American and European academic experience. "In Mexico there is no collaboration with industry. In the USA the professorial pursuit of IP is dominant as a way to get personal funding. Here in the Netherlands I witness far more synergy and collaboration. There are fewer barriers or conflicts of interest, because issues are worked out beforehand."

Liyang Yu
Power to the molecules

PhD student Liyang Yu's main inspiration comes from people. People are similar to atoms, says Yu, because the sum of their interactions determines how they behave as a group. The Large Area Thin Film Electronics Yu works on hinges on the willingness of all molecules within these films to co-operate.

Liyang Yu is a PhD student at Imperial College in London (UK). His inspiration? "People," says Yu: "The materials I deal with in my work remind me of people. Molecules resemble people in that they group together like families or societies. Some people like each other and work together while other people dislike each other; it is a process of attraction and rejection. In a large group – be it a family, a city or the entire world – even a small change can impact on the whole group. Just like the world community is based on the collection of interactions between all people, a material's properties are a consequence of all the inter-actions between all molecules within the material."

Change the world

In Yu's field of research, the analogy is striking: "We are trying to give plastics semiconducting properties in order to be able to make transistors and integrated circuits from them. Plastic electronics are much cheaper than silicon chips. They can for instance be used to make screens, processors, or solar cells. This can change the world as we know it. But we are not there yet. One of the major problems in this research area is the inhomogeneity of large films made from semiconductor plastics. One of the current high-performance materials for plastic electronic films is TIPS-pentacene. The yield in production is low: only a few high-performance devices can be found over a large wafer that comprises a large number of transistors. "This non-homogeneity is a consequence of the properties of all molecules within the material." Yu works on optimizing small molecular organic semiconductors based on fused-ring polycycles by blending with another material to control film-formation. Yu: "Its electrical properties may not meet those of the neat semiconductor, but the good news is that blending leads to large areafilms that are significantly more homogeneous."

There are many ways to produce these films. It is not clear yet which of these possibilities works best. Yu: "In order to find the best production method, we have to study the micro-arrangement of the molecules within the material. In the end, I hope to find a structure in which all molecules work together."

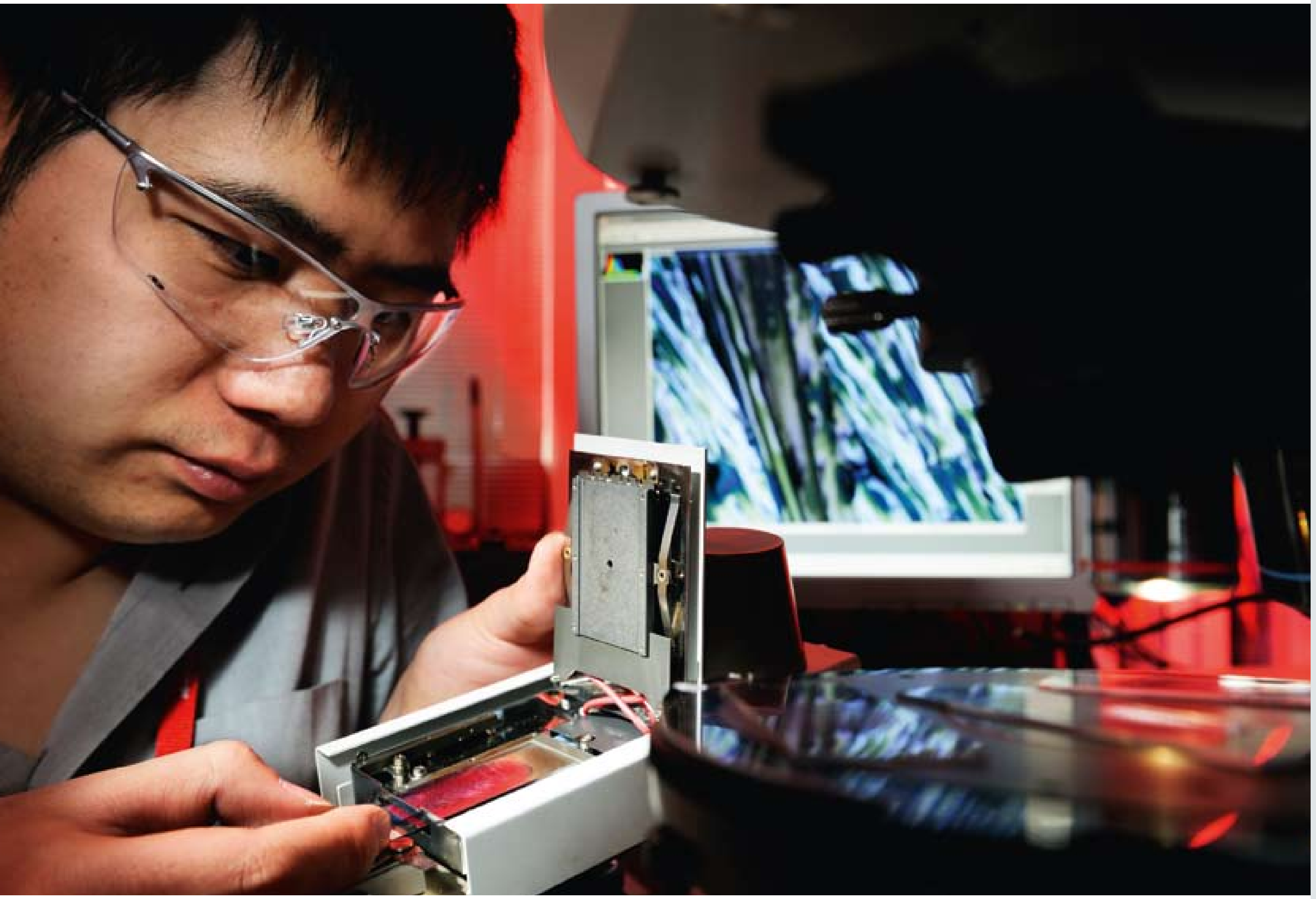
> **"During a journey you experience a lot and you get in touch with new things."**
>
> **Liyang Yu** – PhD student at Imperial College in London

Open mind

Yu's passion is travelling: "I'm from China, and there are not many parts of China that I haven't seen. One day I asked myself: where should I go next? I said to myself I had to go to Europe. I am living in London now and I visit Eindhoven University of Technology regularly, but I've been in many other European countries. My favourite is probably Italy. It has a beautiful seaside, great food and a relaxed atmosphere."

Travelling helps Yu in his research, he says: "First of all, you meet a lot of people. This teaches you to communicate more freely. Secondly, during a journey you experience a lot and you get in touch with new things. This teaches you to have an open mind and not fear what is new or different. For a researcher, this is an essential trait."

"In the end, I hope to find a structure in which all molecules work together."



Objectives

Whereas Functional Polymer Systems (FPS) focuses on materials development and initial device performance, Large-Area Thin-Film Electronics (LATFE) is the typical next step in the value chain focusing on fundamental issues related to processing for large area deposition and disruptive architectures for large area devices.

Large-Area Thin-Film Electronics is a perfect example of a highly interdisciplinary topic area: from chemistry and physics to engineering. The fundamental knowledge generated should facilitate reliable production of organic electronic devices and, in the longer term, contribute to the development of thin film sensor devices.

Subprogrammes

Large area material deposition using solution processing
The objective is to study fundamental issues of large area polymer material deposition using roll-to-roll solution processing (gravure, flexo, screen, slot-die) to realize the transition from lab scale to industrial scale for reliably processed devices. Although lab-scale devices have ultimate performance, we lack the industrial processes and the fundamental knowledge about large area material deposition from solution needed to make proper choices of the deposition technique for mass production.

Disruptive device architectures
The objective is to develop disruptive device architectures for more reliable and easier production and to understand the failure mechanisms occurring in industrially produced devices. Current device architectures require very thin films (~ 100 nm) having less than 2% thickness deviation. These architectures place very strict demands on the processing and production of devices, and this is currently resulting in poor yields and many failures. New device architectures allowing more robust processing and production and improving yield without affecting device performance (efficiency, homogeneity of light output) are very much welcomed.

Facts and figures

Partners from industry
Philips, OTB Display and TNO/Holst Centre.

Partners from the research world
The Netherlands: Universities of Groningen and Eindhoven.
Germany: University of Cologne.
UK: Imperial College London.
Portugal: University of Algarve.

Budget and Organization
Total expenditure in 2008 amounted to € 0.67 million (budget € 1.31 million). As the Technology Area was in its start-up phase, applicants spent most of their time searching and recruiting skilled researchers, resulting in underspending of the budget. The total number of FTEs allocated at the end of 2008 was 6 (8 researchers). Total expenditure on equipment, expensive consumables and special analysis time amounted to € 148k. During 2008 Programme Area Coordinator Dr. John van Haare was actively engaged in further establishing the Technology Area and granting projects after proper industrial evaluation and peer review. A scientific chairman has not been appointed yet.

Publications and inventions
In the start-up phase of the TA LATFE many contributions to scientific symposia in the form of poster and presentations were made. The running excellent projects will certainly generate a take off in scientific publications in 2009. In March 2008 the TA organized a public kick-off meeting to attract broader attention from interested industries and academia for the LATFE research programme. Almost all running projects were fully staffed in 2008.

Detailed information on page 91.

The role of the Corporate Research Programme has been to initiate and support enabling science and conceptual new science that is of interest to all partners of DPI because of its long-term potential impact. This programme is primarily science-driven, based on a vision of future industrial needs and opportunities.

Bringing people together

Corporate research within DPI is nothing like applied contract research. The role of academia is mainly to unravel fundamental phenomena. Co-operation between DSM and Eindhoven University of Technology (TU/e) in the Netherlands shows many examples of this. DPI is seen as the enabler of bridging gaps that lead to new ideas and competences.

As a nicely alliterative phrase would have it, innovation starts with inspiration. To Markus Bulters, Competence Manager, Materials Processing and Materials Properties at DSM, this is true: “I’m inspired by research itself, regardless of the subject, be it rheology or traffic jams. As long as the approach is sound, it’s fine by me. The kick is to have insight into knowledge only few people have and to explain this to others. Even better is to see the ideas you have contributed being converted into real-life applications, like thermally conductive Stanyl® polyamide used in housings for LED lights.” Lambert van Breemen, Researcher in modelling of friction & wear, Department of Mechanical engineering at TU/e, agrees: “To put a phenomenon you don’t understand into a model and to unravel fundamental processes is a pure bliss.” Leon Govaert, Associate Professor of polymer mechanics, Department of Mechanical Engineering, TU/e: “It’s also about understanding why something happens. Insight into material behaviour opens the way to better polymers.”

Van Breemen gives an example: “The phenomenon of friction within polymers is still not fully understood. Entire journals have been dedicated to this subject. Now, thanks to our modelling, we are among the first in the world to be able to explain what we see in experiments. We start noticing trends and hope to translate these into suitable friction properties. It is great to be part of such a breakthrough.”

Gerard Werumeus Buning, R&D manager Performance Materials Chemistry & Technology at DSM, is nowadays more involved in management than in research. But he knows what research is about: “Because of the sheer complexity several people and disciplines need to be involved to contribute in understanding and solving a problem together. The business community is interested in innovation, but is not aware of the hard work that needs to be done on fundamental knowledge before you get new applications. Only afterwards will everybody be glad the money was invested.”

