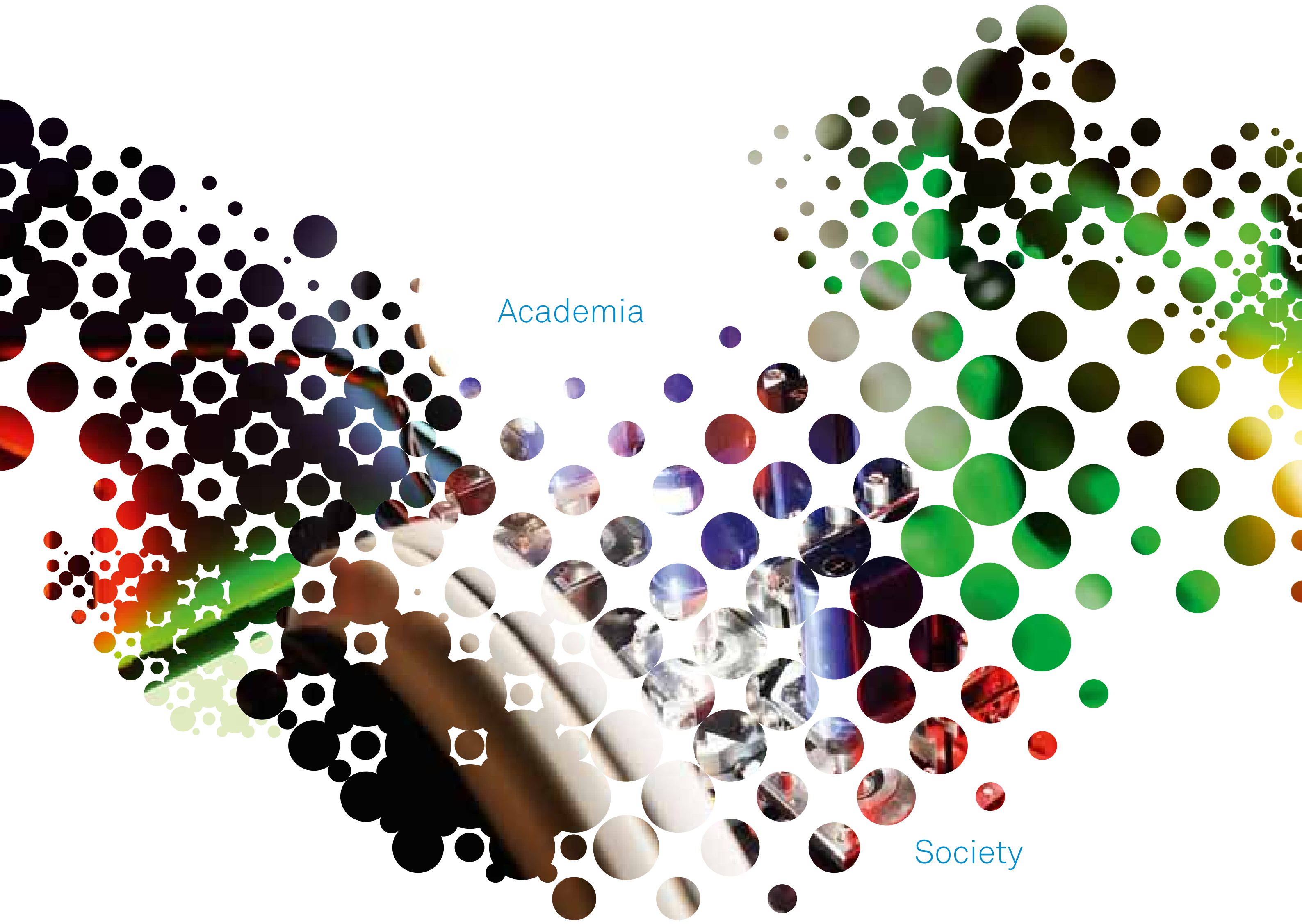
Annual Report 2009

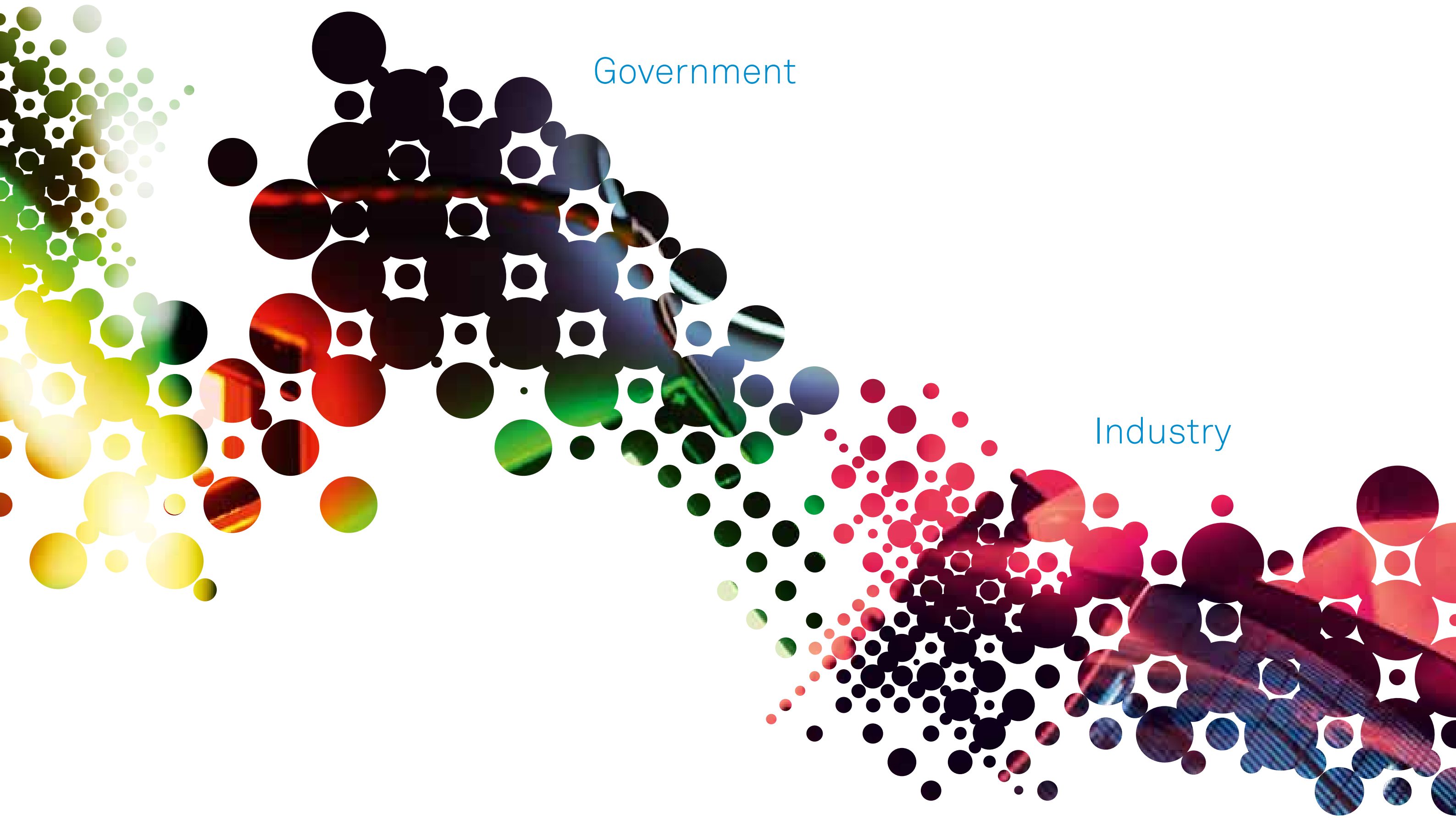
Creating value

DPI
Dutch Polymer Institute


Academia
Society

The art of connecting

The polymer world is facing a number of challenges. There is a growth in market demand. The range and quality of technological options driven by modern science and technology are rapidly increasing. And there is strong pressure from society for sustainability and new technological solutions. The challenges are too broad and too complex to be addressed by a single party. The Dutch Polymer Institute truly addresses those challenges by organising polymer knowledge and connecting polymer technologists through the value chain.



Jacques Joosten

Martien Cohen Stuart

Introduction
Creating value

The crisis as a springboard

For DPI 2009 was a tough year – and at the same time also an exciting year. As a result of the economic crisis, many of our industrial partners were confronted with declining sales, profits and employment. To help companies maintain their R&D capacities, the Dutch government introduced the so-called Knowledge Workers Scheme (KWR), an initiative that we were able to take full advantage of thanks to our extensive network of universities and companies. The KWR initiative enabled us to set up a number of new projects involving 150 researchers from companies whom we linked to new international researchers at universities.

The economic crisis made it difficult for DPI to attract new partner companies and to retain existing partners. Lack of financial resources meant that new projects could not easily be started. It was only by drawing on our financial reserves that we were able to create room for promising new projects. As always, these projects are based on the principle that researchers at universities carry out high-level scientific research in areas that are important to the participating companies.

In 2010 the challenge for DPI is twofold: to neutralise the negative impact of the crisis and at the same time to increase our research volume. We will make every effort to get new parties on board and to convince those already on board to take part in DPI projects on a larger scale. We also intend to try and obtain additional funding via subsidies from other countries, including EU subsidies.

Focus on cradle-to-cradle

The KWR projects lend an important new dimension to DPI's portfolio. The emphasis in these projects is on research into technologies that will enable companies to explore new routes towards sustainability. A large number of these projects have been defined along the lines of the cradle-to-cradle principle. DPI has been looking seriously at adopting this principle for our projects since 2007, when the founder of this principle, the German chemist Michael Braungart, was a guest at our annual meeting. The KWR projects signify the first steps in this direction. One of the projects focuses on minimizing the ecological footprint of coatings.

These projects form a welcome addition to our existing project portfolio. They bring us into contact with a different category of researchers who are often working further down the polymer applications value chain.

This broadening of our network means that we will be able to give an extra boost to innovation in the field of polymers and their applications.

DPI Annual Meeting

Our two-day annual meeting in November 2009 included a large-scale networking session. The more than 350 participants included researchers from DPI members (universities and industry) as well as clients of the DPI Value Centre (people from the SME sector). Several parallel sessions were organised in which small new companies were able to present themselves. All in all, it was a lively gathering with plenty of networking opportunities for young researchers, entrepreneurs, venture capitalists and representatives from large companies. According to many of the attendees, the annual meeting was a most inspiring and valuable event.

During the annual meeting the Golden Thesis Award 2009 was presented to the DPI researcher with the best PhD study and thesis. An independent judging committee granted the award to Casper van Oosten of Eindhoven University of Technology for his thesis entitled "Responsive Liquid Crystal Networks". Van Oosten carried out research into a kind of plastic cilia (hair-like microstructures similar to those in biological cells) that can be set in motion by light or a magnetic field. Casper van Oosten's start-up company, Peer+, was among the young companies that presented themselves during the networking session.

Introduction to valuable network

It is DPI tradition to organise a Young DPI Meeting on the day before the annual meeting. We see this meeting as an ideal opportunity to enable young academic researchers to get acquainted with the unique character and the scope of DPI's international network – a network in which polymer chemists and technologists from universities and industry help each other to solve problems. The DPI network also makes it easier for a researcher to find a job at one of the affiliated universities or companies. This is a successful approach, as is evidenced by the fact that after completing their research majority of the researchers find jobs with DPI partner companies or universities.

> "The science review by the European scientists was highly positive."

Martien Cohen Stuart

From left to right: Jan Stamhuis, Peter Kuppens, Richard van den Hof, Peter Nossin, Harold Gankema, Annemarie van den Langenberg, Christianne Bastiaens and John van Haare. Second row: Miranda Heuvelmans, Jacques Joosten, Jeanne van Asperdt and Shila de Vries. Third row: Sherida Koenders, Leo Robben, Renée Hoogers, Johan Tiesnitsch and Monique Bruining.

> "It is our challenge to neutralise the negative impact of the economic crisis and to increase our research volume."
>
> **Jacques Joosten**

Scientific recognition

In the context of our annual science review, a committee of European scientists screened our entire portfolio and output, using Key Performance Indicators to evaluate the quality of our research projects. The committee's report was highly positive and included several recommendations, such as new research areas worth exploring more, and certain fields where more focus is desirable.

As the report shows, the committee positively assessed DPI's achievements in several Areas. For example, through our pioneering academic research we succeeded in breaking new ground in coatings, a field long considered to lack innovation. We also have reason to be proud of the DPI project in which a group from Eindhoven University of Technology collaborated with Holst Centre and the University of Groningen on research into polymer electronics. The research resulted in a publication about self-assembled monolayer field-effect transistors (SAMFET) in the science journal Nature.

This project and the projects carried out by the winner and the nominees of the Golden Thesis Award are only a small sample of the top-class research carried out at DPI. This is also apparent from the recently published report 'Science and Technology Indicators 2010', which presents the results of a bi-annual study by the Netherlands Observatory of Science and Technology (NOWT). The study, in which the research results of universities, institutes, university hospitals and companies in the Netherlands are compared, shows DPI to have a Citation Impact factor of 2.19 in 2009. This score puts DPI in second place amongst institutes in the Netherlands.

Many of our research projects are highly innovative and their results are therefore patentable. DPI affiliated companies and knowledge institutes can stake a claim to such a patent. If there are no takers, DPI transfers these patents to the DPI Value Centre, from where they find their way to new or recently established companies and thus generate new business activity.

> "We want to enable young researchers to get acquainted with our unique and international network."
>
> **Martien Cohen Stuart**

> “The new strategy involves attracting new companies that fit into the value chains based on renewable resources.”

Jacques Joosten

New strategy offering new opportunities

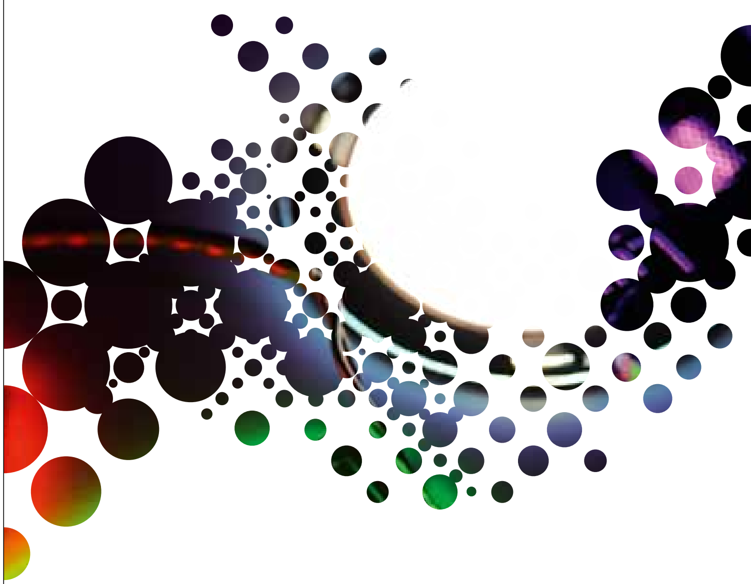
A new feature of DPI’s participation model is that SMEs can participate in DPI research projects. To make this possible, the threshold for participation has been lowered. An SME can now buy a ‘basic participation’ for 25% of the regular participation fee, which gives the SME observer status. Another possibility is that two or three SMEs pool their resources to jointly buy a ‘group participation’ for a four-year period, which gives them the same rights and obligations as a single, fully participating company.

Through its collaboration with the DPI Value Centre, DPI is building closer relationships with the SME sector. The polymer innovation scheme that has been initiated in collaboration with Agentschap NL (previously named SenterNovem) will lead to even more initiatives. This will increase our name recognition and our reach. The consortium projects in which one or two of our partner companies collaborate with SMEs from the sector will represent a particularly exciting challenge.

Another element of the new strategy involves attracting companies that fit into value chains based on renewable resources, for example companies from the agricultural sector.

Pooled strength

Our sector could not avoid being hit by the crisis. But we have been quick to respond adequately by investing even more in innovation in order to stay ahead of the competition. A key condition for fulfilling our ambitions is a multi-year commitment from our partners: companies, universities and the government. Based on the results achieved so far, the great interest shown by companies and universities eager to join DPI, and industry’s increasing interest in the activities of the DPI Value Centre, we are looking to the future with great confidence.



Jacques Joosten
Managing Director

Martien Cohen Stuart
Scientific Director

Contents

Organisation 2009

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- Prof.dr.ir. C.J. van Duijn
- Ir. F. Kuijpers
- Prof.ir. K.C.A.M. Luyben
- Prof. G. Marrucci
- Prof.dr. J. Put

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- Dr. H.M.H. van Wechem, *Chairman* (June-October 2009)
- Dr.ir. M. Steijns, Dow Benelux, *Chairman* (until June 2009)

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- Prof.dr. M.A. Cohen Stuart, *Scientific Director*

Programme Area Coordinators

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- Dr.ir. H. Gankema, *High-Throughput Experimentation, Coatings 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, Emerging Technologies*

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. F. de Schryver, *Functional Polymer Systems*
- Prof.dr. C.D. Eisenbach, *Coatings Technology*
- Prof.dr. U.S. Schubert, *High-Throughput Experimentation*
- Prof.dr. G. Eggink, *Bio-Inspired Polymers*
- Prof.dr. M.A. Cohen Stuart, *Corporate Research*

Organisation Staff

- A.F.J. van Asperdt, *Financial Administration*
- C.H.L.M. Bastiaens, *Communications*
- Dr.ir. M.J. Bruining, *General Affairs*
- M.M.G. Heuvelmans, *Financial Administration*
- R. Hoogers, *Secretariat*
- S.G. Koenders, *Project Administration*
- P.J.J. Kuppens AA, *Controlling*
- A.M.G. van den Langenberg, *Project Administration*
- Ir. S.K. de Vries, *Intellectual Property and Legal*

DPI Value Centre

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

Summary of Financial Data 2009

Income

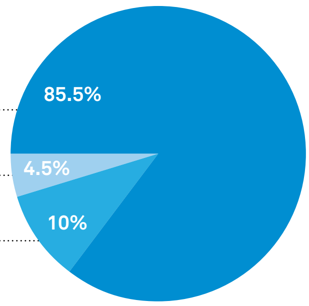
Income	(x EUR million)	%
Contributions from industrial partners	4.95	26
Revenue DPI Value Centre	0.34	2
Contributions from knowledge institutes	4.63	24.5
Contributions from Ministry of Economic Affairs	9.00	47
Knowledge Workers Scheme	0.10	0.5
Total income	**19.02**	**100%**

Expenditure (x EUR million)

By nature

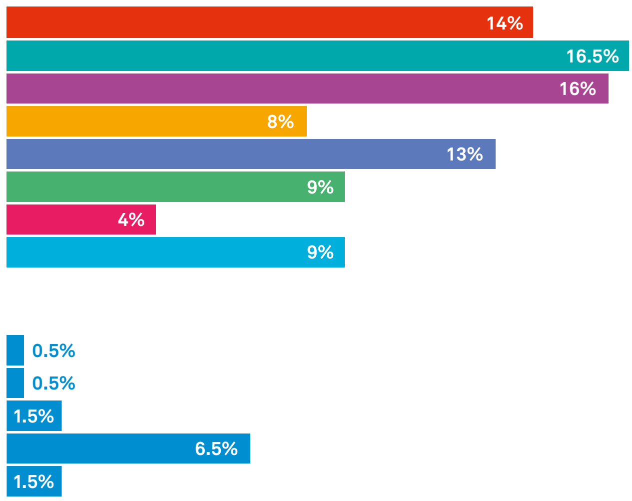
The nagative result is approved by the Supervisory Board and reduces the positive equity.

Personnel costs	17.29
Depreciation	0.94
Other costs	1.99
Total expenditure	**20.22**



By Programme Area

Polyolefins	2.79
Performance Polymers	3.30
Functional Polymer Systems	3.23
Coatings Technology	1.62
High-Throughput Experimentation	2.66
Bio-Inspired Polymers	1.76
Large-Area Thin-Film Electronics	0.83
Corporate Research	1.81
Emerging Technologies	0.12
Knowledge Workers Scheme	0.12
Knowledge Transfer	0.31
Organisation and support	1.33
Support to DPI Value Centre	0.34
Total expenditure	**20.22**



Key Performance Indicators 2009

Number of industrial partners

2008	34
2009	32

European governmental funding (% of total funding)

2008	0%
2009	0%

Number of partner knowledge institutes
(universities etc.)

2008	44
2009	48

Participation of foreign knowledge institutes
as % of total expenditure

2008	29%
2009	34%

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

End 2008	27%
End 2009	26%

End 2008: EUR 4,409,949 cash + EUR 377,882 in kind
End 2009: EUR 4,695,739 cash + EUR 257,556 in kind

Overhead costs
as % of total expenditure

2008	7%
2009	6.5%

Expenditure for knowledge transfer

2008	EUR 358,000
2009	EUR 379,000

Contribution Ministry of Economic Affairs
as % of total expenditure

End 2008	50%
End 2009	47.5%

Number of patents filed by DPI

2008	12
2009	10

Number of patents licensed or transferred to industrial partners and DPI Value Centre

2008	1
2009	6

Interest shown by industrial partners	9
Interest shown by university partners	2
Interest shown by DPI Value Centre	8
Number of patents to be transferred	**19**

Track record DPI researchers

Left in total	72
Employed by partner knowledge institute	34
Employed by non-partner knowledge institute	7
Employed by partner industrial company	6
Employed by non-partner industrial company or start-up	11
Returned to native or foreign country	5
Unknown	9

Research output

Research output	2008	2009
Scientific publications	165	176
PhD theses	27	26

Partners 2009

Industry

- Akzo Nobel
- BASF
- Bayer
- Borealis
- Braskem
- Chemspeed Technologies
- Ciba Specialty Chemicals
- Dow Benelux
- DSM
- ECN
- Evonik
- Food and Biobased Research Wageningen UR
- Forschungs Gesellschaft Kunststoffe
- FrieslandCampina
- Industrial Technology Research Institute Taiwan *
- LyondellBasell
- Merck
- Michelin
- Microdrop Technologies *
- Nano Technology Instruments – Europe
- Océ Technologies
- OTB Group *
- Philips
- Sabic Europe
  Sabic Innovative Plastics
- Shell
- SKF
- Symyx
- Teijin Aramid
- Ticona
- TNO
- Waters Technologies Corporation

Knowledge institutes

- Delft University of Technology
- Deutsches Kunststoff Institut
- ECN
- Eindhoven University of Technology
- ESCPE
- ESPCI
- Food and Biobased Research Wageningen UR
- Forschungsinstitut für Pigmente und Lacke
- Friedrich-Schiller-University Jena
- Imperial College London
- Innovent

Japan Advanced Institute of Science and Technology *

Leibniz-Institut für Polymerforschung Dresden

Loughborough University

Martin-Luther University of Halle-Wittenberg *

Max-Planck Institute fur Polymer Forschung

Nanoforce Technology

National Technical University of Athens

NWO

Polymer Technology Group Eindhoven

Queen Mary & Westfield College, University of London

Queens University *

Radboud University Nijmegen

Stellenbosch University

TNO

University Maastricht

University of Algarve

University of Amsterdam

University of Bayreuth

University of Cambridge

University of Cologne

University of Duisburg-Essen

University of Groningen

University of Haute-Alsace

University of Leeds

University of Leiden

University of Liverpool

University of Manitoba

University of Münster

University of Naples Federico II

University of Ottawa

University of Perugia

University of Salerno *

University of Twente

University of Ulm

University of Wuppertal

Utrecht University

Wageningen University

* new per 2009 * left in 2010

Empowered by
Ministry of Economic Affairs

Intellectual Property (IP)

DPI inventions and patents 2009

In 2009 DPI filed ten patent applications on the basis of 16 reported inventions. These numbers are comparable to previous years, when compared to the research budget available. The inventions and patent applications per million euros spent within DPI are comparable to the numbers for other research organisations and industrial R&D of similar nature.

The technology area High-Throughput Experimentation stands out when it comes to IP. It has produced five inventions, four of which have been filed as patent applications as a result of interest from the industrial partners. In each of the technology areas Performance Polymers, Coating Technology and Functional Polymer Systems, two patent applications have been filed. The research in the 'younger' technology areas Large-Area Thin-Film Electronics and Bio-Inspired Polymers has not yet resulted in patentable inventions.

Honouring our researchers

In order to honour the researchers who have produced an invention of interest to our partners, we award Certificates of Invention during our annual meeting. At our annual meeting in November 2009, at partner knowledge institute Eindhoven University of Technology, we awarded a total of 41 Certificates of Invention to the inventors of 13 patent applications filed within the academic year 2008-2009. For each Certificate of Invention there is a corresponding award of 500 euros.

This year's Golden Thesis Award was granted to Dr. Casper van Oosten. His research project resulted in a total of four patent applications whose transfer to a partner company or third party is currently under discussion.

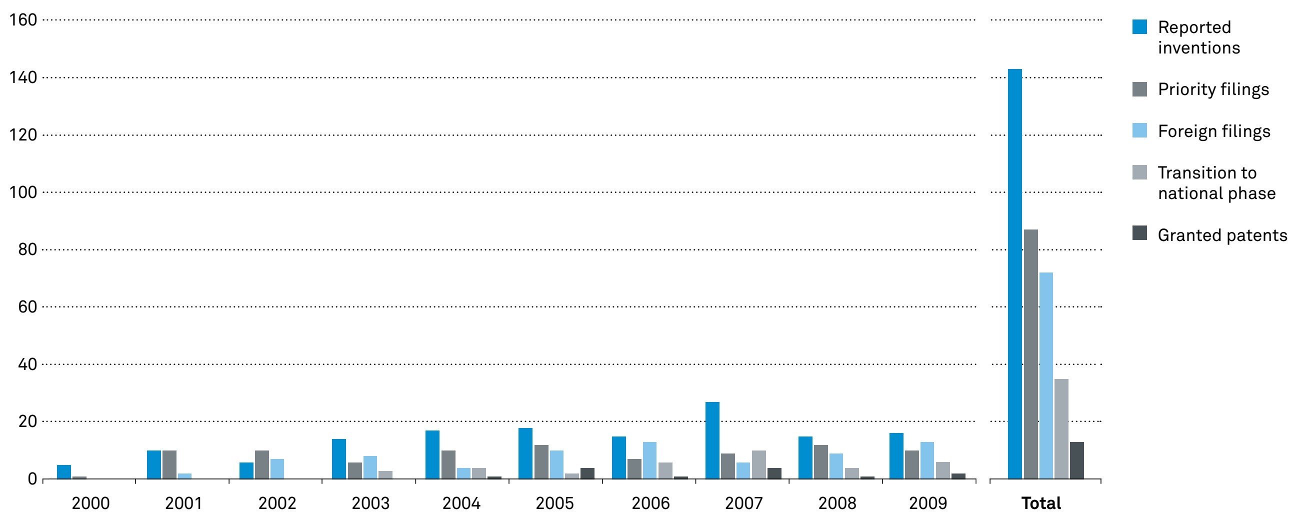
Furthermore, during a dedicated session at the European Polymer Congress in Graz on 14 July 2009 the second Pieter Jan Lemstra award was presented to Professor Ulrich Schubert for his inventive work in the area of High-Throughput Experimentation.

Continuing the valorisation of Intellectual Property

In order to find the best way of transferring our technology to industrial partner companies and universities we continuously look for ways to optimise our IP regulations and processes. We reviewed several possibilities in 2009 and some small adjustments were made. This procedure will be continued next year with more in-depth consultations with the partners.

The discussions with partner companies and universities about the transfer of specific patent applications are on-going. Furthermore, we have an agreement with our partner DPI Value Centre to follow up on the valorisation of our IP with parties outside the DPI community. The Value Centre has an option on DPI patent applications during an initial period and once a business case is found, a transfer agreement will be drawn up for those cases.

DPI patents 2000-2009



KWR reduces crisis in polymer sector

Like other sectors the chemistry sector has been hit by the economic difficulties of 2009 that has forced many companies to make cut-backs, even on research. It will not be an easy job to rebuild the loss of research capacity after the crisis. The Knowledge Workers Scheme (KWR) is an initiative of the Ministry of Economic Affairs aimed at helping companies to maintain their research capacity during this period. Researchers are being temporarily detached to knowledge and research institutes, including DPI, while remaining in the service of industry. Companies are recompensed for a substantial part of the salaries of these workers for a period of up to one and a half years. In addition, the knowledge and research institutes are compensated for supervising the knowledge workers.