Fundamental issues

For some years now, sustainability has been part of DSM’s corporate strategy. Werumeus Buning: “Our research community was working on sustainability long before that, because we saw it coming. Take, for example, the DPI tender we introduced on new monomers from sustainable building blocks. This suits the DPI environment: to play around and gain experience with embryonic subjects before the company embraces them.” Bulters adds: “Apart from that, we also like to use the partnership to enhance or fine-tune current processes. And let’s not forget that from a recruitment perspective as well, we benefit from getting into contact with well-educated researchers with the right basic competences.”

However, Bulters does not see DPI as a steering mechanism from industry

> **“It is not about research on behalf of industry, but about fundamental research with industrial relevance.”**
>
> **Leon Govaert** – associate professor of polymer mechanics, Department of Mechanical engineering, Eindhoven University of Technology

“The best research groups follow a highly concentrated strategy.”

Marcus Bulters – competence manager, Materials Processing and MaterialsProperties at DSM

to academia. “In fundamental research it doesn’t work like that. Universities shouldn’t allow companies to define their research agenda. But allowing some influence, in order to be able to do relevant research, is another thing.” Govaert agrees: “It is not about research on behalf of industry, but about fundamental research with industrial relevance.” Van Breemen: “It works both ways. Together we look for a match between the input we can provide and the knowledge demand in industry.”

Werumeus Buning: “Companies should have the discipline not to pose product development questions to universities. There are enough relevant fundamental issues to solve.” Bulters: “Take, for instance, the deformation behaviour of semi-crystalline polymers. In the long run we hope to have methods and techniques that we can use.” Van Breemen co-operates with Bulters’ group, on the topic of modelling glassy polymers. “It involves fundamental phenomena that weren’t understood before. The outcomes can now be used in calculations.”

Start-ups and spin-outs

Werumeus Buning concludes that DPI has succeeded in creating more co-ordination and co-operation between academia and industry. But he thinks DPI shouldn’t be expected to boost economic growth as a ‘start-up generator’. The Dutch situation differs too much from the USA for that: “We don’t have professor-entrepreneurs like there. Our innovative and entrepreneurial culture is not as strongly developed.”

Govaert looks at this from another angle: “The fundamental field we work in is not the obvious discipline to create start-ups. In the materials field we are working on explanations for material behaviour and on polymer enhancement. For established companies this knowledge on wear, robustness and impact is highly important, as it makes it possible to attain better applications while using less material.” Werumeus Buning: “The same goes for research on bio-renewables, the creation of new monomers on the basis of fermentation: highly interesting for established companies.” Govaert: “But in mechanical engineering there are nice examples of starts-ups. Take for instance the high potential company Optimum Forming Solutions with its flexible mould for packagings.”

“Companies should have the discipline not to pose product development questions to universities.”

Gerard Werumeus Buning – R&D manager Performance Materials, Chemistry & Technology, DSM

Werumeus Buning: “DSM screens start-ups. We decide to participate when they are a valuable asset to our technology portfolio. I can only conclude that we seldom participate in Dutch start-ups.” Bulters adds: “Or rather that marketing doesn’t fit the mindset of most Dutch scientists.” But start-ups are not the only promise for economic growth. Spin-outs, like DSM’s Emerging Business Area BioMedical , can also contribute to growth. All agree that these are interesting ways to convert scientific excellence into industrial activity through the DPI approach of open innovation.

Concentration

An important aspect of open innovation is informal contacts. Van Breemen: “I enjoy the DPI meetings in the Physics cluster a lot. You get in touch with content outside your own field. And yet you can often bridge the differences and find common ground. There is no other group in the Netherlands like ours involved in the same modelling area. But you can exchange interesting insights on general computational methods.” Werumeus Buning observes more or less the same: “I hear a lot of good things about the DPI days. The user community is a nice system for both academia and industry. It enables

Leon Govaert, Marcus Bulters, Lambert van Breemen and Gerard Werumeus Buning

us to broaden our scope.” Govaert: “You find parallels which unexpectedly open the way to co-operation.”

DPI is seeking to improve its services to further stimulate open innovation. According to Bulters, this is largely out of the hands of DPI: “The institute facilitates research, but success depends firstly on the brilliance of young researchers, secondly on the way they are supervised and only thirdly on DPI.” Werumeus Buning: “But the supervision affects DPI. There is some risk that research gets fragmented. I think there is a risk when a professor manages four or five projects in different technology fields. They could be based on shared concepts but in some cases I doubt that.” Bulters remarks: “The best groups, from our perspective, always follow a highly concentrated research strategy.”

“To put a phenomenon you don’t understand into a model and to unravel fundamental processes is a pure bliss.”

Lambert van Breemen – researcher in modelling of friction & wear, Department of Mechanical engineering, Eindhoven University of Technology

Bringing people together

Govaert: “I agree to that. I like to stay focused on the same subjects, although this seems something of the past nowadays. But there is another side to diversity. It is stimulated by the university system, as every senior scientific staff member under a professor holds his own technology field. This can lead to a huge diversity within the same research group. On the positive side this creates the opportunity to build bridges at the outer limits of your own field. Often it proves that someone else has already thought up a solution for your problem, if you only care to look for it. Take for instance bone tissue scans in biomedical technology, fed to finite element calculations. We were able to apply this technique in materials technology and benefit from it. It is just the beauty of DPI that it enables communication leading to this kind of exchange of ideas and competences. That is DPI at its best: bringing people together.”

Giuseppe Portale
My heart is in applied research

The moment Giuseppe Portale changed his wooden tennis racket for a composite one, he lost his heart to materials sciences. "I'm fascinated by the way new materials help us improve the quality of, for instance, car bumpers, computer components or sailboats. Our challenge is to fully understand and predict the correlation between the properties and structure of polymers," he says. For inspiration, he takes a walk on the beach.

Funded by the Dutch Polymer Institute, Giuseppe Portale devoted the past three years to a study of the correlation between the properties and structure of commercial and novel polymers. "Our ambition was to understand and improve the performance of polymeric materials," he says. "We wanted to see how the materials react to the application of external forces." He took polymers, shaped them, applied forces to them and then watched what happened by coupling X-ray experiments with other characterization techniques. "I prepared the materials in Eindhoven in the Netherlands, then took the samples to Grenoble in France, where I applied forces to them while simultaneously carrying out X-ray analyses," he says. "These in situ measurements allowed us to understand the force-induced modification of the structures. The measurements resulted in a huge amount of data. We then developed a model that explains these data and enables us to predict the influence of certain circumstances on the properties of materials."

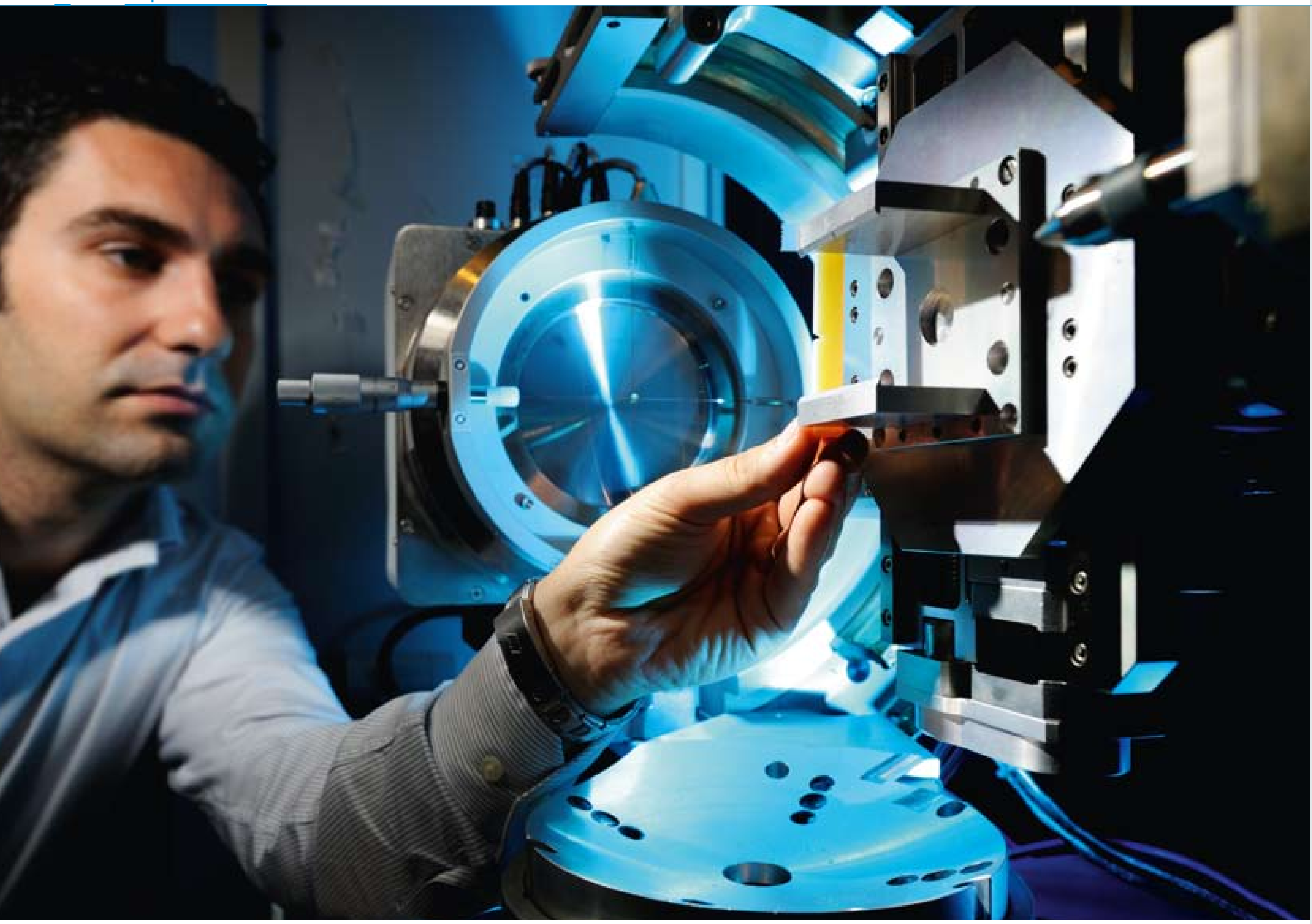
> **"Whenever I get stuck in my research, I go to the seaside."**
>
> **Giuseppe Portale** – scientist at the ESRF in Grenoble (France)

Materials

Giuseppe's doctoral research was closely followed by industry. "My heart is in applied research," he acknowledges. "I studied materials that industry uses every day. My research will hopefully help companies to improve the properties of their products, such as car bumpers or computer components." This is in fact his long-term ambition. "Ever since I changed my wooden tennis racket for one made out of composite materials, I have been intrigued by the way in which new materials improve our life and performance. Of course, deep down, one day I hope to find a terribly smart material no one has ever thought of before that will have an enormous impact on society."

Energy applications

Maybe this dream will come true in the area he is now focusing on, in his new position as beamline scientist at the Dutch/Belgian beamline at the ESRF.