Maintaining research capacity

The KWR launched by the Ministry of Economic Affairs has been embraced by the Dutch plastics sector. At the end of 2009 some 150 researchers from four companies from the DPI network, via DPI Value Centre, are working on fourteen KWR research projects at, among others, SABIC Innovative Plastics, DSM and Avantium. These projects also created positions at universities for 20 young researchers. The KWR work is conditional to the research being sustainable in nature. “These projects are both relevant to the companies involved and to the universities. They help retain human capital,” says Peter Nossin, coordinator of the KWR programme. “We have been able to respond well since the existing DPI formula is based on cooperation between companies and universities and therefore a relatively large number of knowledge workers can be retained through the KWR. The projects are already up and running, with the project execution residing with DPI Value Centre.”

Focus on mid to long-term research

Nossin views this as a double blessing: “The university knows that it is performing long-term research that is important for the industry and the companies get to know more about the relevant research, existing and potential, being performed by the universities through their knowledge workers. In recent years a growing gap threatened to divide the universities from industry as companies increasingly began to focus on the short term. This project helps to bridge that gap. Companies and universities are getting closer to each other and there is attention for mid to long-term research.”

Innovation in polymers

Louis Jetten, coordinator of the KWR programme, adds: “We expect these projects to find a follow up after the scheme is over. There are so many potential opportunities, for instance in the field of bio-based polymers. This push being given by the Ministry of Economic Affairs maintains the strong position the Netherlands has in polymers. Something we continue to work on.”

IP statistics per area 2009

	PO	PP	FPS	CT	HTE	BIO	LATFE	Corp	Total
Reported inventions	1	7	1	2	5				**16**
Priority filings		2	2	2	4				**10**
Foreign filings		1.5	4	2	5	0.5			**13**
Transition to national phase		1.5	2	0.5	2				**6**
Granted patents			2						**2**

Innovating with DPI Value Centre

More customers, new projects and a considerable response to the current themes; bio-polymers, sustainability, recycling and cradle-to-cradle. The formula for DPI Value Centre's cooperation with partners like NRK, Syntens and NL Agency is bearing fruit. Workshops are being attended by a large number of interested participants and the number of new entrepreneurs is rising. A few examples of activities which took place in 2009 are the coaching of new entrepreneurs, the Polymer Innovation Day, new innovation projects, bio-polymer market days, Dutch Design Week, the C2C polymer knowledge network and entrepreneurship in chemistry.

A flying start

DPI Value Centre supports new entrepreneurs who innovate with polymers. There were more than 25 in 2009, eight of whom followed an intensive coaching programme as part of their start-up phase. Experienced entrepreneurs coach these starters in business support sessions. Support is also tailored to specific aspects such as purchase, sales, product development, legal matters, marketing and financing, and external experts are also called in to assist where necessary. "The DPI Value Centre network is really valuable for start-ups to establish useful contacts, which considerably boost the chances of their success" says Femke Markhorst, New Business project leader.

The first Polymer Innovation Day on 18 November was organised around 20 new entrepreneurs. Approximately 350 visitors, including potential clients, were inspired by innovative ideas. SMEs, large companies, knowledge institutes and government – the grassroots of DPI and DPI Value Centre – all shared their interest in polymer innovation. Arie Brouwer, director of DPI Value Centre: "We can look back on a very successful day. There are many (new) innovative companies in the DPI Value Centre network. We have seen that companies can help and strengthen each other. Worlds have opened up and all kinds of contacts have been made. A day certainly worth repeating." Jacques Joosten, director of DPI, is also enthusiastic about the approach: "Instead of the big companies telling their stories to their smaller counterparts, the new entrepreneurs were able to share their dreams with the established order, including several investors."

OptiMal Forming Solutions, Flexible Moulds for Flexible Businesses

Moulds or dies are almost exclusively used for mass production because they are expensive, complicated to create and take a long time to develop. Now OptiMal Forming Solutions has come up with the FlexiMould concept for processes in which these moulds are too expensive to use. The FlexiMould concept is based on a bed of needles. It offers new opportunities that had not previously been considered viable for forming technology, from customised injection-moulded components or automotive parts and individualised applications for patients like (breast) implants or insoles to unique die-cast rubber or even concrete products.

New innovation projects

In 2009 a total of nine feasibility projects, four SME Innovation projects and three Innovation projects have started. The Polymer subsidy scheme begun in 2008 found its continuance in 2009 with DPI Value Centre offering support to subsidy scheme applications. The scheme is open to companies that want to innovate with polymers. Louis Jetten, Business Development: "In 2009, too, the call by NL Agency to submit project proposals in the context of this scheme had a very good response. Many of the applications, around 60%, had the support of DPI Value Centre."

Bio-polymers

The two market days organised for bio-polymers brought plastics processors and suppliers of bio-plastics and additives together, to meet and discuss innovation opportunities. The processing companies that are now considering bio-plastics were introduced to the latest developments and for those processors that already had contacts, this was an efficient way of re-establishing these contacts and talking about the latest trends as well as the opportunities for innovation. Around 40% of the participants were keen to follow up the session bilaterally or by carrying out tests.

Sustainable design

The theme 'sustainable design and innovation with polymers' was a central theme of Dutch Design Week. Almost 100 people from various backgrounds were

From left to right: Lonneke de Graaff, Louis Jetten, Judith Tesser, Caroline de Ruijter, Martin van Dord, Karin Molenveld, Arie Brouwer, Femke Markhorst, Peter Nossin and Johan Tiesnitsch.

enthusiastic attendees at the ICSE (International Centre for Sustainable Excellence) in Eindhoven. Speakers from the DPI Value Centre network showed fascinating examples of bio-polymers and self-healing materials, among other things. In two brainstorming sessions, in cooperation with Pezy Product Innovation, designers and material scientists generated new ideas. The conclusion drawn by the forum was that creativity and determination were key to producing sustainable innovation.

C2C polymer knowledge network

The new cradle-to-cradle (C2C) polymer knowledge network, founded in 2009, already has more than 80 large and small companies participating in a platform where companies can exchange knowledge and experience as well as encourage new developments in the field of C2C in the polymer sector. This network's target group includes both pioneering and inspirational companies in the polymer sector that use or want to use C2C in their product or process. In June companies from the knowledge network – raw materials suppliers, adopters, users of end products and recyclers – came together for the first time. The main issues discussed included: "What is the added value of C2C against environmental efficiency?" and "Does C2C lead to higher product quality?"

FITS Technology, Foamed In-situ Thermoformable Sandwich Revolution

FITS technology introduces the revolutionary technique of the thermoformable composite sandwich, the sheet material of the future. FITS panels are high strength and very light. They can be used for aircraft interiors, which means a significant reduction in the need for kerosene. The sheet material can also be used in cars and boats. In fact, almost anywhere. The end products are lighter, stronger and cheaper to manufacture, quicker to produce, easier to work with and have better physical characteristics than today's alternatives. FITS has plenty to offer for cradle to cradle design.

Entrepreneurship in chemistry

Working in chemistry is fun. Yet studies reveal that quite soon there will be a shortage of well trained and educated employees in chemistry. Human Capital for Chemistry activities focus on encouraging more people to work in chemistry. A variety of channels and resources are being employed to encourage pupils, teachers, entrepreneurs and employees to choose chemistry. DPI Value Centre focuses on entrepreneurship in chemistry. Judith Tesser, coordinator of the programme: "There are plenty of opportunities for new entrepreneurs in the field of polymers. But starting your own company is not easy. We identify the pitfalls in this sector and try through our activities to boost the success rate of these new entrepreneurs."

Much of our sector's employment capacity has been retained due to the Knowledge Workers Scheme introduced by the Ministry of Economic Affairs and set up in collaboration with DPI.

Polyolefins

Polyolefins (PO) are the only class of macromolecules that 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 organised structures is practically infinite.

Professor Busico receives Ziegler-Natta Lecture Award 2009

Professor Vincenzo Busico, Scientific Chairman of the DPI Polyolefins Technology Area and Professor of Inorganic Chemistry at the University of Naples, Italy, has been awarded the Karl Ziegler-Gulio Natta Lecture Award 2009 by the German Chemical Society.

This Lecture Award was established between the Italian and German Chemical Societies in 1993 to enhance scientific links and build stronger ties between the chemical communities of the two countries. Professor Busico delivered his lecture on 31 August 2009 at a special session of the GDCh Chemistry Forum held in Frankfurt, Germany.

Professor Busico receives this honorary award for his outstanding scientific contributions to the area of catalytic olefin polymerisation, the basis of which was laid by the revolutionary discoveries of Ziegler and Natta (recipients of the 1963 Nobel Prize for Chemistry).

Borealis Student Innovation Award 2009

The recipient of the 2009 Borealis Student Innovation Award for PhD studies is Dr. Amir Jabri who was involved in a DPI project in the Polyolefins Technology Area during his studies at the University of Ottawa, Canada.

This Innovation Award to Amir Jabri was given for his PhD thesis, sponsored by the Dutch Polymer Institute, which concerned an experimental study of how the transition-metal catalysts used in polyolefin production function on a molecular level. Dr. Amir Jabri, a US citizen, graduated from the University of Ottawa in 2009 and currently works in the area of computational chemistry. He published his findings in the renowned scientific journals, 'Angewandte Chemie' and 'Journal of the American Chemical Society'.

Polyolefins
The art of connecting in Polyolefins

DPI provides academic and industrial researchers with a platform where they can help each other, for example by carrying out joint DPI research projects, finding the missing link in the chain of knowledge or informing each other about new technological developments. There are many companies and academic groups participating in DPI's Polyolefins cluster, thus communication and networking are of paramount importance.

"At Teijin open innovation is actively promoted. We participate in DPI not only because we are interested in certain Technology Areas but also to become inspired by the latest technology developments. Polyolefin chemistry and processing still offer enormous potential for application in new areas, even though the polyolefins industry is more than seventy years old. New technologies and scientific progress in this field allow us to develop new materials with special combinations of properties for application in cars, aircraft, electronics, healthcare products and many more," says Ton de Weijer of Teijin Aramid in the Netherlands.

"DPI offers a large platform where people from different universities and companies can discuss these developments, for example whether the mechanisms have been identified and the scientific ideas are feasible. At Teijin we are not always capable of making a quick decision on adopting a new development or not because information and knowledge is often incomplete. DPI offers a platform where experts from different backgrounds can give their opinion. This helps us to take sound decisions," explains De Weijer.

Access to quality fundamental research

"Through DPI we have access to quality fundamental research," says John Severn of Borealis. "Developing new products is like building a house, very much dependent on the quality of the foundation. Our scientists are therefore extremely interested in new 'tools and technologies' for building and supporting the foundation of our innovations. For this reason we are involved with DPI, which acts on a more pre-competitive fundamental basis. If you look more generally to Polyolefins you will notice that the fundamental and technological research has led to applications you could not have dreamed about ten years ago. Polyolefins are now even challenging some of the engineering plastics."

What he also notes is that through DPI companies and universities are able to build-up joint infrastructures for fundamental research with the desired critical mass in specific areas. This has much to do with the so-called chain-of-knowledge approach. One of the projects in DPI's Polyolefins Area for example is about developing new block polymers. A research group at Eindhoven University of Technology, led by Rob Duchateau, is working on making new catalysts that can fully control the

Discussion partners

Ton de Weijer is Group Head of New Product Technology at the research institute of Teijin Aramid in Arnhem in the Netherlands. In 1995 he joined AkzoNobel and worked in the area of polyaramid fibres. In 2000, after the Japanese company Teijin had taken over the aramid activities of AkzoNobel, he worked a few years in Japan at Teijin's corporate research laboratories. He is the industrial contact for Teijin for DPI's Polyolefins cluster and also involved with a few other clusters.

Han Goossens is associate professor in the group of Polymer Technology at the Eindhoven University of Technology. He joined the group in 1997 and became associate professor in 2007. He and his research group study the relationship between the morphology of polymers and their physical properties with the emphasis on mechanical and rheological properties.

John Severn worked as a research associate for DPI at Eindhoven University of Technology between 2000 and 2004. Since 2005 he has been working for Borealis where he has become group expert for High-Throughput Experimentation and Catalyst Research at the company's innovation centre in Porvooi, Finland. Because of his move from DPI to Borealis he considers himself more or less as 'a product of the value chain'.

John Severn, Han Goossens and Ton de Weijer

“DPI offers a platform where experts from different backgrounds can give their opinion. This helps us to take sound decisions.”

Ton de Weijer

polymerisation process so that polyolefin copolymers can be made with a pre-defined structure. Another research group studies the relationship between the polymer structures and their physical properties. This is the group of Han Goossens, associate professor of Polymer Technology. A third group evaluates the mechanical properties of the newly prepared copolymers. And in the near future a peer group will look at the engineering aspects of producing these new copolymers.

Facilities of an industrial partner

Han Goossens welcomes the cooperation between academic research groups and researchers from different companies: “Our group is working out new concepts on basis of experiments. For that purpose we need small quantities of new catalytic material. But if our colleagues can deliver us only one gram of this material we can’t do anything with it. If an industrial partner has the facilities to produce such a catalyst and polymer in sufficient quantities, this can really help us to move forward.”

Faster development

For the same reason DPI stimulates close cooperation between research groups. Formerly, researchers worked for DPI in separate projects, for instance on catalysis and process engineering. Nowadays, researchers from different disciplines are working together in one large project. This results in a faster and more complete development from fundamental idea to industrial process or product. Ton de Weijer: “Teijin is following the same approach. Although we still have different research departments for polymerisation, spinning and analysis, we work in multidisciplinary teams on the development of new products.”

“At Borealis we follow the same kind of approach. We work with competence pools, which are assigned to deliver a new product or product family. A project manager sets up a project by arranging the resources from the competence pools of several locations in such a way that a new team is formed,” says Severn.

Goossens: “In the academic world the chain-of-knowledge approach is not advocated by everyone. Some groups working in a smaller research field like to concentrate on their main expertise and leave it at that.” According to De Weijer, such a group should be allowed to do so. “As long as you can ensure that there’s a link with other research groups or industrial partners, progress will be made and at some point the group will be able

“I always tell my PhD students that they should take the opportunity to talk to others.”