"I am studying polymers that are used in energy applications, such as polymeric fuel cells and organic solar cells," he says. "Polymers are usually seen as insulating materials. But when we play with their molecular structure, some polymers seem to be able to conduct protons or electrons. This is a very innovative and creative line of thinking that may help solve the world's energy problem. I would very much like to make a contribution to this."

Fresh ideas

Portale is inspired by all kinds of objects in his daily life. Still, sometimes he gets stuck in his research. Then he goes to the seaside or to the lakes. "All I have to do is sit back and relax or take a walk. New ideas will then come to mind spontaneously." Another option is woodcraft: "I like to make things by hand," he says. "It clears my mind and opens it to fresh ideas."

> **"This is a very innovative and creative line of thinking that may help solve the world's energy problem."**

Objectives

The role of the Corporate Research Programme has been to initiate and support enabling science and conceptual new science that is of interest to all partners of DPI because of its long-term potential impact. This programme is primarily science-driven, based on a vision of future industrial needs and opportunities. It operates at the forefront of scientific knowledge and capabilities of polymer science. Four sub-clusters have been designated.

Subprogrammes

Enabling Science

- Polymer characterization: surfaces and interfaces (applying mainly microscopic techniques) and molecular characterization (SEC techniques, cross-linked architectures and networks, and analysis of polymer distribution).
- Structure vs. performance: modelling different length scales, fluid dynamics (rheology) and solid-state properties (bulk materials and surface properties).

New Science

New concepts in polymer chemistry and polymer physics in view of long-term future needs of sustainability, durability and bio-related polymer systems.

Infrastructure

Corporate Research is also aimed at strengthening the equipment infrastructure, which is beneficial for the entire DPI community.

DPI fellowship programme

The aim of this programme is to appoint young, talented researchers with a tenured or tenure track position at a Dutch University as 'DPI fellow' in order to ensure their commitment to the Dutch polymer science community and to give them the opportunity to develop science leadership within an area matching DPI's current or future strategy.

Facts and figures

Partners from industry

There is no industrial partnership in this area yet. All Technology Areas are represented by their Scientific Chairmen.

Partners from the research world

The Netherlands: University of Amsterdam, Eindhoven University of Technology, NWO, University of Twente, University of Groningen, Radboud University of Nijmegen, Polymer Technology Group Eindhoven, FOM, TiFN.
Germany: Deutsches Kunststoff Institut, Leibniz-Institut für Polymerforschung.
South Africa: University of Stellenbosch.

Budget and organization

Total expenditure in 2008 was € 1.81 million (budget € 2.05 million). An amount of € 553k was spent on equipment. A total of 10 FTEs were allocated, distributed over 22 researchers. Richard van den Hof chaired the Corporate Research Programme until June 2008 as interim Programme Area Coordinator. Since June 2008 Dr.ir. Monique Bruining has chaired the Corporate Research Area as Programme Area Coordinator.

Publications and inventions

In 2008 a total number of 29 scientific publications appeared, including 6 theses.

Detailed information on page 91.

Output per area 2008

Polyolefins

Projects

#387: Advanced characterization of Ziegler-Natta catalysts on flat surfaces
#495: Single-site catalyst immobilization using magnesium chloride supports
#633: Understanding structure/performance relationships for non-metallocene olefin polymerization catalysts
#635: Measuring active site concentration of olefin polymerization catalysts
#638: Thermally stable olefin polymerization catalysts by reversible intramolecular alkyl shuttling
#639: Quantity and quality of active sites in immobilized and solid olefin polymerization catalysts
#637: Influence of entanglements on the flow behaviour of polyolefins
#634: Characterization of the specific density of semi-crystalline polymers
#354: Investigation of catalytic gas-phase olefin polymerization reactors, radioactive particle tracking and CFD studies
#507: Comparison of slurry and gas-phase polymerization for HDPE: kinetics, chemical composition, molecular weight distribution
#547: Experimental and computational study of high-pressure fluidization of polymeric materials
#632: Experimental and computational study of dense gas fluidized beds with liquid injection
#636: Study of the influence of the support, support preparation and initial conditions on olefin polymerization
#641: High-throughput computational pre-screening of catalysts
#642/643: Development of high-temperature 2-dimensional liquid chromatography for the characterization of polyolefins (jointly with the Corporate Research Technology Area)
#644/645: High-throughput experimentation approaches to Ziegler-Natta-type catalytic olefin polymerizations (jointly with the HTE Technology Area)
#646/647: New functionalized materials by Rh and Pd mediated carbene homopolymerization and olefin/carbene copolymerization (jointly with the Performance Polymers Technology Area)
#674: Rheology control by branching modelling

Theses

L. Balzano
Flow induced crystallization of polyolefins

W. Li
Copolymerization of ethene and functionalized comonomers with cationic α-diiminie palladium catalysts

R.Huang
Immobilization and activation of early- and late- transition metal catalysts for ethylene polymerization using MgCL2-based supports

J.W. Housmans
Flow induced crystallization of isotactic polypropylenes

Scientific publications

K. Albahily, D. Al-Baldawi, S. Gambarotta, R. Duchateau, E. Koç, T.J. Burchell
Preparation and Characterization of a Switchable Single-Component Chromium Trimerization Catalyst
Organometallics
27, 5708–5711

K. Albahily, D. Al-Baldawi, S. Gambarotta, E. Koç, R. Duchateau,
Isolation of a Chromium Hydride Single-Component Ethylene Polymerization Catalyst
Organometallics
27, 5943–5947

K. Albahily, E. Koç, D. Al-Baldawi, D. Savard, S. Gambarotta, T.J.. Burchell, R. Duchateau,
Chromium Catalysts Supported by a Nonspectator NPN Ligand: Isolation of Single-Component Chromium Polymerization Catalysts
Angew. Chem. Int. Ed.
47, 5816 –5819

A. Albrecht, R. Brull, T. Macko, P. Sinha, H. Pasch
Analysing the chemical composition distribution of ethylene-acrylate copolymers: Comparison of HT-HPLC, CRYSTAF and TREF.
Macromol. Chem. Phys.
209 (18), 1909-1919

A. Andoni, J.C. Chadwick, H.J.W. Niemantsverdriet, P.C. Thune
The role of electron donors on lateral surfaces of MgCl2-supported Ziegler-Natta catalysts: Observation by AFM and SEM
J. Catal.
257 (1), 81-86

L. Balzano, N. Kukalyekar, S. Rastogi, G.W.M. Peters, J.C. Chadwick
Crystallization and dissolution of flow-induced precursors
Phys. Rev. Lett.
100 (4), -

L. Balzano, S. Rastogi, G.W.M. Peters
Flow induced crystallization in isotactic polypropylene - 1,3 : 2,4-bis(3,4-dimethylbenzylidene) sorbitol blends: Implications on morphology of shear and phase separation
Macromolecules
41 (2), 399-408

V. Busico, M. Causa, R. Cipullo, R. Credendino, F. Cutillo, N. Friederichs, R. Lamanna, A. Segre, V.V. Castellit
Periodic DFT and high-resolution magic-angle-spinning (HR-MAS) H-1 NMR investigation of the active surfaces of MgCl2-supported Ziegler-Natta catalysts. The MgCl2 matrix
Journal of Physical Chemistry C
112 (4), 1081-1089

D. Byelov, P. Panine, K. Remerie, E. Biemond, G.C. Alfonso, W.H. de Jeu
Crystallization under shear in isotactic polypropylene containing nucleators
Polymer
49 (13-14), 3076-3083

J. Flapper, P. Wormald, M. Lutz, A.L. Spek, P.W.N.M. van Leeuwen, C.J. Elsevier, P.C.J. Kamer
Cis, trans - or Both: Steric Bulk Determines Coordination Mode of Dimeric Palladium Complexes with Bridging Pyridine-Phosphane Ligands
Eur. J. Inorg. Chem.
(31), 4968-4976

W. Godlieb, N.G. Deen, J.A.M. Kuipers
On the relationship between operating pressure and granular temperature: A discrete particle simulation study
Powder Technol.
182 (2), 250-256

R. Huang, R. Duchateau, C.E. Koning, J.C. Chadwick
Zirconocene immobilization and activation on MgCl2-based supports: Factors affecting ethylene polymerization activity
Macromolecules
41 (3), 579-590

R. Huang, F. Malizia, G. Pennini, C.E. Koning, J.C. Chadwick
Effects of MgCl2 Crystallographic Structure on Active Centre Formation in Immobilized Single-Centre and Ziegler-Natta Catalysts for Ethylene Polymerization
Macromol. Rapid Commun.
29 (21), 1732-1738

A. Jabri, C.B. Mason, Y. Sim, S. Gambarotta, T.J. Burchell, R. Duchateau
Isolation of Single-Component Trimerization and Polymerization Chromium Catalysts: The Role of the Metal Oxidation State
Angew. chem. Int. Ed.
47, 9717 –9721

S. Jain, J.G.P. Goossens, G.W.M. Peters, M. van Duin, P.J. Lemstra
Strong decrease in viscosity of nanoparticle-filled polymer melts through selective adsorption
Soft Matter
4 (9), 1848-1854

J.A. Laverman, I. Roghair, M.V. Annaland, H. Kuipers
Investigation into the hydrodynamics of gas-solid fluidized beds using particle image velocimetry coupled with digital image analysis
Can. J. Chem. Eng.
86 (3), 523-535

W.D. Li, X.C. Zhang, A. Meetsma, B. Hessen
Reactions of cationic palladium alpha-diimine complexes with nitrogen-containing olefins: Branched polyethylene with carbazole functionalities
Organometallics
27 (9), 2052-2057

T.J.J. Sciarone, C.A. Nijhuis, A. Meetsma, B. Hessen
Neutral and cationic para-magnetic amino-amidinate Iron(II) complexes: F-19 NMR evidence for interactions with weakly coordinating anions
Organometallics
27 (9), 2058-2065

Performance Polymers

Projects

#356: Investigations into blending, reinforcement and curing in EPDM/ NR/ BR rubber compound for the tire side-wall application
#432: Improved catalysts for controlled propylene oxide polymerization
#479: Tri-block copolymers with crystallizable amide segments
#537: Sub-micrometer thermoplastic vulcanizates
#580: Modification/crosslinking of saturated elastomers using functionalized azides
#585: The 'sticky blocks' concept, furnishing EPs with enhanced processability
#647: New functionalized materials by Rh and Pd mediated carbene homopolymerization and carbene/olefin copolymerization (jointly with the Polyolefins Technology Area)
#649: Thermoplastic elastomers via living radical graft polymerization from functional elastomers
#651: Smart surface modifiers for engineering plastics
#653: Bio-degradable thermoplastic polyurethanes from renewable resources
#656: Green rigid blocks for engineering plastics with enhanced performance
#650: Molecular modelling of cavitation in polymer melts and rubbers
#584: Micro friction and wear of polymers
#654: Effects of the nano-scale structure of polymer surfaces on their adhesion and friction properties
#582: Encapsulation of reactive chemicals for the design of self-healing engineering plastics
#583: Dispersion of fillers in engineering polymers for thermal, electrical and rheological properties
#616: Flow of particle-filled viscoelastic fluids in complex geometries
#623: Fundamental aspects of nano-composites
#648: Graphene-based nano-composites
#652: Rubber/silica nano-composites via reactive extrusion
#664: Sustainable elastomers and thermoplastics by short-cut fibre reinforcement
#481: Stability of Engineering Plastics
#581: Long-term heat (thermo-oxidative) stability of engineering plastics
#614: Consequences of molecular degradation in load-bearing components
#671: Optimized plastication in extruders for better economy and product properties