Han Goossens

to transfer its knowledge to others in the value chain." Goossens mentions some additional advantages of working for DPI. "It is easier for us to find out where we can plug-in our ideas to interest parties for funding as well as find academic partners who are willing to join us in calls for national or European research projects."

Talking to others

Severn, De Weijer and Goossens are well aware that DPI is not only about projects but more particularly about people and communication between people. "I always tell my PhD students that they should not only give a presentation about their project at DPI meetings but also take the opportunity to talk to others, be it academics or industrial contact persons. This can be very fruitful to their own work. Some of them, however, have difficulties reaching the right company and the right person," says Goossens. Severn: "PhD students sometimes complain that the industrial partners don't talk to them. But you can't blame one person for not contacting you if you have not made an effort and picked-up the phone yourself."

De Weijer: "PhD students should also realise that they belong not only to their research group at the university but also to the DPI community. DPI is more than a source of subsidy. It is also a platform where universities and companies meet each other, exchange knowledge and give direction to pre-competitive research. This also helps them to find a job. Many industrial contacts who are now actively involved with DPI projects are former PhDs that worked for DPI."

Learning how to make contacts

"Exposure to other disciplines and business aspects is very important for innovation, " Severn adds. "When I worked as a chemist in synthetic organic metals for DPI, I made interesting molecules from which I hoped that these might be useful as a catalyst. Through DPI's network, however, I got to know the principles of polymer reactor engineering and realised that it did not matter what I did with these fancy ligand structures: if the polymerisation was not carried out properly, it would make no sense. I was completely unaware of that before I came to DPI. Thanks to DPI I learned to speak easily with people from other disciplines, which enabled me to break down barriers, to understand more and to learn more. In fact, DPI teaches you how to make contacts and how to make connections. And this is a prerequisite for innovation."

> "Developing new products is like building a house, very much dependent on the quality of the foundation."
>
> **John Severn**

Objectives

Polyolefin-based materials can be customised for a wide range of applications: from ultra-rigid thermoplastics to high-performance elastomers. This vast spectrum of performance is achieved by a variety of polyolefin molecular structures, whose common features are full atom economy in their synthesis, low cost, excellent performance, long lifecycle and ease of recycling.

The research programme of the Polyolefins Technology Area addresses the breadth and depth of the complete knowledge chain, aiming for 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 characterised by innovation whereby gradual and continual technology renewal enables new applications and reduces the manufacture and user eco-footprint.

Subprogrammes

Catalysis
Investigation, screening and development of novel homogeneous and heterogeneous catalyst systems, new approaches for the immobilisation and activation of heterogeneous and single-site catalysts for polyolefin (co)polymerisation.

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

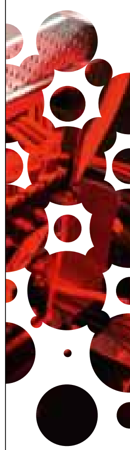
Polymer reactor engineering
Studies on various reactor and technology unit operations to produce a quantitative description and acquire a thorough understanding of the crucial aspects of polymerisation processes.

New methods and exploratory research
New characterisation and polymerisation methods, high-throughput screening and experimentation, embryonic research and concept development.

Facts and figures

Partners from industry
- Borealis
- Braskem
- Dow Benelux
- DSM
- LyondellBasell
- Sabic Europe
- Shell
- Symyx
- Teijin Aramid
- Ticona

Partners from the research world
- Deutsches Kunststoff Institut
- Eindhoven University of Technology
- ESCPE
- Japan Advanced Institute of Science and Technology
- Loughborough University
- Martin-Luther University of Halle-Wittenberg
- Queens University
- Radboud University Nijmegen
- University of Amsterdam
- University of Groningen
- University of Manitoba
- University of Naples Federico II
- University of Ottawa
- University of Perugia
- University of Salerno
- University of Twente



Budget and organisation
Overall expenditure in 2009 was € 2.79 million (budget: € 2.91 million). Expenditure on equipment was limited to € 141k; the total number of FTEs allocated at the end of 2009 was 25 (42 researchers).
Professor Dr. Vincenzo Busico is Scientific Chairman of the Technology Area and Dr. Jan Stamhuis is Programme Area Coordinator.

Publications and inventions
A total of 22 reviewed papers and four theses were published in the Technology Area. One invention was reported.

Detailed information on page 74.

Annual Meeting 2009

DPI held its annual meeting at the Eindhoven University of Technology campus in the Netherlands on 17 and 18 November 2009.

On the day before the annual meeting, a special session was held for young scientists who had started their PhD project in the past academic year. It included a special programme with lectures to introduce them to the ins and outs of DPI, a session on thinking out of the box and a networking dinner at a former farm in Eindhoven.

The first day, 17 November, was open to DPI members only and 220 of them attended the meeting. The theme was Polymers and the Biosphere. The lifecycle of polymers does not end when a product is discarded: it ends up somewhere in the biosphere. Therefore DPI wants to consider the challenge of how material cycles in polymers can be closed. Polymers and pollutants, natural and biodegradable polymers and bio-based polymer chemistry were addressed by several speakers throughout the day.

A total of 41 Certificates of Inventions were awarded to the inventors of 13 patent applications filed within the academic year. Also the Golden Thesis Award was granted during the conference dinner at the DAF-museum.

The second day, 18 November, was called Polymer Innovation Day and was organised by DPI and DPI Value Centre together. The 220 participants of the day before were joined by 150 non-DPI members. The focus was on Value for money – on valorisation through interaction between DPI's industrial and academic partners, and DPI Value Centre's customers: small and medium-sized enterprises. Fifteen start-up companies related to DPI Value Centre presented their innovations.


Annual Meeting








13




Cocktails

Performance Polymers

Performance Polymers (PP) create new opportunities to respond to the new sustainability challenges posed to the industrial sectors of construction, transport, appliances and electronics. These polymers have great potential to contribute to reducing energy use, environmental impact and the effects of climate change through component consolidation, weight reduction, lifetime extension, recyclability and utilisation of renewable feedstocks.

Professor Noordermeer wins George S. Whitby Award 2010

On 14 October 2009 it was announced that Jacques Noordermeer, Scientific Chairman of the DPI Technology Area Performance Polymers, would receive the George S. Whitby Award 2010 from the American Chemical Society Rubber Division for 'Distinguished Teaching and Research'.

"This award honours outstanding international teachers of chemistry and polymer science and recognises innovative research as well as outstanding contributions to the integration of chemistry and polymer science into the educational system".

Jacques Noordermeer received the award at the spring meeting of the ACS Rubber Division on 27 April 2010 in the US city of Akron, Ohio.

Seven reported inventions

In 2009 the Technology Area had seven reported inventions, the highest number of reported inventions of all Technology Areas. The inventions are the results of the following projects:

#580 Modification/Crosslinking of saturated elastomers using functionalised azides,
#583 Dispersion of fillers in engineering polymers for thermal electrical and rheological properties,
#648 Graphene-based nano-composites- A study on the potential of graphene nanosheets as an alternative low-cost filler for multi-functional polymeric materials,
#653 Biodegradable Thermoplastic Polyurethanes from Renewable Resources and,
#656 Green Rigid blocks for Engineering plastics with enhanced performance.

Performance Polymers
About well-processed knowledge and technology readiness

In many applications polymers are the materials of choice because of their mechanical properties and the possibility to adapt them to specific needs. Friction and wear are properties that play an important role, for instance, in making energy-efficient ball bearings.

“Basically what we are doing in this project,” says Antoine Chateauminois, kicking off the discussion, “is to investigate how the mechanical properties of thin polymer films are modified when you shear them or when you apply frictional forces. Usually, when you want to investigate mechanical properties of coatings, you use normal indentation techniques but for thin polymer films on rigid surfaces this approach presents several limitations. We have developed an alternative contact method in which we apply a cyclic shear to the film with a macroscopic probe. We then measure the lateral contact resistance that gives us the shear modulus of the film in the linear and non-linear regimes. We want to relate these mechanical properties to the microscopic changes at the film interface. For that we cooperate with Alexey Lyulin of the Theoretical and Polymer Physics group of Eindhoven University of Technology, who is modelling the changes at the interface at a molecular level.”

Distinguishing feature

The idea is, of course, that if you know these mechanisms, you can influence them and make materials with better wear and friction properties. That is the reason for DSM’s interest. Marcel Meuwissen explains DSM’s involvement. “We want to supply our customers with a material tailored to their application. We want to be able to say: in your application you need these kinds of properties and you can get them in this way or that. This helps us to distinguish ourselves. In fact, we use the knowledge generated in this project to improve our polymers.”

These polymers will eventually be used in applications, such as the bearings made by SKF, where wear and friction is important. The bearings are mostly made of metal, but polymers are used in the seals and cages. Babak Hosseinkhani explains the involvement of SKF in the project: “Sixty per cent of the friction in a bearing come from the seals and the cages, not from the contact between the ball and the raceway. Low-friction polymers enable us to make energy-efficient bearings. We do not

> “You must be willing to pursue a new idea when it comes up, listening to what industrial people need.”
>
> **Antoine Chateauminois**

Discussion partners

Antoine Chateauminois is Research Fellow at the Centre National de la Recherche Scientifique (CRNS) in France. He has worked at the Ecole Centrale de Lyon, Imperial College in London and at the Ecole Supérieure de Physique et de Chimie Industrielles (ESPCI). His research activities over the past fifteen years encompass the field of polymer tribology, including friction, wear and adhesive properties. In the project discussed he is responsible for the experimental work on the mechanical properties of thin polymer films.

Marcel Meuwissen is a mechanical engineer by training. After his PhD at Eindhoven University of Technology, the Netherlands, he worked for nine years at TNO, the Dutch organisation for applied science, and in 2007 joined DSM. His field of interest is the mechanical properties of polymers and he is involved in both experimental and numerical modelling work.

Babak Hosseinkhani studied physics at the University of Leiden, the Netherlands. After his PhD at the same university he worked for two years as a postdoc at Delft University of Technology, the Netherlands. Two years ago he started working at the research department of SKF, where materials modelling is his main interest. SKF will use the knowledge generated in the project discussed in bearings with low friction losses.

Babak Hosseinkhani, Antoine Chateauminois and Marcel Meuwissen

have the resources to investigate all possible materials ourselves. Besides, our knowledge is not infinite and since we do not want to reinvent the wheel, it is important to keep ourselves informed about what is going on in the field. For us, DPI projects are the best way to do that."

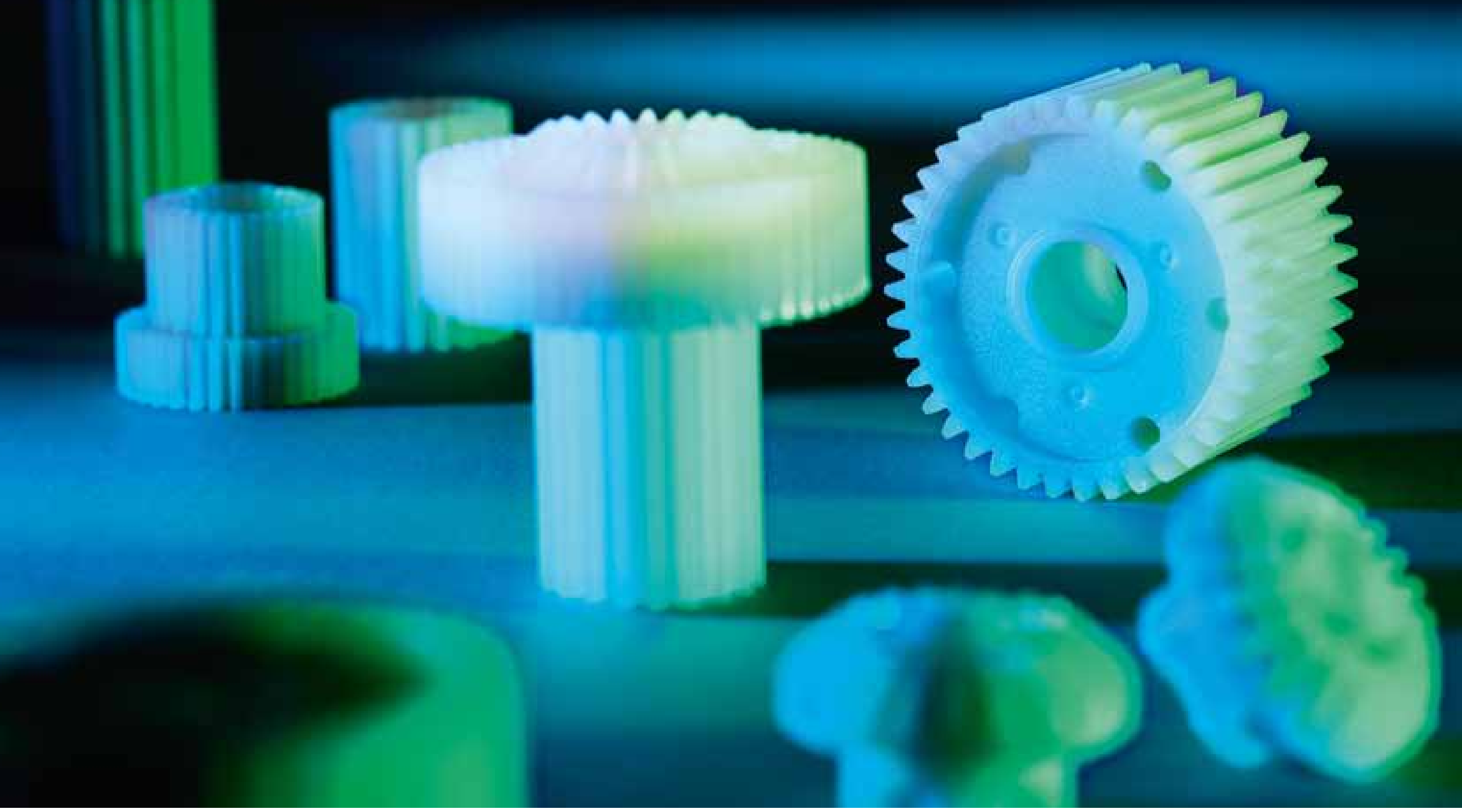
Academic freedom

In the early days of the DPI a project was, in fact, the work of one individual but now all stakeholders in the knowledge chain are taking part in it. The idea is that in doing so there is more interaction between the partners during the project itself and not only at cluster meetings. For PhD students this has the advantage of enabling them to see that the scope is wider than their particular subject and thesis, and that it takes more to get the results to a working application. This implies that in this project two companies, a material supplier, and a polymer user are looking over the shoulders of the academic researchers. When asked, Chateauminois responds that he does not feel the pressure that might be involved. Chateauminois: "You still have a lot of academic freedom to define what you will do, also when industry is involved in a project. But you must have an open mind. You must be willing to pursue a new idea when it comes up, listening to what industrial people need. I find it very stimulating to work in such a close interaction with industry. When people ask questions, you get new ideas." Meuwissen adds: "The things we need at short notice we will do ourselves. DPI projects have a longer time horizon and do not have to consider the most appropriate material in the end. We learn from model materials how things work, get new ideas and use them later in other materials to our own advantage." DPI projects are not about solving a problem for a company, they are about generating knowledge that is of use to many companies.

Matching

Although Hosseinkhani agrees, he would still like to see DPI's responsibility to go a bit further. "DPI should not say 'Company, here is a pool of knowledge, take from it what you can use'. For a company it is often difficult to choose from the raw knowledge. If the knowledge is taken one step further towards what I would call 'technology readiness' this 'processed knowledge' will be more attractive and easier to absorb for a company." He explains what he means by that, giving an example. "If I want to have superb sound, I buy the best hifi system and excellent loudspeakers, but if the impedance levels don't match, the sound quality will be very poor. Matching the impedances could be a very useful extension for DPI projects." It will not be easy to incorporate that in the present DPI organisation. Jan Stamhuis, Programme Area Coordinator for Performance Polymers, thinks that such a sequel to present projects would require a follow-up project perhaps carried out under different conditions, additional to the current DPI strategy. Different companies may have different interests and a way to accommodate these must be found. Also opportunities and limitations

> "We want to supply our customers with a material tailored to their application to distinguish ourselves."
>
> **Marcel Meuwissen**



within the government subsidy schemes must be taken into account. A first proposal has been made for a company that takes a second participation in a certain Technology Area can decide the technology direction within a specific project. However, the results will still be available for all other partners in this Technology Area. Other suggestions, including separate projects with consortia along the value chain, are currently being reviewed in the DPI strategy renewal.

It is not any dissatisfaction with DPI's role and activities that prompts Hosseinkhani to come up with yet another suggestion for improvement. Indeed, he is very positive about DPI but simply reacts enthusiastically when asked for possible improvements. "DPI is quite strong and well established, not only in the Netherlands but also in Europe. It could be a good focal point for European projects as well. Submitting an EU proposal means a lot of tedious paperwork for a company. It is not always easy to decide whether that will be worth your while, also because you do not know beforehand whether the consortium you will end up with is your first choice. What tends to happen is that you are invited to join an existing consortium in a project. The proposal is often not exactly what you want, but you say, OK, and see afterwards what you can use. If DPI, with its good knowledge of the field, could take the lead, form a good consortium and do all the paperwork, this would be a more efficient way for a company to proceed. The chance that the results really will be used for innovative products will increase."
Yet another way to improve DPI's approach would be to find the overlap between DPI's value chain and that of companies or even find some form of mutual adaptation to ensure that the results of DPI projects will actually be used by the companies. Hosseinkhani elaborates. "If, at the start of a project, you have an agreement between companies about the value chain, you have more or less decided on where you want to be at the end of project. You can also agree on what happens next and whose responsibility it will be. This prevents a situation in which a company can say, 'Thank you very much for this result and we will see what we can do with it', and then do nothing with it." DPI should play a role in making the final results of a project more clear to the rest of the world by demonstrating it in a product prototype.

"If the knowledge is taken one step further, it will be more attractive and easier for a company to absorb."

Babak Hosseinkhani

Objectives

The performance requirements of complex parts and assembly necessitate close technological cooperation between polymer supplier, converter and end-user. In turn, this calls for a thorough understanding of polymerisation, 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 include investigations related to fundamental issues in the value chain using a 'chain of knowledge' approach in terms of energy saving, durability, ultimate performance and sustainability.

Subprogrammes

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

Processing for properties
Understanding 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 vulcanisation studies of elastomer blends.

Advanced reinforced thermoplastics and synthetic fibres
Studies on the interface effects in fibre-reinforced composite systems, the 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 realising fit-for-use design over the entire lifecycle.

Facts and figures

Partners from industry

- BASF
- Bayer
- Dow Benelux
- DSM
- Evonik
- LyondellBasell
- Sabic Innovative Plastics
- SKF
- Teijin Aramid

Partners from the research world

- Delft University of Technology
- Deutsches Kunststoff Institut
- Eindhoven University of Technology
- ESPCI
- Leibniz-Institut für Polymerforschung Dresden
- National Technical University of Athens
- Queen Mary & Westfield College, University of London
- Stellenbosch University
- University of Amsterdam
- University of Twente
- Wageningen University

Budget and organisation

Expenditure in 2009 totalled € 3.30 million (budget: € 2.67 million).
A total of € 72k was spent on equipment; the total number of FTEs allocated at year-end 2009 was 33.5 (46 researchers).
Richard van den Hof, MSc, and Professor Dr. Jacques Noordermeer acted as Scientific Chairmen of the Performance Polymers Technology Area and Dr. Jan Stamhuis as Programme Area Coordinator.

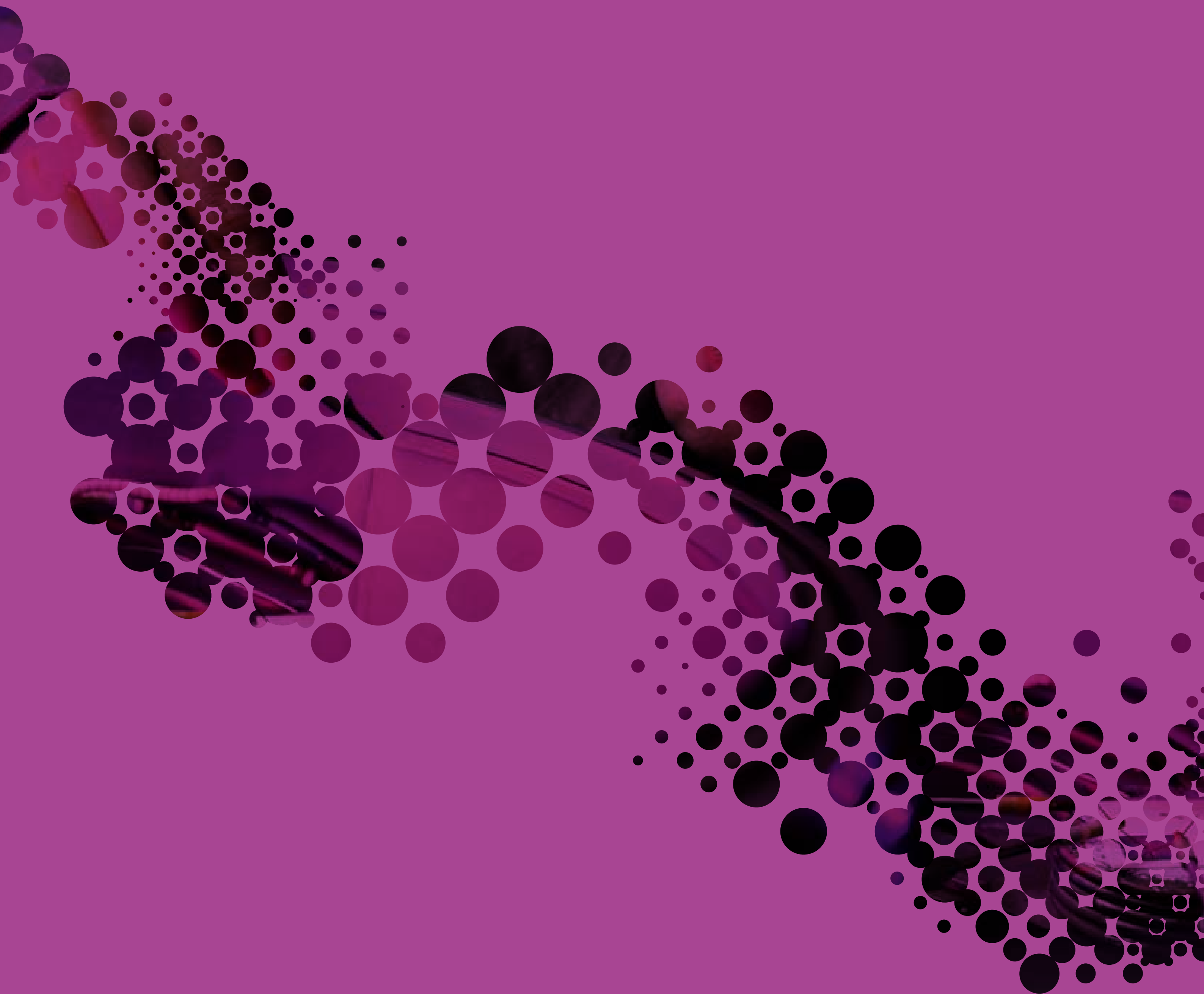
Publications and inventions

A total of 29 reviewed papers and six theses were published in the Technology Area. Seven inventions were reported and two patent applications were filed.

Detailed information on page 75.

Functional Polymer Systems

The Functional Polymer Systems (FPS) Technology Area performs research on the 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.



Looking deeply into polymer solar cells

Researchers from the Eindhoven University of Technology and the University of Ulm in Germany have made the first high-resolution 3D images of the inside of a polymer solar cell, which provides important new insights in the nanoscale structure of polymer solar cells and its effect on the performance.
The findings were published online in ‘Nature Materials’ on Sunday 13 September 2009. The investigations shed new light on the operational principles of polymer solar cells.

Hybrid polymer solar cells
In these hybrid solar cells, a mixture of two different materials, a polymer and a metal oxide, are used to create charges at their interface when the mixture is illuminated by the sun. The degree of mixing of the two materials is essential for the efficiency. Meticulous mixing enhances the area of the interface where charges are formed but, at the same time, hinders charge transport because it leads to long and winding roads for the charges to travel. Larger domains do exactly the opposite. The vastly different chemical nature of polymers and metal oxides generally makes it very difficult to control the nanoscale structure. The Eindhoven researchers have been able to largely circumvent this problem by using a precursor compound that mixes with the polymer and is only converted into the metal oxide after it is incorporated in the photoactive layer. This allows better mixing and enables up to 50% of the absorbed photons to be extracted as charges in an external circuit.

Future
Even though these hybrid polymer solar cells are among the most efficient reported to date for this class, their power conversion efficiency of 2% in sunlight must be enhanced to make them really useful. This can be achieved through improved control of the morphology of the photoactive blend, for example by creating polymers that can interact with the metal oxide and by developing polymers or molecules that absorb a larger part of the solar spectrum. This will enable the intrinsic advantages of hybrid polymer solar cells to be fully exploited in terms of low cost and thermal stability of the nanoscale structure.

Publication
The publication “The effect of three-dimensional morphology on the efficiency of hybrid polymer solar cells” by Stefan Oosterhout et al. can be found at Nature Materials 8, 818-824.

Functional Polymer Systems
New materials for a bright and colourful future

The colour and brightness of the light emitted by organic light-emitting diodes (OLEDs) depend on the interaction between metal-organic complexes in the active material. There is an ongoing search for new materials with improved properties. Iridium is a metal conventionally used in OLEDs and now platinum is showing promising results.

Luisa de Cola starts the discussion by explaining the project. “It is perhaps a more visionary project than most projects within the scope of OLEDs. Our idea is to use platinum complexes in OLEDs because they are more highly efficient triplet emitters than the more conventionally used iridium. Moreover, interaction between the platinum complexes can produce strong colouring, something we can take advantage of to regulate the colour of the emitted light. Platinum complexes tend to aggregate and then quench the emission, so we also have to consider their combination with solvents and solid matrices when we try to synthesise and spectroscopically characterise these materials.” Peter Bäuerle’s group is doing synthesis and characterisation in solutions while De Cola’s group is more involved in the solid-state properties and the photophysical characterisation. Bäuerle: “This DPI project is a perfect example of good collaboration. PhD students are exchanged frequently between Ulm, Münster and Cologne, where Klaus Meerholz’s group tests the materials in OLED devices. Exchanges last several weeks and the students can learn about other’s parts of the project.” That aspect, among others, is also what attracts Edward Plummer. “I enjoy the work, get inspiration from it and let the results surprise me. And meanwhile I get some experience with companies, which will help me to make a more conscious choice between a career in industry or at a university.”

> “You profit more from projects with a more intense cooperation model.”
>
> **Reinder Coehoorn**

Discussion partners

Luisa de Cola has been a full-time professor in the department of chemistry and physics at the Westfälische Wilhelms-Universität in Münster (Germany) since 2005. She trained as a materials chemist at the University of Messina in Italy. She worked at the University of Amsterdam from 1998 until 2004. Her connection with the DPI dates back to that time. In Münster she leads the Nanophotonics Group.

Edward Plummer is working as a postdoc with Luisa de Cola in a DPI project at the Westfälische Wilhelms-Universität in Münster (Germany). He is a chemist with experience in synthetic procedures and spectroscopy. In the project discussed below, his job is to synthesise new materials and to study them spectroscopically.

Elmar Keßenich is a chemist by training and started working in research at BASF in the field of photopolymer printing plates. Since 2007 he has been the business development manager for the organic light-emitting diodes programme and, as such, is involved in DPI’s OLED project. He is now focusing on small molecules for OLED applications, in particular on processing them from the vapour phase as well as from solution.

Reinder Coehoorn has been a Research Fellow at Philips Research in Eindhoven since 1984. He is a physicist by training and has been working on device modelling of small-molecule OLEDs for lighting applications since 2002. Before then he worked in the field of thin magnetic films. He is also part-time professor at the Eindhoven University of Technology in the department of molecular materials and nano systems.

Peter Bäuerle is director of the Institute of Organic Chemistry II and Advanced Materials at the University of Ulm, Germany. His current research interests include organic materials, in particular organic semiconductors and conductors. The project *Tuning the (electro)luminescent properties of a polymeric film by controlling inter- and /or intramolecular interactions* is being carried out partly in his group and partly in Luisa de Cola’s group.