Theses

W.B. Wennekes
Adhesion of RFL-treated cords to rubber. New insights into interfacial phenomena

P.G. Malchev
Short fiber reinforced thermo-plastic blends

I. Cotiuga
High aspect ratio nano-fillers: expectations vs. reality

E. Vinken
Polyamides: hydrogen bonding, the Brill transition, and super-heated water

Scientific publications

A. Arun, K.K.J. Baack, R.J. Gaymans
Polyurethane triblock copolymers with mono-disperse hard segments. influence of the hard segment length on thermal and thermomechanical properties
Polym. Eng. Sci.
48 (6), 1222-1230

A. Arun, R.J. Gaymans
Tri-block copolymers with mono-disperse crystallizable diamide segments: Synthesis, analysis and rheological properties
Polymer
49 (10), 2461-2470

A. Arun, R.J. Gaymans
Segmented block copolymers with monodisperse aramide end-segments
Macromol. Chem. Phys.
209 (8), 854-863

G.J.E. Biemond, K. Braspenning, R.J. Gaymans
Polyurethanes with monodisperse rigid segments based on a diamine-diamide chain extender
J. Appl. Polym. Sci.
107 (4), 2180-2189

G.J.E. Biemond, J. Feijen, R.J. Gaymans
Influence of polydispersity of crystallizable segments on the properties of segmented block copolymers
Polym. Eng. Sci.
48 (7), 1389-1400

G.J.E. Biemond, J. Feijen, R.J. Gaymans
Tensile properties of segmented block copolymers with mono-disperse hard segments
Journal of Materials Science
43 (10), 3689-3696

D. De, R.J. Gaymans
Polyurethanes with Narrow- and Polydisperse Hard Segment Distributions
Macromolecular Materials and Engineering
293 (11), 887-894

D. De, R.J. Gaymans
Thermoplastic polyurethanes with poly(butylene terephthalate) as crystallizable hard phase
Macromolecular Materials and Engineering
293 (3), 228-234

M. Diepens, P. Gijsman
Photo-oxidative degradation of bisphenol A polycarbonate and its possible initiation processes
Polym. Degrad. Stab.
93 (7), 1383-1388

N. Grossiord, J. Loos, L. van Laake, M. Maugey, C. Zakri, C.E. Koning, A.J. Hart
High-Conductivity Polymer Nanocomposites Obtained by Tailoring the Characteristics of Carbon Nanotube Fillers
Adv. Funct. Mater.
18 (20), 3226-3234

D. Husken, R.J. Gaymans
The structure of water in PEO-based segmented block copolymers and its effect on transition temperatures
Macromol. Chem. Phys.
209 (9), 967-979

R. l'Abee, H. Goossens, M. van Duin
Thermoplastic vulcanizates obtained by reaction-induced phase separation: Interplay between phase separation dynamics, final morphology and mechanical properties
Polymer
49 (9), 2288-2297

M.A.G. Jansen, L.H. Wu, J.G.P. Goossens, G. de Wit, C. Bailly, C.E. Koning, G. Portale
The incorporation of rigid diol monomers into poly(butylene terephthalate) via solid-state copolymerization and melt copolymerization
Journal of Polymer Science Part a-Polymer Chemistry
46 (4), 1203-1217

S.D. Mookhoek, B.J. Blaiszik, H.R. Fischer, N.R. Sottos, S.R. White, S. van der Zwaag
Peripherally decorated binary microcapsules containing two liquids
J. Mater. Chem.
18 (44), 5390-5394

R. Sablong, R. Duchateau, C.E. Koning, G. de Wit, D. van Es, R. Koelewijn, J. van Haveren
Incorporation of Isosorbide into Poly(butylene terephthalate) via Solid-State Polymerization
Biomacromolecules
9 (11), 3090-3097

M.A.J. van der Mee, J.G.P. Goossens, M. van Duin
Thermoreversible crosslinking of maleated ethylene/propylene rubber using ionic interactions, hydrogen bonding and a combination thereof
Rubber Chem. Technol.
81 (1), 96-109

M.A.J. van der Mee, J.G.P. Goossens, M. van Duin
Thermoreversible cross-linking of maleated ethylene/propylene copolymers with diamines and amino-alcohols
Polymer
49 (5), 1239-1248

M.A.J. van der Mee, J.G.P. Goossens, M. van Duin
Thermoreversible covalent crosslinking of maleated ethylene/propylene copolymers with diols
Journal of Polymer Science Part a-Polymer Chemistry
46 (5), 1810-1825

M.A.J. van der Mee, R.M.A. l'Abee, G. Portale, J.G.P. Goossens, M. van Duin
Synthesis, structure, and properties of ionic thermoplastic elastomers based on maleated ethylene/propylene co-polymers
Macromolecules
41 (14), 5493-5501

E. Vinken, A.E. Terryt, O. van Asselen, A.B. Spoelstra, R. Graf, S. Rastogi
Role of superheated water in the dissolution and perturbation of hydrogen bonding in the crystalline lattice of polyamide 4,6
Langmuir
24 (12), 6313-6326

D.P.N. Vlasveld, H.R. Fischer, E. Swierenga, S.J. Picken
Interaction of SWCNT and PPTA with sulfuric acid - Compatibilization of two materials in a common solvent
Journal of Polymer Science Part B-Polymer Physics
46 (18), 1914-1922

W.B. Wennekes, R.N. Datta, J.W.M. Noordermeer, F. Elkink
Adhesion to Rubber Compounds
Rubber Chem. Technol.
81 (3), 523-540

Y. Yan, A.A. Martens, N.A.M. Besseling, F.A. de Wolf, A. de Keizer, M. Drechsler, M.A. Cohen Stuart
Nanoribbons self-assembled from triblock peptide polymers and coordination polymers
Angew. Chem. Int. Ed.
120 (22), 4260-4263

W.J.C. Zuiderduin, R.J. Gaymans
Polycarbonate modified with crystallisable bis-ester tetra-amide units in a reaction extrusion process
Reactive & Functional Polymers
68 (2), 527-534

Filed patent applications

#582: S.D. Mookhoek, S. van der Zwaag, H.R. Fischer, N.R. Sottos, B.J. Blaiszik, S.R. White
Multi-capsule system

#603 + #460: J.A.W. Harings, Y.S. Deshmukh, E. Vinken, S. Rastogi
Polyamide with reduced crystallinity

Reported inventions

#583: S. Vaidya, S. Rastogi
Polyaniline composite

#356: H. Zhang, J.W.M. Noordermeer, R.N. Datta, A. Talma
Modification of EPDM

#356: C.L. van Oosten, C.W.M. Bastiaansen, D.J. Broer
Rubber blends containing EPDM

#648: E. Tkalya, C.E. Koning
Graphene polymer composition

Functional Polymer Systems

Projects

#427: Maskless lithography with liquid crystals
#435: Tunable conductivity levels in nano filler/polymer matrix composites
#516: Complementary logic circuits by combining ambipolar field-effect transistors with surface modified electrodes
#518: Singlet to triplet exciton formation in polymeric light-emitting diodes
#522: Towards a push-and-pull muscle fibre: an electroactive polymer composite
#523: Memory devices: zinc oxide nano-particles in a polystyrene matrix
#524: Polymer-fullerene solar cells and low band-gap donor materials for photovoltaics
#529: Conductive block copolymer systems with extremely low wt% of carbon nanotubes
#530: Photo-embossing of polymeric bi-layers
#532: Polymer MEMS - an integrated approach towards activated surfaces for microfluidic systems and pro-active devices
#624: Electronic noses for high-volume system in foil applications
#625: Polymeric sensors in smart packaging
#626: Hardening of elastomers (and gels) in response to magnetic fields
#627: Air-stable n-type field-effect transistors
#628: Tuning the (electro)-luminescent properties of a polymeric film by controlling intermolecular and/or intra-molecular interactions
#629: Polymer lighting with new triplet emitters and multi-layer structural design
#630: Functional polymer based nano- and micro-optics for solid state lighting management
#631: Triplet recombination in polymer solar cells
#660: Bulk heterojunction polymer: zinc oxide solar cells from novel organozinc precursors
#661: Structurally defined conjugated dendrimers and hyper-branched polymers in solar cells
#677: Understanding interactions between polymer surfaces and proteins: towards ideal polymer biosensor substrate materials.
#678: Air stable organic photovoltaics
#679: Smart textiles
#680: Charge carrier transport and recombination in advanced OLEDs
#681: Hybrid solar cells based on Si nanoparticles and conjugated polymers
#682: Creation of functional nanostructures in solution/dispersion
#683: Photo-embossed gratings for efficient light harvesting in organic solar cells

Theses

L. Huijbregts
Charge transport and morphology in nanofillers and polymer composites

F. Verbakel
Resistive switching in polymer-metal oxide diodes

B. Serano-Ramon
Maskless lithography using self-organization of liquid crystals

M. Yuan
Tunable conductivity level in nanosized phthalcon/polymer composites

M. de la Rosa
Strukturierung organischer Polymere und deren Anwendung in elektro-optischen Bauteilen

Scientific publications

P.T.K. Chin, J.W. Stouwman, S.S. van Bavel, R.A.J. Janssen
Cluster synthesis of branched CdTe nanocrystals for use in light-emitting diodes
Nanotechnology
19 [20], 205602

B. C. de Brito, E.C.P. Smits, P.A. van Hal, T.C.T. Geuns, B. de Boer, C.J.M. Lasance, H.L. Gomes, D.M. de Leeuw
Ultralow Power Microfuses for Write-Once Read-Many Organic Memory Elements
Adv. Mater.
20 (19), 3750

W. Eerenstein, L.H. Slooff, S.C. Veenstra, J.M. Kroon
Optical modeling as optimization tool for single and double junction polymer solar cells
Thin Solid Films
516 (20), 7188-7192

N.Grossiord, P.J.J. Kivit, J. Loos, J. Meuldijk, A.V. Yrylyuk, P. van der Schoot, C.E. Koning
On the influence of the processing conditions on the performance of electrically conductive carbon nanotube/olymer nanocomposites
Polymer
49 (12), 2866-2872

W.J. Grzegorczyk, T.J. Savenije, M. Heeney, S. Tierney, I. McCulloch, S. Bavel, L.D.A. van Siebbeles
Relationship between Film Morphology, Optical, and Conductive Properties of Poly(thienothiophene): [6,6]-Phenyl C-61-Butyric Acid Methyl Ester Bulk Heterojunctions
Journal of Physical Chemistry C
112 [41], 15973-15979

K. Hermans, I. Tomatsu, M. Matecki, R.P. Sijbesma, C.W.M. Bastiaansen, D.J. Broer
Highly Efficient Surface Relief Formation via Photoembossing of a Supramolecular Polymer
Macromol. Chem. Phys.
209 (20), 2094-2099

K. Hermans, I. Tomatsu, M. Matecki, R.P. Sijbesma, C.W.M. Bastiaansen, D.J. Broer
Photo-embossing of supra-molecular photopolymers
Macromol. Chem. Phys.
209(20), 2094-2099

K. Hermans, M. van Delden, C.W.M. Bastiaansen, D.J. Broer
An in situ sealing method for liquid-filled micro-cavities based on photoembossing
Journal of Micromechanics and Microengineering
18 (9), 0950022

S. Hoeppener, V.N. Marin, U.S. Schubert
Mono-substituted 4,4 '-dimethyl-2,2 '-bipyridine ligands at the solid-liquid interface: Study of the molecular organization
Current Nanoscience
4 (2), 208-211

L.J. Huijbregts, H.B. Brom, J.C.M. Brokken-Zijp, W.E. Kleinjan, M.A.J. Michels
Dielectric quantification of conductivity limitations due to nanofiller size in conductive powders and nano-composites
Physical Review B
77 (7), 075322

L.J. Huijbregts, H.B. Brom, J.C.M. Brokken-Zijp, M. Yuan, M.A.J. Michels
Hopping parameters in densely packed submicron crystallites
Physical Status Solidi C
5, 765-767

M. Kemerink, D.S. Charrier, E.C.P. Smits, S.G.J. Mathijssen, D.M. de Leeuw, R.A.J. Janssen
On the width of the recombination zone in organic light emitting field-effect transistors
Appl. Phys. Lett.
33312

J.D. Kotlarski, P.W.M. Blom, L.J.A. Koster, M. Lenes, L.H. Slooff,
Combined optical and electrical modeling of polymer : fullerene bulk heterojunction solar cells
J. Appl. Phys.
103 (8), 084502

R. Kroon, M. Lenes, J.C. Hummelen, P.W.M. Blom, B. de Boer
Small bandgap polymers for organic solar cells
Polymer Reviews
48, 531

A.V. Kyrylyuk, P. van der Schoot
Continuum percolation of carbon nanotubes in polymeric and colloidal media
Proceedings of the National Academy of Sciences of the United States of America
105 (24), 8221-8226

M. Lenes, G.J.A.H. Wetzelaer, F.B. Kooistra, S.C. Veenstra, J.C. Hummelen, P.W.M. Blom
Fullerene bisadducts for enhanced open-circuit voltages and efficiencies in polymer solar cells
Adv. Mater.
20 (11), 2116

J. Loos, S. van Bavel, X. Yang
Morphology of heterojunction solar cells
Organic Photovoltaics, Eds: C. Brabec, V. Dyakonov, U. Scherf, Wiley-VCH, Weinheim
299-326

C. Luengo Gonzalez, C.W.M. Bastiaansen, J. Lub, J. Loos, K. Lu, H.J. Wondergem, D.J. Broer
Nanoporous membranes made of hydrogen bridged smectic networks with nanometer transverse pore dimensions
Advanced Materials
20, 1-7

F. Maddalena, M. Spijkman, J.J. Brondijk, P. Fonteijn, F. Brouwer, J.C. Hummelen, D.M. de Leeuw, P.W.M. Blom, B. de Boer
Device characteristics of polymer dual-gate field-effect transistors
Org. Electron.
9, 839

A. Mani, C. Huisman, A. Goossens, J. Schoonman
Mott-Schottky analysis and impedance Spectroscopy of TiO2/6T and ZnO/6T devices
J. Phys. Chem. B
112 (33), 10086-10091

S.G.J. Mathijssen, P.A. van Hal, T.J.M. van den Biggelaar, E.C.P. Smits, B. de Boer, M. Kemerink, R.A.J. Janssen, D.M. de Leeuw
Manipulating the local light emission in organic light-emitting diodes using patterned self-assembled monolayers
Adv. Mater.
20, 2703

O.V. Mikhnenko, F. Cordella, A.B. Sieval, J.C. Hummelen, P.W.M. Blom, M.A. Loi
Temperature dependence of exciton diffusion in conjugated polymers
J. Phys. Chem. B
112 (37), 11601-11604

C.L. van Oosten, D. Corbett, D. Davies, M. Warner, C.W.M. Bastiaansen, D.J. Broer
Bending Dynamics and Directionality Reversal in Liquid Crystal Network Photoactuators
Macromolecules
41(22), 8592-8596

J. Perelaer, K. Hermans, C.W.M. Bastiaansen, D.J. Broer, U.S. Schubert
Photo-embossed surface relief structures with an increased aspect ratios by addition of a reversible addition-fragmentation chain transfer agent
Adv. Mater.
20 (16), 3117-3121

W. Pisula, A.K. Mishra, J. Li, M. Baumgarten, K. Müllen
Carbazole-based /Conjugated Polymers as Donor Material for Photovoltaic Devices
"Organic Photovoltaics: Materials, Device Physics and Manufacturing Technologies" by C. Brabec, V. Dyakonov, U. Scherf (eds.)
Wiley VCH, Weinheim

C. Sanchez, F. Verbakel, M.J. Escuti, C.W.M. Bastiaansen, D.J. Broer
Printing of monolithic polymeric microstructures using reactive mesogens
Adv. Mater.
20 (1), 74

Serrano-Ramon; C.H. Kjellander, S. Zakerhamidi, C.W.M. Bastiaansen, D.J. Broer
3D-structured liquid crystal networks formed by dichroic photoinitiator initiated photo-polymerization
Proceedings of SPIE
691109/1-13

L.H. Slooff, S. Böhme, W. Eerenstein, S.C. Veenstra, W. Verhees, J.M. Kroon, T. Söderström
Fabrication and characterisation of polymer based solar cells
Proceedings of SPIE
7052, 17-19

E.C.P. Smits, S.G.J. Mathijssen, P.A. van Hal, S. Setayesh, T.C.T. Geuns, K.A.H.A. Mutsaers, E. Cantatore, H.J. Wondergem, O. Werzer, R. Resel, M. Kemerink, S. Kirchmeyer, A.M. Muzafarov, S.A. Ponomarenko, B. de Boer, P.W.M. Blom, D.M. de Leeuw
Bottom-up organic integrated circuits
Nature
455 (7215), 956-959

M. Spijkman, E.C.P. Smits, P.W.M. Blom, D.M. de Leeuw, Y. Bon Saint Com, S. Setayesh, E. Cantatore
Increasing the noise margin in organic circuits using dual gate field-effect transistors
Appl. Phys. Lett.
92, 143304

P. Stallinga, A.R.V. Benvenho, E.C.P. Smits, S.G.J. Mathijssen, M. Coelle, H.L. Gomes, D.M. de Leeuw
Determining the carrier mobility from a MIS diode structure
Org. Electron.
9, 735

J. den Toonder, F. Bos, D. Broer, L. Filippini, M. Gillies, J. de Goede, T. Mol, M. Reijme, W. Talen, H. Wilderbeek, V. Khatavkar, P. Anderson
Artificial Cilia for Active Micro-Fluidic Mixing
Lab Chip
8, 533-541

D. Veldman, O. Ipek, S.C.J. Meskers, J. Sweelssen, M.M. Koetse, S.C. Veenstra, J.M. Kroon, S.S. van Bavel, J. Loos, R.A.J. Janssen
Compositional and electric field dependence of the dissociation of charge transfer excitons in alternating polyfluorene copolymer/fullerene blends
J. Am. Chem. Soc.
130 (24), 7721-7735

F. Verbakel, S.C.J. Meskers, D.M. de Leeuw, R.A.J. Janssen
Resistive switching in organic memories with a spin-coated metal oxide nanoparticle layer
Journal of Physical Chemistry C
112 (14), 5254-5257

F. Verbakel, S.C.J. Meskers, R.A.J. Janssen, H.L. Gomes, A.J.M. van den Biggelaar, D.M. de Leeuw
Switching dynamics in non-volatile polymer memories
Org. Electron.
9 (5), 829-833

Y.Y. Yimer, P.A. Bobbert, R. Coehoorn
Charge transport in disordered organic host-guest systems: effects of carrier density and electric field
Journal of Physics-Condensed Matter
20 (33), 335204

M. Yuan, J.C.M. Brokken-Zijp, L.J. Huijbregts, G. de With
Filler size effects on the conductivity of polymer nano-composites: Semiconductive phthalocyanine nanoparticles in epoxy matrices
Journal of Polymer Science Part B-Polymer Physics
46 (11), 1079-1093
A.P. Zoombelt, M.A.M. Leenen, M. Fonrodona, M.M. Wienk, R.A.J. Janssen
The synthesis and photovoltaic performance of regioregular poly[3-(n-butoxymethyl)-thiophene]
Thin Solid Films
516 (20), 7176-7180

Filed patent applications

#532: C.L. van Oosten, C.W.M. Bastiaansen, S.J. Picken, J.M.J. den Toonder, D.J. Broer
Fluid manipulation in micro-channels

#530: K. Hermans, I. Tomatsu, R. Sijbesma, C.W.M. Bastiaansen, D.J. Broer
High aspect ratio photo-embossing

#427: B. Serrano Ramon, C.W.M. Bastiaansen, D.J. Broer
Structured films

#532: C.L. van Oosten, C.W.M. Bastiaansen, D.J. Broer
Preparation of polymer micro-actuators

Reported inventions

#427: B. Serrano Ramon, C.W.M. Bastiaansen, D.J. Broer
Structured films

#532: C.L. van Oosten, C.W.M. Bastiaansen, D.J. Broer
Thermal insulation material

Coating Technology

Projects

#292: Kinetics of adsorption and desorption of mixtures of polymers and surfactants
#419: Weathering and durability of industrial coatings
#422: Low-temperature powder coating by encapsulated cross-linker
#423: Self-replenishing low-adherence coatings
#439: Correlation of molecular changes, physical parameters and product properties of selected coatings in early stages utilizing a novel testing/characterization approach
#440: Durability of metal oxide / coating interfaces
#451: Bio-based building blocks for coating and toner resins
#452: Dispersing pigments in waterborne paints
#494: Light-switchable coatings
#556: Self-healing coatings based on nano-capsules in waterborne coatings
#557: Coatings with layered silica based novel pigments and/or reinforcing fillers
#564: Colloidal interactions modified by associative thickeners in waterborne paint formulations; surface force experiments and Scheutjens-Fleer theory
#565: Thiol-ene based 2-pack-in-1-pot waterborne coating
#570: Self-stratifying antimicrobial coatings
#576: Incorporation of olefins in emulsion copolymers: towards super hydrophobic coatings
#600: Molecular aspects of scratch resistance
#606: Real-time 3D imaging of microscopic dynamics during film formation
#607: Polycarbonate powder coatings
#617: Mobility of water and charge carriers in polymer / oxide / Aluminium alloys
#655: Fully reversible coating networks
#657: Dyktiogenic polymer ions
#658: Waterborne polyurethane dispersions based on renewable resources
#672: Dopamine modification of interfaces between polymers and metals
#673: Starch-based performance coating materials
#676: UV to daylight curing of organic coatings

Theses

B.A.J. Noordover
Biobased step-growth polymers: chemistry, functionality and applicability