Edward Plummer, Reinder Coehoorn and Luisa de Cola

"I enjoy the work, get inspiration from it and let the results surprise me."

Edward Plummer

New OLED materials with higher efficiencies whose colour can be regulated will most certainly interest materials suppliers, as Elmar Keßenich of BASF admits. "The biggest challenge in the OLED field is still the blue emission. If this new material helps to solve that issue and the stability is sufficiently improved, we will certainly test it in our OLED devices. What I have seen so far of this platinum project is very promising. The lifetime is not yet good enough, but that is only natural at the beginning of a project." Not only researchers and materials suppliers but also the actual device makers that will use the new materials are participating in the project and are eager to absorb the results. Reinder Coehoorn of Philips Research comments: "We profit a lot from all the information and the results that are being discussed and brought forward at the cluster meetings. For more then ten years, this long-standing pattern of collaboration has already brought us interesting new results. In order to assess how useful a new material will be, we want to know about its behaviour in a device and we are willing to help the researchers to go in the right direction."

Proactive

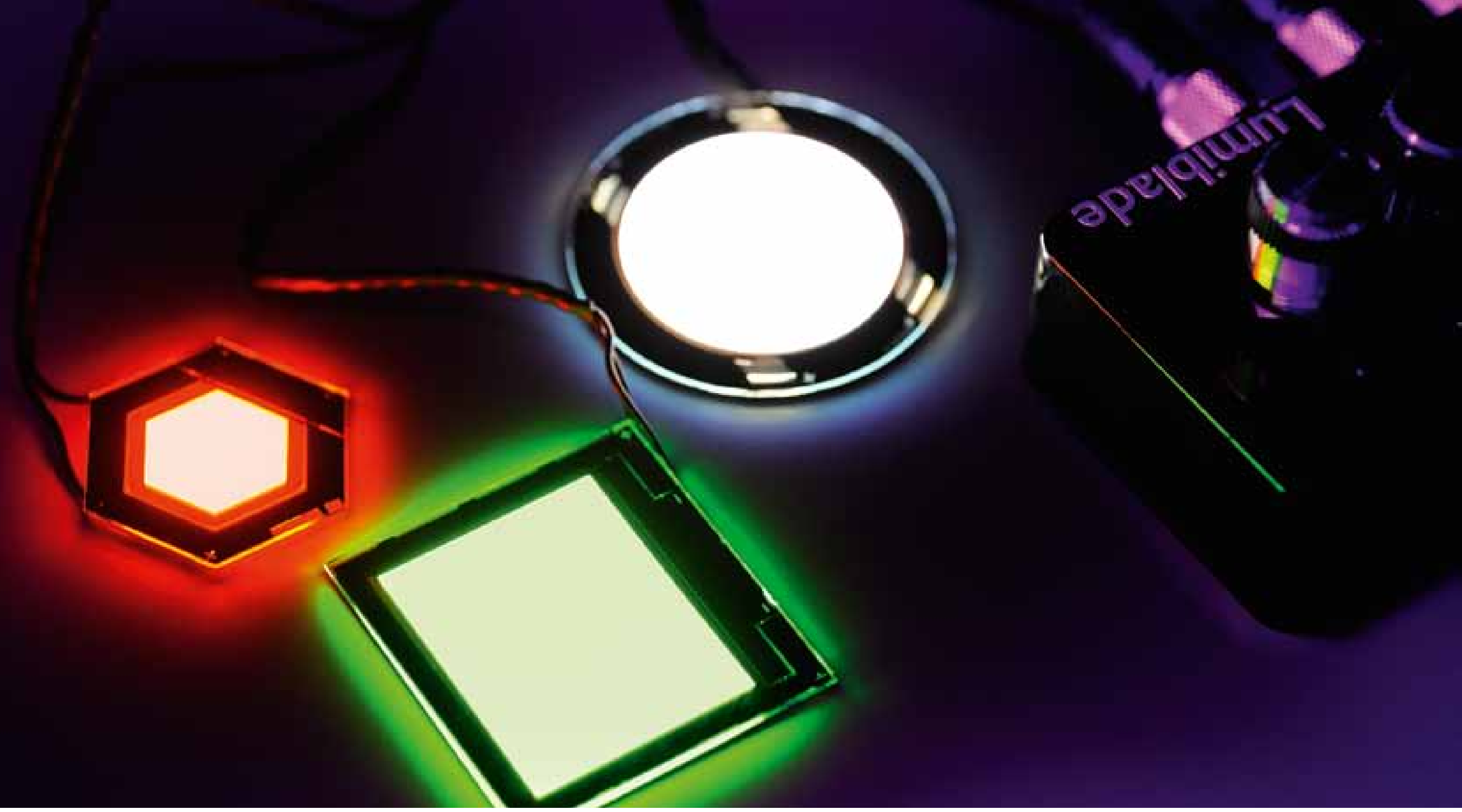
The whole value chain is represented in the project and this is appreciated by all project partners. Access to experts in the field is the much heralded advantage of cooperation with DPI. There is, however, also a point of criticism from Bäuerle. "Because the industrial partners do not clearly express their interests during the review meetings, it is difficult to estimate their appreciation of the academic results," he says. De Cola makes a suggestion for a future approach to working in DPI projects that could lead to a more proactive role from the industrial partners. "Why can't we, DPI and academia, organise interaction with possible industrial partners before we submit a proposal. In that way we will generate more feedback and more commitment from industry and increase the chance that our information is absorbed in and by industry. When working with a company in a bilateral project there is more interaction and we both benefit a lot from that. In a multi-partner programme it is more difficult to realise." Coehoorn adds from his experience that "you profit more from projects with a more intense cooperation model than just waiting for the results presented at a biannual review meeting. For Philips, because we know the field of OLEDs very well, partly due to the DPI network, it is already common practice to team up with universities before a proposal is submitted."

Pre-competitive

DPI projects are always a balancing act between the company's interests and satisfying scientific curiosity.

"PhD students are exchanged frequently between universities to learn about other parts of the project."

Peter Bäuerle



“Why can’t we team up with industry before we submit a proposal to generate more feedback and more commitment?”

Luisa de Cola

Of course, universities should put pure academic research first, and that is what the industrial partners think. In cooperation with companies, it is best to remain in the pre-competitive stage and consider carefully the subjects to work on. Keßenich: “It is difficult for us to give guidance to universities on how to study specific materials. We should not do that. We would only consider materials that are already advanced so nothing really new would emerge. What we can give is guidance regarding the specifications for commercialisation. The academic partners should have the freedom to choose from their scientific perspective the most promising materials that might be able to fulfil future criteria. But besides the selection of specific materials, we definitely need mechanistic structure studies on the molecular degradation of metal complexes in general.”

Coehoorn agrees: “You do not have to use the most innovative materials to investigate degradation mechanisms in working OLEDs, so there you can really remain in the pre-competitive stage. Materials suppliers can help to make these materials – and all the knowledge they have about them – available in larger quantities than universities can.” More insight into molecular degradation and interface interactions will, of course, help researchers in their molecular design efforts with OLED applications in mind. De Cola thinks there is enough scope for universities to do interesting research into new phenomena with useful consequences for applications: “The control of the morphology or the control of the distance between the emitters are things that have never been looked at. If we know more about that, it could also be a means to improve stability. Nobody really knows what happens in a device after manufacture.”

Confident that all issues will be solved, the industrial partners see a bright future for OLEDs. BASF sees solution processing of OLEDs with the same efficiencies and stabilities as wafer-processed OLEDs as the next challenge. Philips has already had a product in the market since 2008 and there are more to come. “If we solve the remaining questions with respect to efficiency, lifetime and colour stability, and in particular the cost issue, more general lighting applications for homes and offices will become reality,” says Coehoorn. “It is not solely a materials issue, it is everything together.” There still are enough fundamental and technological issues to be solved and there will also be other applications. Displays, medical applications, flexible substrates … more than enough to ensure that the field will be interesting to work in for the foreseeable future.

“What I have seen so far of this platinum project is very promising.”

Elmar Keßenich

Objectives

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.

Subprogrammes

Polymer lighting and field-effect transistors
The aim of this theme is to gain a thorough fundamental understanding of the behaviour of materials under operational conditions in order to gain breakthroughs in device performance. Additionally, new materials are explored in the search for significant improvement of efficacy (lm/W) in polymer lighting applications. The research focuses on understanding materials and device performance, photo-physics and charge transport of white-emitting materials, mobility improvements and stability under ambient conditions (air, water).
This theme strongly supports interdisciplinary research projects bringing together materials scientists, photo-physicists and particularly device physicists.

Polymers for information and communication technology
The objective of the sub-area is the structuring of polymers on nano- and micro-scale via 'top-down' approaches combined with 'bottom-up' techniques based on self-assembly or supramolecular chemistry, for example, so that new or strongly enhanced properties for optical, electrical, biomedical and sensor applications can 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 third generation photovoltaic (PV) technology, namely polymer bulk heterojunction PV. Besides many other PV technologies, polymer PV is very promising for large-area cost-effective PV for sustainable energy production in the long term. The research focuses on novel low band-gap materials, hybrid (inorganic-organic) blends, stable materials under ambient conditions, 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 commercially ready polymer PV devices, initially for powering small consumer applications or niche 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 displacement upon an external electrical, magnetic, optical and/or chemical trigger. Further focal areas are new materials and devices for selective sensoring gases, time-temperature, bio fluids, etc. along with the actuating principles of rubber-like materials and corresponding devices.

Facts and figures

Partners from industry
- BASF
- DSM
- ECN
- Evonik
- Industrial Technology Research Institute Taiwan
- Merck
- Océ Technologies
- Philips
- Shell
- TNO

Partners from the research world
- Delft University of Technology
- ECN
- Eindhoven University of Technology
- Imperial College London
- Nanoforce Technology
- Queen Mary & Westfield College, University of London
- University of Bayreuth
- University of Cologne
- University of Duisburg-Essen
- University of Groningen
- University of Münster
- University of Ulm
- University of Wuppertal
- Wageningen University

Budget and Organisation
Total expenditure in 2009 amounted to € 3.23 million (budget € 2.86 million). The total number of FTEs allocated at the end of 2009 was 32.4 (55 researchers). Total expenditure on equipment was to € 49k. Professor Frans de Schryver 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 seven theses and 37 scientific publications. One invention was reported and two patents were filed.

Detailed information on page 77.

Golden Thesis Award
Casper van Oosten

Fascination for moving polymers

Polymers are often the material of choice in applications because of their static mechanical properties, but mechanical engineer Casper van Oosten was fascinated by moving polymers and inspired by self-assembly processes in nature, both aspects were addressed in his PhD work.

“After my graduation as a mechanical engineer at the Delft University of Technology I worked for one year as an innovation consultant, but that was not concrete enough to my liking. As a mechanical engineer I am interested not only in objects that move but also in materials science. I found the combination of the two in a PhD project of DPI: materials that move repeatedly and reproducibly after exposure to a stimulus, for instance light. I was lucky that Dick Broer and Kees Bastiaansen in the Polymer Technology department at Eindhoven University of Technology were open-minded enough to offer me, without any background in chemistry, the chance to work in this field,” says Casper van Oosten about the project that, to his surprise, resulted in the Golden Thesis Award 2009. The jury judged his work a complete whole in which all aspects of DPI projects were present. Van Oosten is extremely proud of his award and says it will certainly help him in his further career.

Since he defended his thesis entitled “Responsive Crystal Networks” on 12 March 2009, Van Oosten has been working full-time in the company he co-founded during his PhD project and where he had already worked one day a week in his last year: Peer+. Its product is glass with an organic coating that can switch from a bright state to a privacy or a dark state by applying an electric voltage. The window uses the unwanted light to generate electricity. “I supervised a student who was investigating this organic coating. At the start of the project he had the idea to found a company but on second thoughts he did not feel sufficiently entrepreneurial to do it. I liked the idea and have always been interested in becoming an entrepreneur myself, so I took over from him,” explains Van Oosten. Peer+ is just one of the companies where DPI Value Centre helps out in the start-up phase.

The other two nominees, Edsger Smits and Joris Sprakel, were also very strong candidates, and it was in fact a close finish. They both wrote outstanding theses. Edsger Smit’s thesis is entitled “Ambipolar and self-assembled organic electronics” and Joris Sprakel’s thesis is entitled “Physics of Associative Polymers; Bridging Time and Length Scales”.

Pieter Jan Lemstra Invention Award **Ulrich Schubert**

Significantly contributed to the development of polymer technology

On 14 July 2009 at the European Polymer Congress 2009 in Graz, Austria, Professor Ulrich S. Schubert of Eindhoven University of Technology and Friedrich Schiller Universität Jena was presented with the Pieter Jan Lemstra Invention Award of the Dutch Polymer Institute. This biennial award is presented to a researcher who has significantly contributed to the development of polymer technology in Europe and who has enabled scientific knowledge to be quickly converted into industrial applications.

Jacques Joosten, Managing Director of DPI: “Ulrich Schubert is a very important scientist for the polymer world. During the period that this award covers, ten patent applications were filed in his name. His inventions attract a lot of interest from partner companies. Some of the projects have led to new business opportunities currently being explored. We also recognise Professor Schubert for his role in the development of High-Throughput Experimentation.”

Pieter Jan Lemstra

The Dutch Polymer Institute inaugurated this prize in 2006 to honour its founder and very first director, Professor Pieter Jan Lemstra. Due in part to his network, collaborative public-private partnerships have been developed, which are still a driving force within the Dutch Polymer Institute. In addition, Pieter Jan Lemstra was at the birth of many initiatives in the polymer sector, such as Kunststoffenhuis, Polymer Technology Group Eindhoven, the Rolduc Polymer conference, the Polymer Technology Netherlands research school, the European Polymer Federation, the Kunststof.net community and the E-polymers website.

Coatings Technology

Within the Coatings 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 coatings technologies. The research is pre-competitive and is focussed at achieving sustainability, quality of life improvements, economic growth and preparing the coatings industry for future challenges.

Outstanding researcher Joris Sprakel

Former Wageningen University PhD student Joris Sprakel who graduated with honour, is continuing his career as a PostDoc at Harvard University in the Experimental Soft Condensed Matter Group. Joris was one of the nominees for the Golden Thesis Award 2009 with his thesis entitled “Physics of associative polymers; bridging time and length scales”.