T. Dikic
Self-replenishing low-adherence polymer coatings

D. Senatore
Microencapsulation for controlled release of liquid crosslinker: towards low temperature curing powder coatings

B.R. Postmus
Polymer vs. surfactant - competitive adsorption on the solid-liquid interface

P.A.P. Geelen (Patricia)
Light switchable coatings

Scientific publications

A.M. Brouwer, T.N. Raja, K. Biemans, T.T. Nabuurs, R. Tennebroek
Probing of Co-Solvents in Polymer Latex Materials using Solvatochromic Fluorescence
Annals of the New York Academy of Science
1130, 157-163

T. Dikic, W. Ming, P.C. Thuene, R.A.T.M. van Benthem, G. de *With Well-defined poly-caprolactone precursors for low surface-energy polyurethane films*
Journal of Polymer Science Part a-Polymer Chemistry
46 (1), 218-227

B.R. Postmus, F.A.M. Leermakers, M.A.C. Stuart
Self-consistent field modeling of adsorption from polymer/surfactant mixtures
Langmuir
24 (13), 6712-6720

B.R. Postmus, F.A.M. Leermakers, M.A.C. Stuart
Self-consistent field modeling of non-ionic surfactants at the silica-water interface: Incorporating molecular detail
Langmuir
24 (8), 3960-3969

B.R. Postmus, F.A.M. Leermakers, M.A.C. Stuart
Self-consistent field modeling of poly(ethylene oxide) adsorption onto silica: The multiple roles of electrolytes
Langmuir
24 (5), 1930-1942

D. Senatore, M.J.A. Berix, J. Laven, R.A.T.M. van Benthem, G. de With, B. Mezari, P.C.M.M. Magusin
Miscibility and Specific Interactions in Blends of Poly (N-vinyl-2-pyrrolidone) and Acid Functional Polyester Resins
Macromolecules
41 (21), 8020-8029

J. Sprakel, E. Bartscherer, G. Hoffmann, M.A. Stuart, J.D. Gucht
Dynamics of polymer bridge formation and disruption
Physical Review E
78 (4), 040802 1-4

J. Sprakel, N.A.M. Besseling, M.A. Cohen, F.A.M. Leermakers
Phase behavior of flowerlike micelles in a SCF cell model
European Physical Journal E
25 (2), 163-173

J. Sprakel, N.A.M. Besseling, M.A.C. Stuart, F.A.M. Leermakers
Capillary adhesion in the limit of saturation: Thermodynamics, self-consistent field modeling and experiment
Langmuir
24 (4), 1308-1317

J. Sprakel, F.A.M. Leermakers, M.A.C. Stuart, N.A.M. Besseling
Comprehensive theory for star-like polymer micelles; combining classical nucleation and polymer brush theory
PCCP
10 (34), 5308-5316

J. Sprakel, E. Spruijt, M.A.C. Stuart, N.A.M. Besseling, M.P. Lettinga, J. van der Gucht
Shear banding and rheochaos in associative polymer networks
Soft Matter
4 (8), 1696-1705

J. Sprakel, J. van der Gucht, M.A.C. Stuart, N.A.M. Besseling
Brownian particles in transient polymer networks
Physical Review E
77 (6), -

W.K. Wijting, J. Laven, R.A.T.M. van Benthem, G. de With
Adsorption of ethoxylated styrene oxide and polyacrylic acid and mixtures there of on organic pigment
J. Colloid Interface Sci.
327 (1), 1-8

Filed patent applications

#451 + #607: M.L.J. Frijns, R. Duchateau, C.E. Koning
Renewable Polycarbonates

Reported inventions

#556: E.T.A. van den Dungen, B. Klumperman
Self healing composition

#565
M. Ottink, B. Klumperman
Synthesis of functional latexes

High-Throughput Experimentation

Projects

#400: New thin-film and dot preparation techniques
#405: Development and application of new tools based on the AFM technology
#447: Determination of residual metal catalysts, additives and stabilizers in polymer solutions, thin films and in the bulk within a high-throughput workflow
#449: Technical support for, and upgrading of, synthesizers/standard characterization
#496: Correlation of optical data (IR and Raman) with physical properties of polymers and polymer materials
#500: Development of integrated knowledge capture systems for combinatorial materials and polymer research
#501: Fast and automated development and optimization of polymeric materials by combinatorial compounding and high-throughput screening (CC-HTS)
#502: Combinatorial approaches to rational coating design: From polymerization kinetics via coating libraries to structure-property relationships and mathematical descriptors
#508: Quantitative characterization of morphology and structure development of multi-component/ multi-phase polymers on the nanoscale
#509: Comprehensive characterization of branched polymers
#510: Advanced nanoscale characterization of interfaces
#543: Polymer manufacturing using new approaches
#546: Combinatorial discovery and optimization of photo-embossed polymeric bi-layers with dual functionalities
#588: Optimization of polyoxymethylene (POM) additive recipes by combinatorial compounding for lower formaldehyde emission
#589: High-throughput screening of functional materials in plastic electronics: optimizing ink-jet printing and electro-optical property pre-screening
#611: From polymer synthesis to mechanical testing by high-throughput experimentation
#612: High-throughput investigation of well-defined (co)polymers with lower critical solution temperature
#613: Optimization of acrylonitrile/ butadiene/ styrene (ABS) and polycarbonate(PC) / ABS additive recipes by combinatorial compounding for UV stabilization
#619: Development of polymer ontologies
#620: Rapid prototyping and inkjet printing using polyurethane precursors
#621: In-situ preparation of polymer nanoblends
#622: Combinatorial screening of polymer solubility
#645: High-throughput experimentation approaches to Ziegler-Natta-type catalytic olefin polymerizations
#666: 3D printing of hydrogels base on liquid free-form fabrication of modified polysaccharides
#667: Advanced copolymer analysis by MALDI TOF/TOF-MS/MS
#668: Microwave-assisted synthesis of polyamides from amines and carboxylic acids
#670: Mechanical screening of films by combinatorial compounding

Theses

I.Y.Phang
Marine biofouling of surfaces: morphology and nanomechanics of barnacle cyprid adhesion proteins by AFM

C.M. Chiper
Advanced supramolecular assemblies based on terpyridine metal complexes: understanding reaction parameters and designing new materials

Scientific publications

K. Albahily, D. Al-Baldawi, S. Gambarotta, R. Duchateau, E. Koç, T.J. Burchell
Preparation and Characterization of a Switchable Single-Component Chromium Trimerization Catalyst
Organometallics
27, 5708–5711

K. Albahily, D. Al-Baldawi, S. Gambarotta, E. Koç, T.J. Burchell, R. Duchateau
Isolation of a Chromium Hydride Single-Component Ethylene Polymerization Catalyst
Organometallics
27, 5943–5947

K. Albahily, E. Koç, D. Al-Baldawi, D. Savard, S. Gambarotta, T.J. Burchell, R. Duchateau
Chromium Catalysts Supported by a Nonspectator NPN Ligand: Isolation of Single-Component Chromium Polymerization Catalysts
Angew. Chem. Int. Ed.
47, 5816 –5819

A. Baumgaertel, C.R. Becer, M. Gottschaldt, U.S. Schubert
Matrix-assisted Laser Desorption/Ionization Time-of-flight Mass spectrometry coupled with collision-induced dissociation (CID) measurements of poly(methyl methacrylate)
Macromol. Rapid Commun.
29 (15), 1309-1315

C.R. Becer, A.M. Groth, R. Hoogenboom, R.M. Paulus, U.S. Schubert
Protocol for automated kinetic investigation/optimization of the RAFT polymerization of various monomers
Qsar & Combinatorial Science
27 (8), 977-983.

C.R. Becer, S. Hahn, M.W.M. Fijten, H.M.L. Thijs, R. Hoogenboom, U.S. Schubert
Libraries of Methacrylic Acid and Oligo(ethylene glycol) Methacrylate Copolymers with LCST Behavior
Journal of Polymer Science Part a-Polymer Chemistry
46 (21), 7138-7147

C.R. Becer, R.M. Paulus, S. Hoppener, R. Hoogenboom, C.A. Fustin, J.F.O. Gohy, U.S. Schubert
Synthesis of poly (2-ethyl-2-oxazoline)-b-poly(styrene) copolymers via a dual initiator route combining cationic ring-opening polymerization and atom transfer radical polymerization
Macromolecules
41 (14), 5210-5215

M. Chiper, D. Fournier, R. Hoogenboom, U.S. Schubert
Thermosensitive and Switchable Terpyridine-Functionalized Metallo-Supramolecular Poly(N-isopropylacrylamide)
Macromol. Rapid Commun.
29 (20), 1640-1647

M. Chiper, R. Hoogenboom, U.S. Schubert
Ruthenium(II) Ions triggered direct supramolecular polymerization of bis-terpyridine poly-(ethylene glycol): New Insights on synthesis and optimization
E-Polymers
157, 1-9

M. Chiper, M.A.R. Meier, D. Wouters, S. Hoeppener, C.A. Fustin, J.F. Gohy, U.S. Schubert
Supramolecular self-assembled Ni(II), Fe(II), and Co(II) ABA triblock copolymers
Macromolecules
41 (8), 2771-2777

M. Chiper, A. Winter, R. Hoogenboom, D.A.M. Egbe, D. Wouters, S. Hoeppener, C.A. Fustin, J.F. Gohy, U.S. Schubert
Synthesis and Micellization of Coil-Rod-Coil Ruthenium(II) Terpyridine Assemblies
Macromolecules
41 (22), 8823-8831

R. Edam, D.M. Meunier, E.P.C. Mes, F.A. van Damme, P.J. Schoenmakers
Branched-polymer separations using comprehensive two-dimensional molecular-topology fractionation x size-exclusion chromatography
J. Chromatogr. A
1201 (2), 208-214

T.M. Eggenhuisen, C.R. Becer, M.W.M. Fijten, R. Eckardt, R. Hoogenboom, U.S. Schubert
Libraries of statistical hydro-xypropyl acrylate containing copolymers with LCST p roperties prepared by NMP
Macromolecules
41 (14), 5132-5140

T. Erdmenger, R.M. Paulus, R. Hoogenboom, U.S. Schubert
Up-Scaling the synthesis of 1-butyl-3-methylimidazolium chloride under microwave irradiation
Aust. J. Chem.
61 (3), 197-203

T. Erdmenger, J. Vitz, F. Wiesbrock, U.S. Schubert
Influence of different branched alkyl side chains on the properties of imidazolium-based ionic liquids
J. Mater. Chem.
18 (43), 5267-5273

M.W.M. Fijten, C. Haensch, R. Hoogenboom, U.S. Schubert
Clickable poly(2-oxazoline)s as versatile building blocks
Macromol. Chem. Phys.
209 (18), 1887-1895

M.W.M. Fijten, R. Hoogenboom, U.S. Schubert
Initiator effect on the cationic ring-opening copolymerization of 2-ethyl-2-oxazoline and 2-phenyl-2-oxazoline
Journal of Polymer Science Part a-Polymer Chemistry
46 (14), 4804-4816

C.A. Fustin, P. Guillet, M.J. Misner, T.P. Russell, U.S. Schubert, J.F. Gohy
Self-assembly of metallo-supramolecular block copolymers in thin films
Journal of Polymer Science Part a-Polymer Chemistry
46 (14), 4719-4724

C. Guerrero-Sanchez, J.F. Gohy, C. D'Haese, H. Thijs, R. Hoogenboom, U.S. Schubert
Controlled thermoreversible transfer of poly(oxazoline) micelles between an ionic liquid and water
Chem. Commun.
(24), 2753-2755

P. Guillet, C.-A. Fustin, C. Mugemana, C. Ott, U. S. Schubert, J.-F. Gohy
Tuning Block Copolymer Micelles by Metal-Ligand Interactions
Soft Matter
4, 2278 – 2282

C. Haensch, M. Chiper, C. Ulbricht, A. Winter, S. Hoeppener, U.S. Schubert
Reversible Supramolecular Functionalization of Surfaces: Terpyridine Ligands as Versatile Building Blocks for Noncovalent Architectures
Langmuir
24 (22), 12981-12985

C.E. Hendriks, P.J. Smith, J. Perelaer, A.M.J. van den Berg, U.S. Schubert
"Invisible" silver tracks produced by combining hot-embossing and inkjet printing
Adv. Funct. Mater.
18 (7), 1031-1038

R. Hoogenboom, D. Fournier, U.S. Schubert
Asymmetrical supramolecular interactions as basis for complex responsive macromolecular architectures
Chem. Commun.
(2), 155-162

R. Hoogenboom, H.M.L. Thijs, M.J.H.C. Jochems, B.M. van Lankvelt, M.W.M. Fijten, U.S. Schubert
Tuning the LCST of poly(2-oxazoline)s by varying composition and molecular weight: alternatives to poly(N-isopropylacrylamide)?
Chem. Commun.
(44), 5758-5760

R. Hoogenboom, H.M.L. Thijs, D. Wouters, S. Hoeppener, U.S. Schubert
Tuning solution polymer properties by binary water-ethanol solvent mixtures
Soft Matter
59, 103-107

R. Hoogenboom, H.M.L. Thijs, D. Wouters, S. Hoeppener, U.S. Schubert
Solvent responsive micelles based on block and gradient copoly(2-oxazoline)s
Macromolecules
41 (5), 1581-1583

D. Kul, L.M. van Renterghem, M.A.R. Meier, S. Strandman, H. Tenhu, S.S. Yilmaz, U.S. Schubert, F.E. Du Prez
Encapsulation and release by star-shaped block copolymers as unimolecular nanocontainers
Journal of Polymer Science Part a-Polymer Chemistry
46 (2), 650-660

M. Lobert, R. Hoogenboom, C.A. Fustin, J.F. Gohy, U.S. Schubert
Amphiphilic gradient copolymers containing fluorinated 2-phenyl-2-oxazolines: Microwave-assisted one-pot synthesis and self-assembly in water
Journal of Polymer Science Part a-Polymer Chemistry
46 (17), 5859-5868

M. Lobert, U. Koehn, R. Hoogenboom, U.S. Schubert
Synthesis and microwave assisted polymerization of fluorinated 2-phenyl-2-oxazolines: the fastest 2-oxazoline monomer to date
Chem. Commun.
(12), 1458-1460

M. Lobert, H.M.L. Thijs, T. Erdmenger, R. Eckardt, C. Ulbricht, R. Hoogenboom, U.S. Schubert
Synthesis, Microwave-Assisted Polymerization and Polymer Properties of Fluorinated 2-Phenyl-2-oxazolines: A Systematic Study
Chemistry-a European Journal
14 (33), 10396-10407

J. Loos, E. Sourty, S. van Bavel, K. Lu
Advanced transmission electron microscopy for functional polymer systems
Microscopy and microanalysis : the official journal of Microscopy Society of America, Microbeam Analysis Society, Microscopical Society of Canada
14 Suppl 2 (2008) 692-3

K.B. Lu, N. Grossiord, C.E. Koning, H.E. Miltner, B. van Mele, J, Loos
Carbon Nanotube/Isotactic Polypropylene Composites Prepared by Latex Technology: Morphology Analysis of CNT-Induced Nucleation
Macromolecules
41 (21), 8081-8085

A. Mero, G. Pasut, L.D. Via, M.W.M. Fijten, U.S. Schubert, R. Hoogenboom, F.M. Veronese
Synthesis and characterization *of poly(2-ethyl 2-oxazoline)-conjugates with proteins and drugs: Suitable alternatives to PEG-conjugates?*
J. Controlled Release
125 (2), 87-95

H.E. Miltner, N. Grossiord, K.B. Lu, J. Loos, C.E. Koning, B. van Mele
Isotactic polypropylene/carbon nanotube composites prepared by latex technology. Thermal analysis of carbon nanotube-induced nucleation
Macromolecules
41 (15), 5753-5762

R.M. Paulus, C.R. Becer, R. Hoogenboorn, U.S. Schubert
Acetyl halide initiator screening for the cationic ring-opening polymerization of 2-ethyl-2-oxazoline
Macromol. Chem. Phys.
209 (8), 794-800

J. Perelaer, A.W.M. de Laat, C.E. Hendriks, U.S. Schubert
Inkjet-printed silver tracks: low temperature curing and thermal stability investigation
J. Mater. Chem.
18 (27), 3209-3215

J. Perelaer, K. Hermans, C.W.M. Bastiaansen, D.J. Broer, U.S. Schubert
Photo-embossed surface relief structures with an increased aspect ratios by addition of a reversible addition-fragmentation chain transfer agent
Adv. Mater.
20 (16), 3117-3121

J. Perelaer, P.J. Smith, C.E. Hendriks, A.M.J. van den Berg, U.S. Schubert
The preferential deposition of silica micro-particles at the boundary of inkjet printed droplets
Soft Matter
4 (5), 1072-1078

I.Y. Phang, N. Aldred, A.S. Clare, G.J. Vancso
Towards a nanomechanical basis for temporary adhesion in barnacle cyprids (Semibalanus balanoides)
Journal of the Royal Society Interface
5 (21), 397-401

N. Rehmann, C. Ulbricht, A. Koehnen, P. Zacharias, M.C. Gather, D. Hertel, E. Holder, K. Meerholz, U.S. Schubert
Advanced device architecture for highly efficient organic light-emitting diodes with an orange-emitting crosslinkable iridium(III) complex
Adv. Mater.
20 (1), 129-133.

E. Soutry, B. Freitag, D. Wall, D. Tang, K. Lu, J. Loos
Tomographic imaging ultra-thick specimens with nanometer resolution
Microscopy and microanalysis : the official journal of Microscopy Society of America, Microbeam Analysis Society, Microscopical Society of Canada
14 Suppl 2, 1056-1057

E. Soutry, B. Freitag, D. Wall, D. Tang, K. Lu, J. Loos
Tomographic imaging ultra-thick specimens with nanometer resolution
Microscopy and microanalysis : the official journal of Microscopy Society of America, Microbeam Analysis Society, Microscopical Society of Canada
14 Suppl 2, 1056-1057

E. Tekin, D.A.M. Egbe, J.M. Kranenburg, C. Ulbricht, S. Rathgeber, E. Birckner, N. Rehmann, K. Meerholz, U.S. Schubert
Effect of side chain length variation on the optical properties of PPE-PPV hybrid polymers
Chem. Mater.
20 (8), 2727-2735

E. Tekin, P.J. Smith, U.S. Schubert
Inkjet printing as a deposition and patterning tool for polymers and inorganic particles
Soft Matter
4 (4), 703-713

T.H.J. van Osch, J. Perelaer, A.W.M. de Laat, U.S. Schubert
Inkjet printing of narrow conductive tracks on untreated polymeric substrates
Adv. Mater.
20 (2), 343-345

C. Ulbricht, C. R. Becer, A. Winter, D. Veldman, U. S. Schubert
Copolymers containing Phosphorescent Iridium(III) Complexes obtained by Free and Controlled Radical Polymerization Techniques
Macromol. Rapid Commun.
29, 1919 – 1925

A. Winter, C. Friebe, M.D. Hager, U.S. Schubert
Advancing the Solid State Properties of Metallo-Supramolecular Materials: Poly(epsilon-caprolactone) Modified pi-Conjugated Bis(terpyridine)s and their Zn(II) Based Metallo-Polymers
Macromol. Rapid Commun.
29 (20), 1679-1686

A. Winter, M. Chiper, C. Friebe, U. S. Schubert, M. Presselt, B. Dietzek, M. Schmitt, J. Popp
Zinc(II) Bis-Terpyridine Complexes: The Influence of the Cation on the π-Conjugation between Terpyridine and the Lateral Phenyl-Substituent
J. Phys. Chem, Part C.
112, 18651 – 18660

Filed patent applications

#502: J.T. Delaney, U.S. Schubert
Preparation of conductive lines on polymer substrates

#502: J.T. Delaney, U.S. Schubert
Macroporous hydrogels for tissue engineering

#502: J.T. Delaney, S. Hornig, U.S. Schubert
Particle manufacturing method

#502: P. Kröber, J.T. Delaney, U.S. Schubert
Enhancing the contrast of surfaces

#546: J. Perelaer, U.S. Schubert, M. Klokkenburg
Method for Generation of Electrically Conducting Surface Structures, Apparatus Therefore and Use

Reported inventions

#546: I. Reinhold, R. Eckardt, C.E. Hendriks, J. Perelaer, U.S. Schubert
Electrically conducting surface structures (1)

#546: J. Perelaer, U.S. Schubert, M. Klokkenburg, E. Young
Electrically conducting surface structures (2)

#502: J.T. Delaney, U.S. Schubert
Inkjet printing system

#502: J.T. Delaney, M. Gottschaldt, U.S. Schubert
Microfluidic reactor

#502: J.T. Delaney, S. Hornig, U.S. Schubert
Particle manufacturing method

#502: P. Kröber, J.T. Delaney, U.S. Schubert
Enhancing the contrast of surfaces

#502: J.T. Delaney, U.S. Schubert
Printing of conductive inks

Bio-Inspired Polymers

Projects

#587: Crossing the border between synthetic and natural polymers: keratins as cheap feedstock for novel self-organizing oligomers and polymers
#599: Interaction of superheated water with hydrogen bonding semi-crystalline polymers: a computational approach
#602: Collagen-inspired self-organizing materials
#603: Strengthening/shielding of hydrogen bonding by physical processes in the presence of salts and water
#604: Biomimetic polymers for the encapsulation of functional entities
#608: High molecular weight aliphatic polyesters by enzymatic polymerization for medical applications
#609: Advanced materials on the basis of cellulose via novel reaction processes
#610: Molecular engineering with self-assembled peptides/ Mimicking nano-structured natural materials following a modular approach
#684: Smart Materials with programmable response
#685: Ionic interactions in water at superheated state and its implications on the dissolution of biopolymers.
#686: Thermal Catch and Release
#687: Functionality of novel amphiphilic biomaterials synthesized by enzymatic linking of food polysaccharides, food proteins and fatty acids
#688: Lessons from biomineralization: self-organizing and mineralization-directing block coplymers
#689: Bio-inspired hairy surfaces for actuation or sensing, produced with roll-to-toll technology