Great assessment by the Scientific Reference Committee

Very considerable progress in quality has been made in the area over the last couple of years.

The improvement mainly originates from a redefinition of scientifically challenging goals and ambitions while maintaining industrial relevance. In fact, this Technology Area provides a very good example of how a supposedly ‘dull’ and classical scientific area can be rejuvenated if the right ambitions are introduced. The progress is also very nicely reflected in the quality of submitted publications.

Coatings Technology
Towards sustainable coatings

In time it will be necessary to use renewable resources for components to make high-quality sustainable coatings with properties at least as good as those of present-day coatings. Starch is a promising raw material to achieve this. It has to be modified, however, before it can be put to good use. This can be done using enzymatic processes.

A coating is a highly complex cocktail of ingredients. Before the plastics era, coatings or paints used to consist purely of natural ingredients. Those based on linseed oil, for example, were familiar to the ancient Egyptians. The composition of natural coatings depended largely on craftsmanship and tradition. Later, when they were made from crude oil, the coatings' properties, such as hardness, scratch resistance, durability and water resistance, could be improved by varying the composition and improving the properties of the constituents. Together with flow behaviour, adhesion and ease of application, these properties largely determine the quality of a coating.

The polymer binder, which is the backbone of the coating, is the most important constituent since it largely determines how the coating flows. Depending on the sort of coating its volume percentage during application varies between 50 to 90 percent. Apart from the inherent properties of the coating more and more the sustainability of the product itself and the sustainability of its production process and its application by the customer, are taken into account when end users choose a coating.

Backbone

Keimpe van den Berg explains the aim of the project. “We want to make high-quality coatings from renewable raw materials with properties that are at least as good as the properties of coatings based on crude oil. We want to make them from starch.” A car finish, a coating in which scratch resistance, hardness and durability are important, is made of oligomers and hardeners that are polymerised after being applied to a metal or polymer substrate. The polymerisation process largely determines the quality of the coating. At this moment the oligomers and hardeners are prepared from components based on crude oil. If you are looking into the possibilities of making coatings of renewable materials, starch-based polymers have the advantage that they have a very hard backbone which greatly enhances the durability of the coating. But the problem is that starch monomers do not readily mix with the hardener and other components of the coating. For that reason we will have to modify the starch.”

Professor Katja Loos, in charge of the research project, explains how that problem is addressed. “We try to modify starch in such a way that it will mix with the

Discussion partners

Katja Loos works at Polymer Chemistry department of the University of Groningen's Zernike Institute for Advanced Materials in the Netherlands. She heads the Biocatalysis in Polymer Chemistry group and was recently awarded the second DPI Fellowship. Her main research interests currently lie in the different aspects of enzymatic polymerisation and monomer synthesis, biocatalytic modifications of polymers and polysaccharides, the interaction of proteins with specially treated surfaces, living polymerisation techniques and magnetic and semiconducting nano-materials.

Tijs Nabuurs is senior scientist in charge of Acrylic Emulsions with DSM NeoResins+ in Waalwijk, the Netherlands. DSM NeoResins+ develops water-based polymers for the coatings industry (coatings in the broadest sense of the word, meaning decorative and industrial paints, inks and adhesives).

Keimpe van den Berg is, at the time of writing, Innovation Platform Owner with AkzoNobel Car Refinishes in Sassenheim, the Netherlands, where he is responsible for introducing new technologies to the Car Refinishes Business Unit. From 1 April 2010 he is setting up a new expert capability group for polymer chemistry for AkzoNobel in the United States. He will, however, remain a member of the Programme Committee of the Coatings Technology Area and DPI industrial contact person, in which capacity he is also responsible for this project in the Coatings Technology Area.


Tijs Nabuurs, Keimpe van den Berg and Katja Loos

"A paradigm shift is needed to convince everyone in polymer science of the usefulness of biocatalytic processes."

Katja Loos

other components and then harden effectively after it is applied to different surfaces. We do not simply want to synthesise the modified starches, we also want the synthesis to be a sustainable process. Eventually, we also want to use sustainably produced chemicals in this process. We use an enzymatic approach that will make our modification a very selective and tailor-made process that works under mild operation conditions and does not use or produce toxic components." Tijs Nabuurs, looking back at earlier attempts at starch-based coatings, adds: "The starch-based coatings of the past were not good enough. They were very sensitive to degradation when exposed to water." Traditional synthesis has the drawback that starch is decomposed to a certain extent and this, for instance, has a dramatic effect on the colour intensity. Since water resistance is an intrinsic property of starch, the starch must be modified to circumvent it.

Paradigm shift

Loos continues: "Coatings on the basis of chemically modified starch have been made and their properties are comparable to those of coatings from crude oil. So we know that it is possible, but now we also want to make the process a sustainable one. A 100% green car, that is what we want." The people around the table agree that eventually, say in twenty years from now, it will be possible to have completely green high-quality coatings. And these will also be used widely, in their opinion. "We have got to," Nabuurs adds, "because we will not have any affordable oil left by then. It is not only about protecting the environment or saving the planet, there is an economic reason as well." Interest in green raw materials and in biocatalysis is increasing, both in industry and in academic circles. According to Loos, a paradigm shift is needed to convince everyone of the usefulness of the process and the quality of the products. In this respect, it helps that biochemistry and biotechnology are increasingly becoming part of chemistry degree courses at universities. They will eventually find their way to industry.

There are two possible paths to sustainable coatings. They can be made of the same components from which they are currently manufactured, albeit from renewable sources, or they can be manufactured from completely different components. Both paths are being taken but in the long run the latter will probably win, depending on the balance of properties that can be achieved. Meanwhile, though, the first path has the edge.

"The low threshold to participate in DPI projects is very attractive."

Keimpe van den Berg

"We have got to make products based on renewable sources, there will be no affordable oil left twenty years from now."

Tijs Nabuurs

"In DSM the starch project will not be easy to initiate for two reasons: it will be considered too risky and we do not have expertise in this field. To develop this expertise would take us years, so participation in the DPI *Starch based performance coating materials* project is the most effective way for us to explore this field. We profit from the expertise that Groningen has built up over the years", says Nabuurs. DSM is active in the field of sustainable polymers but the company's in-house projects will generally be closer to its business. "And we learn how to make coatings from our products, something we did not yet know, and we can use that knowledge in the future also for other projects," adds Loos, emphasising the benefits of the cooperation for her group.

Low threshold

The three partners agree that doing such a project together has advantages for all of them. Loos adds, "Apart from bringing science to industry and generating scientific outcome in the form of publications, cooperation with DPI partners is also productive in the sense that our researchers find a job in industry, often in the companies they already know from their contacts during the project. In that sense there is also added value as a result of this cooperation." Van den Berg, from his point of view, sees the low threshold for cooperation within DPI as a big advantage: "The partnership within DPI gives us access to knowledge that will be the basis for a new technology in AkzoNobel, and its is relatively inexpensive." Nabuurs adds, "But that is not the only aspect to it. For us cooperation with DPI is an interesting way of keeping in touch with the academic world. We get access to an extensive network of academic groups doing more fundamental research than we would do ourselves. And yet another thing is the fact that you sit at one table with colleagues from other companies to openly discuss interesting options. This enables you to use your time and money efficiently. The fresh input from people outside your daily network often results in new ideas for new projects, and in that way DPI is self-accelerating."

The formal and informal network that DPI offers its participants appears to be a valuable asset. To be able to break new ground you have to know people from universities and from industry and meet them in open discussions. Cluster meetings, project meetings, annual meetings with varying participants are very useful. The success of a project depends mainly on the participants themselves, whether they 'click' or not, but DPI's structured approach with a Technology Area coordinator who keeps track of the progress and timing of a project and facilitates contacts is highly appreciated. A compliment that is equally much appreciated by Harold Gankema, Programme Area Coordinator for Coatings Technology.

Objectives

The goal is to explore novel coatings materials and to develop fundamental insights into the structure-property relationships of coatings that will lead to innovative coating technologies. The pre-competitive research efforts are intended to achieve improvements in sustainability and the quality of life, and to boost economic growth (DPI business plan 2008-2015), thus preparing the coatings industry for future challenges.

Subprogrammes

Renewable raw materials, formulation and powder coatings

- Investigating the feasibility of the use of sustainable, renewable bio-based instead of petrochemistry-based raw materials in coatings' resins, without compromising the final properties of the coating (film).
- Gaining a fundamental understanding of the colloidal stability of waterborne coatings as a basis for increasing shelf-life and broadening the application of the technology.
- Exploring novel powder coating systems suitable for broader application (substrates: wood, MDF, plastics), with special emphasis on low temperature, daylight/sunlight sensitive photoinitiator-based systems.

Functional (smart) coatings

- Investigating possibilities of single-layer or one-step coating systems that comprise several functionalities.
- Studying and developing new coatings with additional functional properties (surface and/or bulk) that go beyond substrate protection or decoration, including self-healing properties, antimicrobial activity or stimulus-responsive and switchable properties.

Durability and testing of industrial coatings

- Establishing fundamental understanding of the degradation mechanisms of coatings in environmental conditions.
- Fundamental studies of corrosion-protective coatings for aluminum (alloys) with special emphasis on the mutual effects of the molecular structure of the coatings system and mobility of water as well as charge carriers.
- Exploring and developing new test and analysis methods for coating properties and performance, e.g., for adhesion, gloss, or scratch resistance.

Facts and figures

Partners from industry

- AkzoNobel
- Bayer
- Dow Benelux
- DSM
- Evonik
- Océ Technologies

Partners from the research world

- Eindhoven University of Technology
- Food and Biobased Research Wageningen UR
- Forschungsinstitut für Pigmente und Lacke
- University of Amsterdam
- University of Groningen
- University of Haute-Alsace
- Wageningen University

Budget and organisation

The total expenditure of the Coatings Technology cluster in 2009 was € 1.62 million (budget € 1.44 million). The total number of FTEs allocated at the end of 2009 was 16.7 distributed over 27 researchers. The total expenditure on equipment was € 17k. In 2009, Professor Dr. Claus D. Eisenbach was Scientific Chairman of the Technology Area, and Dr.ir. Harold Gankema acted as Programme Area Coordinator.

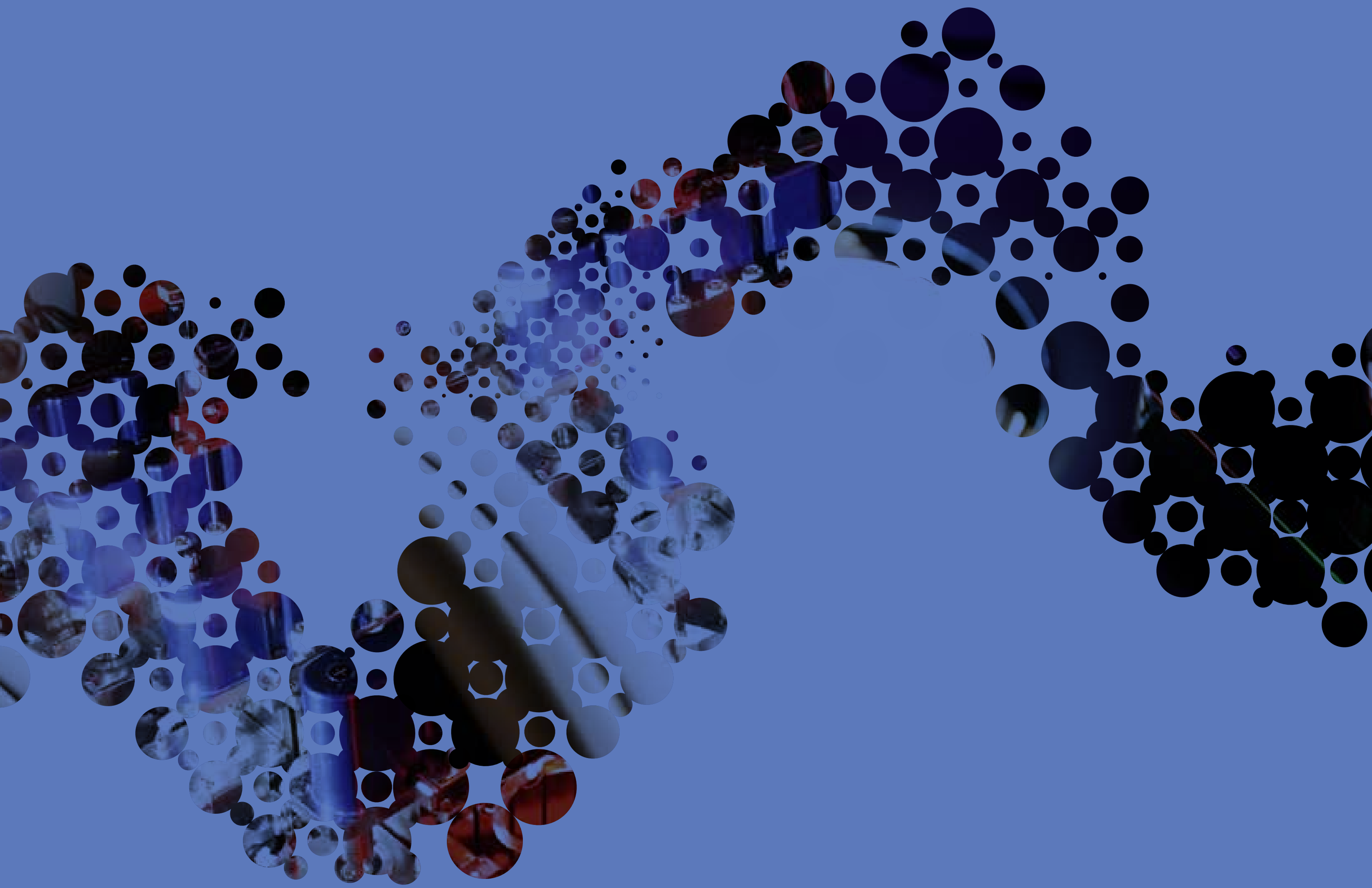
Publications and inventions

The research programme of the Coatings Technology area generated two theses and seven scientific publications. Moreover, there was a significant number of contributions to scientific conferences in the form of posters and oral presentations, reflecting the standing and visibility of the CT area in the science community. Two inventions were reported and two patent application was filed.