Scientific publications

S. Scanlon, A. Aggeli
Self-assembling peptide nanotubes
Nano Today
3, No 3-4, 22-30

J.A.W. Harings, O. van Asselen, R. Graf, R. Broos, S. Rastogi
The role of superheated water on shielding and mediating hydrogen bonding in N,N '-1,2-ethanediyl-bis(6-hydroxy-hexanamide) crystallization
Crystal Growth & Design
8 (9), 3323-3334

J.A.W. Harings, O. van Asselen, R. Graf, R. Broos, S. Rastogi
The role of superheated water on the crystallization of N,N '-1,2-ethanediyl-bis(6-hydroxy-hexanamide): Implications on crystallography and phase transitions
Crystal Growth & Design
8 (7), 2469-2477

Filed patent applications

#603 + #460: J.A.W. Harings, Y.S. Deshmukh, E. Vinken, S. Rastogi
Polyamide with reduced crystallinity

Large-Area Thin-Film Electronics

Projects

#618: Stacked polymer light-emitting diodes
#640: Engineering the morphology of organic (semi-) conductor layers
#659: Crosslinkable semi-conductors for robust polymer electronics
#663: Initiated chemical vapour deposition of polymer interlayers for ultra-high moisture diffusion barrier systems
#665: Composite π–π stacked organic semiconductors: materials and processing towards large area electronics
#704: Forming processes in metal oxide organic light-emitting diodes

Corporate Research

Projects

Enabling Science
#511: Nanostructure and chain mobility in polymers studied with solid-state NMR
#596: Chemically improved polysaccharides – Detailed structure-property relationships
#597: Ultra performance polymer separation
#601: Synthesis of well-defined branched architectures for method development in polymer characterization
#615: 3-D tomographic reconstruction of local morphology and properties of polymer systems with nanometric resolutions by means of TEM and AFM
#643: Development of high-temperature two-dimensional liquid chromatography for the characterization of polyolefins (CR+PO#642)
#446: Structured fluids & rheology in processing
#487: Deformation, damage and failure: deformation mechanisms below the continuum scale
#578: Determining mechanical properties without the need for mechanical testing
#429: High-resolution (energy and lateral) analysis of polymer materials by cryo-transmission electron microscopy based electron energy loss spectroscopy (> cont. #615)
#694: Modelling of draw resonance and related instabilities in polymer processes
#695: Optical microscopy for nanoscale imaging
#698: Designer polypeptides for self-assembled delivery vehicles
#699: Artificial flagella: Nature-inspired micro-object manipulation using responsive polymers
#700: The ultimate stabilizer-free emulsion polymerization
#701: Understanding the viscoelasticity of elastomer-based nanocomposites
#702: Immobilization of molecular catalysts on well-defined flat model surfaces

Infrastructure
#598: DUBBLE, development of (and general support for projects needing) advanced X-ray analysis
#691: Behind state of the art: Scanning Transmission Electron Microscopy (STEM) for analysis of polymer systems
#692: Reading (bio)macromolecules with Tip-Enhanced Raman Spectroscopy (TERS) Imaging: on the way to local sequencing
#693: Elastin-functionalized silica particles

Theses

A. Balguid
Strategies to optimize engineered tissue towards native human aortic valves

T. Mulder
Equilibration and deformation of glass-forming polymers: molecular simulation via connectivity-altering Monte Carlo and scale-jumping methods

A.A. Martens
Silk-collagen-like block copolymers with charged blocks; self-assembly into nanosized ribbons and macroscopic gels

R.A. Orza
Investigation of peroxide crosslinking of EPDM rubber by solid-state NMR

T.A.P. Engels
Predicting performance of glassy polymers

M.K. Singh
Design, analysis, and optimization of distributive mixing

Scientific publications

A. Albrecht, R. Brull, T. Macko, P. Sinha, H. Pasch
Analysing the chemical composition distribution of ethylene-acrylate copolymers: Comparison of HT-HPLC, CRYSTAF and TREF
Macromol. Chem. Phys.
209 (18), 1909-1919

N. Aldred, I.Y. Phang, S.L. Conlan, A.S. Clare, G.J. Vancso
The effects of a serine protease, Alcalase (R), on the adhesives of barnacle cyprids (Balanus amphitrite)
Biofouling
24 (2), 97-107

L. Balzano, G. Portale, G.W.M. Peters, S. Rastogi
Thermoreversible DMDBS phase separation in iPP: The effects of flow on the morphology
Macromolecules
41 (14), 5350-5355

E. J. H. Boelen, G. Lewis, J. Xu, T. Slots, L.H. Koole, C.S.J. van Hooy-Corstjens
Evaluation of a highly-radiopaque iodine-containing acrylic bone cement for use in augmentation of vertebral compression fractures
Journal of Biomedical Materials Research Part A
86A (1), 76-88

D. Boschmann, R. Edam, P.J. Schoenmakers, P. Vana
Z-RAFT star polymerization of styrene: Comprehensive characterization using size-exclusion chromatography
Polymer
49 (24), 5199-5208

G.K. Dalakoglou, K. Karatasos, S.V. Lyulin, A.V. Lyulin
Brownian dynamics simulations of complexes of hyperbranched polymers with linear polyelectrolytes: Effects of the strength of electrostatic interactions on static properties
J. Chem. Phys.
152 (1-3), 114-118

G.K. Dalakoglou, K. Karatasos, S.V. Lyulin, A.V. Lyulin
Shear-induced effects in hyper-branched-linear polyelectrolyte complexes
J. Chem. Phys.
129 (3), 034901-1 -034901-12

M. de Geus, R. Peters, C.E. Koning, A. Heise
Insights into the initiation process of enzymatic ring-opening polymerization from monofunctional alcohols using liquid chromatography under critical conditions
Biomacromolecules
9 (2008) 752-757

C. Hartmann-Thompson, D.L. Keeley, K-J. Eichhorn, Y. Mikhailova, B. Voit
Hyperbranched polyesters with internal and exo-presented hydrogen-bond acidic sensor groups for surface acoustic wave sensors
J. Appl. Polym. Sci.
107, 1401-14

P. J. A. Janssen, P.D. Anderson
A boundary-integral model for drop deformation between two parallel plates with non-unit viscosity ratio drops
Journal of Computational Physics
46 (4), 1203-1217

R. P. M. Janssen, L.E. Govaert, H.E.H. Meijer
An analytical method to predict fatigue life of thermoplastics in uniaxial loading: sensitivity to wave type, frequency and stress amplitude
Macromolecules
41, 2531-2540

R. P. M. Janssen, D. de Kanter, L.E. Govaert, H.E.H. Meijer
Fatigue Life Predictions for Glassy Polymers: A Constitutive Approach
Macromolecules
41, 2520-2530

J. T. A. Kierkels, C.L. Dona, T.A. Tervoort, L.E. Govaert
Kinetics of re-embrittlement of (anti)plasticized glassy polymers after mechanical rejuvenation
Journal of Polymer Science Part B-Polymer Physics
46 (2), 134-147

A. Lederer, S. Boye
Molmassenbestimmung von multifunktionellen Polymeren
LCGCads
November/December 24 – 28

S. V. Lyulin, A.A. Darinskii, A.V. Lyulin
Energetic and conformational aspects of dendrimer overcharging by linear polyelectrolytes
Physical Review E
78 (4), 041801-1 - 041801-9

S. Lyulin, K. Karatasos, A. Darinskii, S. Larin, A. Lyulin
Structural effects in overcharging in complexes of hyperbranched polymers with linear poly-electrolytes
Soft Matter
4 (3), 453-457

T. Mulder, V.A. Harmandaris, A.V. Lyulin, N.F.A. van der Vegt, M.A.J. Michels
Molecular Simulation Via Connectivity-altering Monte Carlo and Scale-jumping Methods: Application to Amorphous Polystyrene
Macromol. Theory Simul.
17 (7-8), 393-402.

T. Mulder, V.A. Harmandaris, A.V. Lyulin, N.F.A. van der Vegt, B. Vorselaars, M.A.J. Michels
Equilibration and deformation of amorphous polystyrene: scale-jumping simulational approach
Macromol. Theory Simul.
17, 290-300

S. Reichelt, K-J. Eichhorn, U.F. Simon, S. Fleischmann, B. Voit
Immobilization of a hyper-branched polyelectrolyte via grafting-to and electron beam irradiation
Langmuir
24, 9392-9400

J.Song, D. Tranchida, G.J. Vancso
Contact mechanics of UV/ozone-treated PDMS by AFM and JKR testing: Mechanical performance from nano- to micrometer length scales
Macromolecules
41 (18), 6757-6762

J.Song, G.J. Vancso
Effects of flame treatment on the interfacial energy of polyethylene assessed by contact mechanics
Langmuir
24 (9), 4845-4852

K. Stumpe, K-J. Eichhorn, B. Voit
Characterization of Thin Composite Films from Hyperbranched Polyphenylene and Thermolabile Hyperbranched Polycarbonate
Macromol.Chem. Phys.
209, 1787-1796

A. Vananroye, P.J.A. Janssen, P.D. Anderson, P. Van Puyvelde, P. Moldenaers
Microconfined equiviscous droplet deformation: Comparison of experimental and numerical results
Physics of Fluids
20 (1), 013101-1 - 013101-10

About DPI ...

DPI is a foundation funded by Dutch industry, universities and the government which was set up to perform exploratory research in the area of polymer materials.

DPI operates at the interface of universities and industry, linking the scientific skills of university research groups to the industrial need for innovation.

DPI carries out pre-competitive research projects to add value to the scientific community through scientific publications and to the industrial community through the creation of intellectual property.

DPI provides a unique platform for generating awareness of new technology, in which participating industrial companies, competitors in the market place, communicate on a pre-competitive basis to trigger innovation.

DPI integrates the scientific disciplines and know-how of universities into the ‘chain of knowledge’ needed to optimise the conditions for making breakthrough inventions and triggering industrial innovation.

DPI aims to combine scientific excellence with a genuinely innovative impact in industry, thereby creating a new mindset in both industrial and academic research.

DPI aims to fill the innovation gap between industry and universities and so resolve the Dutch Paradox of scientific excellence and lack of innovation.

Some 250 researchers (PhDs and Post-Docs) are currently involved in DPI projects at knowledge institutes throughout the world.

Dutch Polymer Institute

Mail address
P.O. Box 902
5600 AX EINDHOVEN
The Netherlands

Visiting address
Kennispoort
John F. Kennedylaan 2
5612 AB EINDHOVEN

T +31 (0) 40 247 56 29
F +31 (0) 40 247 24 62
E info@polymers.nl
W www.polymers.nl

Colophon

Coordination
DPI Communication

Design
Kade 05, Eindhoven

Interviews
Bureau Lorient Communicatie, Valkenburg Z-H
Orbitaal, Haarlem

Photography
Bart van Overbeeke Fotografie, Eindhoven
Foto Verreijt, Nijmegen
FMAX, Delft

Photo Paulina Skrzeszewska: thanks to Antiquarian Bookshop ‘De Wereld aan de Wand’, Nijmegen, specialized in school wall maps

Printing
Lecturis, Eindhoven

Translation
Henk Rhebergen

Excellence & Impact

Polymers for a sustainable society

DPI
DUTCH POLYMER INSTITUTE

www.polymers.nl