Detailed information on page 79.

High-Throughput Experimentation

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



Most scientific publications

Of all the Technology Areas, High-Throughput Experimentation delivered the most scientific publications for 2009. With close to 70 publications, the output of HTE forms a substantial part of the complete scientific output of DPI.

Professor Andrew Cooper has been awarded the Corday-Morgan Prize

Professor Andrew Cooper, working at the University of Liverpool, has been recognised for his work with a prestigious award from the Royal Society of Chemistry (RSC).

Professor Cooper was awarded the Corday-Morgan Prize for his contributions to materials chemistry – in particular, porous organic polymers. Professor Cooper is Head of the University's Department of Chemistry and founding Director of the University's Centre for Materials Discovery, which enables businesses to access high-throughput research facilities for the discovery of new materials for applications such as energy storage, medical equipment and consumer products.

High-Throughput Experimentation
From synthesis to formulation

Eight years ago the High-Throughput Experimentation Technology Area started with the parallel synthesis of materials in an array-like set-up along with the study of printing functional polymers for solar cells and plastic electronics. These two lines of research now come together in a project where, for instance, single-cell tests for toxicity are possible.

Joe Delaney starts the discussion by explaining what his project is about. “Normally when you think of inkjet printing you think about printing documents and pictures. But with the same concept – depositing uniformly sized little droplets in the sub-nanolitre range precisely where you want them – you can do more. Unlike printing documents and pictures, we use inkjet printing to deposit a much broader range of materials with different functionalities. We can do chemistry that would not be possible in another way, such as preparing hundreds of different materials and different formulations that can easily be analysed by other techniques.” An appealing example is to take living cells and make, for instance, single-cell arrays of regenerative cells from patients to find out the different culturing conditions that lead to different cell types. Polymers and other additives play a role in the suspensions of the cells that are charged a little bit to repel each other so that they end up in an array with one living cell per addressable matrix point.”

Norbert Windhab eagerly hooks into this: “You cannot imagine how relevant and important this is. The largest interface of a human being with the outside world is the immune system. To test single-cell responses you have to separate them from each other. Only polymers can do that. To test for toxicity on a large scale we need high-throughput experimentation. There is no other way to do it.” In Europe regulations are adopted to test 12,000 different industrially relevant compounds for toxicity as they affect human beings. Technically and ethically it is not possible to do these tests on humans, but if a smaller standardised system like adult progenitor cells printed in an array can be used as a simplified models for screening, it would help greatly to make some important decisions.

Hot spots

“This means that we will need co-development between different disciplines – life sciences, polymer chemistry, engineering – hot spots where science progresses. Seen from an industrial point of view, this is where the real innovations come from, where people invent and do business at the end,” adds Thomas Riermeier. “We have to get away from the old single experiments towards matrices and libraries,” Ulrich Schubert comments, “but in the end it boils down to elucidate finding the structure-

Discussion partners

Joe Delaney is in the last year of his PhD project in the Macromolecular Chemistry and Nanoscience group of Professor Ulrich Schubert in the Department of Chemistry and Chemical Engineering at Eindhoven University of Technology. Contrary to most other PhD students he has experience of working in industry. Before coming to Europe in 2006 for this project he worked as a chemist with Boston Scientific in the United States. His project is about reactive inkjet printing of thin polymeric films and nanoparticles. To date he has filed 12 patents in the course of his four-year project.

Thomas Riermeier works with Evonik Röhm GmbH in Darmstadt, Germany. He started working for Hoechst in the field of high-throughput screening of catalysts in 1998 and from the start has been in contact with DPI. Presently he is heading the Innovation Management Pharma Polymers of Evonik.

Norbert Windhab also works with Evonik’s Business Line Pharma Polymers and heads strategic projects with customers for new technologies and methodology. He has been member of the programme committee of the BioInspired Technology Area in DPI. His main activity at this moment concerns the possible use of polymers in various pharmaceutical and medical applications.

Ulrich Schubert is Scientific Chairman of the High-Throughput Experimentation Technology Area and chairman of the Laboratory of Macromolecular Chemistry and Nanoscience at Eindhoven University of Technology and the Laboratory of Organic and Macromolecular Chemistry at the Friedrich Schiller University in Jena, Germany. Since 2003 his group has been working on printing polymers with an inkjet printer and has recently moved to biological applications.

Thomas Riermeier, Joe Delaney, Norbert Windhab and Ulrich Schubert

> “With inkjet printing we can do chemistry that would not be possible in another way.”
>
> **Joe Delanay**

property relationships. For each new product and each new application we will learn which parameters have an influence on the properties. In that way we will limit the parameter space and really find structure-property relationships. That knowledge will save us a lot of time and the only way to get it is by high-throughput experimentation.”

HTE started with synthesising polymers, faster than before and in parallel, screening their properties and unravelling quantitative structure-property relationships. It appeared that it is not purely the polymer that counts in the end; it needs to be formulated with something active. And then it needs to be tested for toxicity. The field had to go from synthesis to formulation. “We had the printing technique in-house, but discussions with our industrial partners, with Evonik Röhm and others, brought a growing feeling that we had to combine the two to achieve this,” Schubert explains. “We had never thought that the Technology Area High-Throughput Experimentation would evolve in this way. Suddenly we look at toxicity, we think about cell tag tests, things that were not on our agenda two years ago. It is definitely not a linear development.” Windhab, apparently also happy with this development, adds: “It is wonderful that we can so fast build on your results with the relevant examples. Let me illustrate that. The last few weeks I was called by two large multinational companies that want to use our materials, new formulations, in medical devices. Increasingly they use special coatings that need to be safe. We can now check this in a fast and reliable way and that is wonderful from a business point of view. It also tells us that we are going in the right direction.”

All discussion partners are united in the belief that interaction and networking within the context of DPI are crucial to fast success. And what is more, the time that industries opened large research laboratories and did everything themselves in-house is long gone. The crisis has compelled companies to source out everything to someone else that do better. “But it is not only about resources and money,” Riermeier says, “it is also about the brains. You cannot have all the competences internally. New knowledge is generated by sharing, not by hiding and saying ‘This is mine’. Interaction is essential, including customers, and translating their needs in technology.” Windhab reduces that view to a simple statement: “You are what others make you.”

Proof of value

Schubert agrees fully and illustrates it. “We had an excursion with our whole group to Evonik in Darmstadt to see the laboratory and talk to the people. Then suddenly

> “You are what others make you.”
>
> **Norbert Windhab**

"Outsourcing and cooperation is not only about resources and money, it is also about brains."

Thomas Riermeier

things came together." Windhab remembers a comment from one of the visitors that struck him. "Someone said, 'Finally somebody told us how they do business, not how you do polymer chemistry better than at the university.' Thomas told them how we do innovation together, what our goals are, what we do in our processes ..." Students working in an industrial lab and industrial scientists working in an academic environment for a while are valued highly by all discussion partners. It gives them additional experience and new viewpoints and in the end everyone will benefit.

Windhab: "Proof of principle is not enough, we want proof of value. By that I mean go from the proof of principle to the end where a customer says 'I think that's a good idea and I'm willing to put my money on it'. Then researchers can say that they were really at the heart of the development. We recently introduced this idea successfully in our department. It was a welcome process innovation that benefits from the feedback from the company side. That is also what we explained to Schubert's group. It is often high-risk research, but we have now done it successfully three times, and are gaining more and more confidence. Hands-on collaboration with the full value chain is picking up speed." Classical textbook development only works when you know the market very well. In other cases, where your business is based more on technology or an application, you have to integrate the customer into the development process. Make a demonstrator and when one customer shows commitment, you know you are on the right track and your development is relevant.

Schubert adds: "We would not and could not have done this kind of work as a single university group. We need the input from industry, from people who have expertise in the field, know about patents we are not aware of, who already know which paths are not worth pursuing. In addition, we also need the input from the technology companies like Chemspeed and Microdrop that have developed new machines that enable us to do the work. And now we want to broaden our academic scope: we started a cooperation with Professor Andrew Cooper of the Chemistry Department and Centre for Materials Discovery at the University of Liverpool and with colleagues from the University in Nijmegen with complementary expertise. The good thing about working in a framework like DPI is that we do not have to draw up new contracts every time and make IP rules. We do not discuss how we tackle a problem, we just do it. And we can use the same platform."

"We need the input to discover new materials and to create new functional devices."

Ulrich Schubert

Objectives

In the long term, a kind of 'materials informatics' is envisioned that will allow the design and preparation of customised materials and devices with predetermined properties based on previously established structure-property relationships. 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 the commercial R&D programmes of the industrial partners.

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 establishing structure-property relationships. Besides fundamental research on the use of microwave irradiation, feasibility studies are performed on scaling up microwave-assisted polymerisation procedures. The synthesis efforts have been intensified in the direction of water-soluble polymers. In addition to fast synthesis and formulation platforms, investigations concern the incorporation of high-throughput screening techniques for molar mass, polymerisation kinetics and thermal and surface properties, among others. The existing high-throughput workflow has been further expanded to include capabilities for polymer water uptake screening and polymer solubility screening.

Thin-Film Library Preparation & Screening
This sub-cluster focuses on detailed understanding of thin-film preparation technologies, the application of these technologies and the screening of thin-film material properties by automated atomic force microscopy and nano indentation technologies. Application fields include the processing of light-emitting materials, surface patterning, cell screening and the preparation of conductive tracks on polymeric substrates.

Combinatorial Compounding
The central objective of this programme is the development of a process, that facilitates the acceleration of the preparation, characterisation and optimisation of plastic formulations. The combinatorial extrusion line used for this purpose has been equipped with in-line and on-line screening techniques (e.g. IR, UV/Vis, rheometry, ultrasonic spectroscopy) as well as data acquisition, analysis and visualisation systems.

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 to support 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.

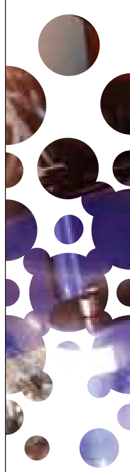
Characterisation Techniques
This sub-cluster deals with the development of detailed characterisation methodologies. An important aspect is the combination of different measurement techniques to characterise multiphase or multicomponent materials at macro, micro and nanoscale. Another focus of interest is the analysis of branched polymers by means of two-dimensional liquid chromatography. Furthermore, tools and models for nanoscale characterisation of interfaces using AFM technology are being developed.

Facts and figures

Partners from industry
- Chemspeed Technologies
- Dow Benelux
- Evonik
- Forschungs Gesellschaft Kunststoffe
- LyondellBasell
- Microdrop Technologies
- Nano Technology Instruments – Europe
- Michelin
- Waters Technologies Corporation

Partners from the research world
- Deutsches Kunststoff Institut
- Eindhoven University of Technology
- Friedrich-Schiller-University Jena
- Innovent
- University of Amsterdam
- University of Cambridge
- University of Liverpool

Budget and organisation
The total expenditure for the High-Throughput Experimentation Technology Area in 2009 amounted to € 2.66 million (budget € 2.26 million). About € 225k was spent on equipment. The remaining budget was allocated to 51 researchers (26.2 FTE). In 2009, Professor Dr. Ulrich S. Schubert was Scientific Chairman of the Technology Area, Dr.ir. Harold Gankema the Programme Area Coordinator.



Publications and inventions
The research programme of the Technology Area generated five theses and 67 scientific publications. Five inventions were reported and four patent applications were filed.

Detailed information on page 79.

Plastic Soup

At DPI's annual meeting 2009 one of the keynote speakers was journalist Jesse Goossens whose book entitled 'Plastic Soup' is about plastic at the end of its lifecycle and dealing with the problem of plastic waste in the oceans.

Captain Charles Moore discovered the Great Pacific Garbage Patch, the 'Plastic Soup', in 1997 sailing through the North Pacific Gyre, a spot as far away from human civilization as possible. An unimaginable amount of plastic waste from that same human civilization is assembled there by the ocean currents. He later calculated that about 5 kg of plastic per square kilometre was floating there. In 2006 the United Nations estimated that the ocean contained 46,000 floating pieces of plastic per square kilometre while below the surface this was as much as 25 times that amount of plastic.

Microplastic

The plastic that ends up in the oceans is a big problem. Only 20% of the waste comes from ships at sea and consists of fishing nets, containers, other cargo and waste lost at sea in bad weather or deliberately ditched overboard. The other 80% has land-based origins and arrives in the sea by rain, streams and rivers. Sea life is threatened not only because marine animals suffocate in plastic bags they take for food but, in particular, because of the unintentional intake of all the plastic and the toxic ingredients. Most of the plastic in the ocean is microplastic, small plastic particles with a diameter of less than 0.3mm, the residue of plastic falling apart in the water. Not only is marine life threatened but also our oxygen supply; half the total amount of oxygen on Earth is produced by the oceans.

The solution to this major problem is not easy. While larger plastic waste can, in principle, be fished up, the tiny particles cannot. And, then again, who should do it? Outside the 200-mile coastal zone there is 'open sea' and no specific country is responsible. There may be legislation on dumping waste at sea and securing cargo so that it isn't washed overboard, but even then 80% of the plastic waste is not accounted for. Specially equipped boats can fish debris out of the water but tiny parts and particles will eventually sink to the bottom and become buried under sand. However, even if we manage to control

the present problem, it is vital to ensure that the amount of plastic in the oceans does not increase.

Reduce, reuse and recycle

Initiatives are being taken to reduce the use of plastic, such as the ban on plastic shopping bags in, for instance, San Francisco in the US or Calafate in Argentina. Environmental associations such as Greenpeace and the Waddenvereniging clean up beaches. Plastic is increasingly being recycled and designed in such a way that it can easily be broken down in building blocks for reuse, a less expensive and more energy efficient option to making new plastic from raw materials. In countries such as China and India, where plastic waste stills represents a certain value, plastic is assembled and sold as fuel. Plastic sweet wrappings are used to make bowls, bracelets and all kind of other items in third-world countries. Initiatives such as Green Gorilla – a website with myths to influence children – and O'Neill Sea Odyssee – sea trips to make children aware of the importance of the sea for life on land – must increase awareness and change the way humans use plastic.

It is everyone's responsibility to contribute in his or her way to making the production, use and discarding of plastic a circular and not a linear process.

DPI's role

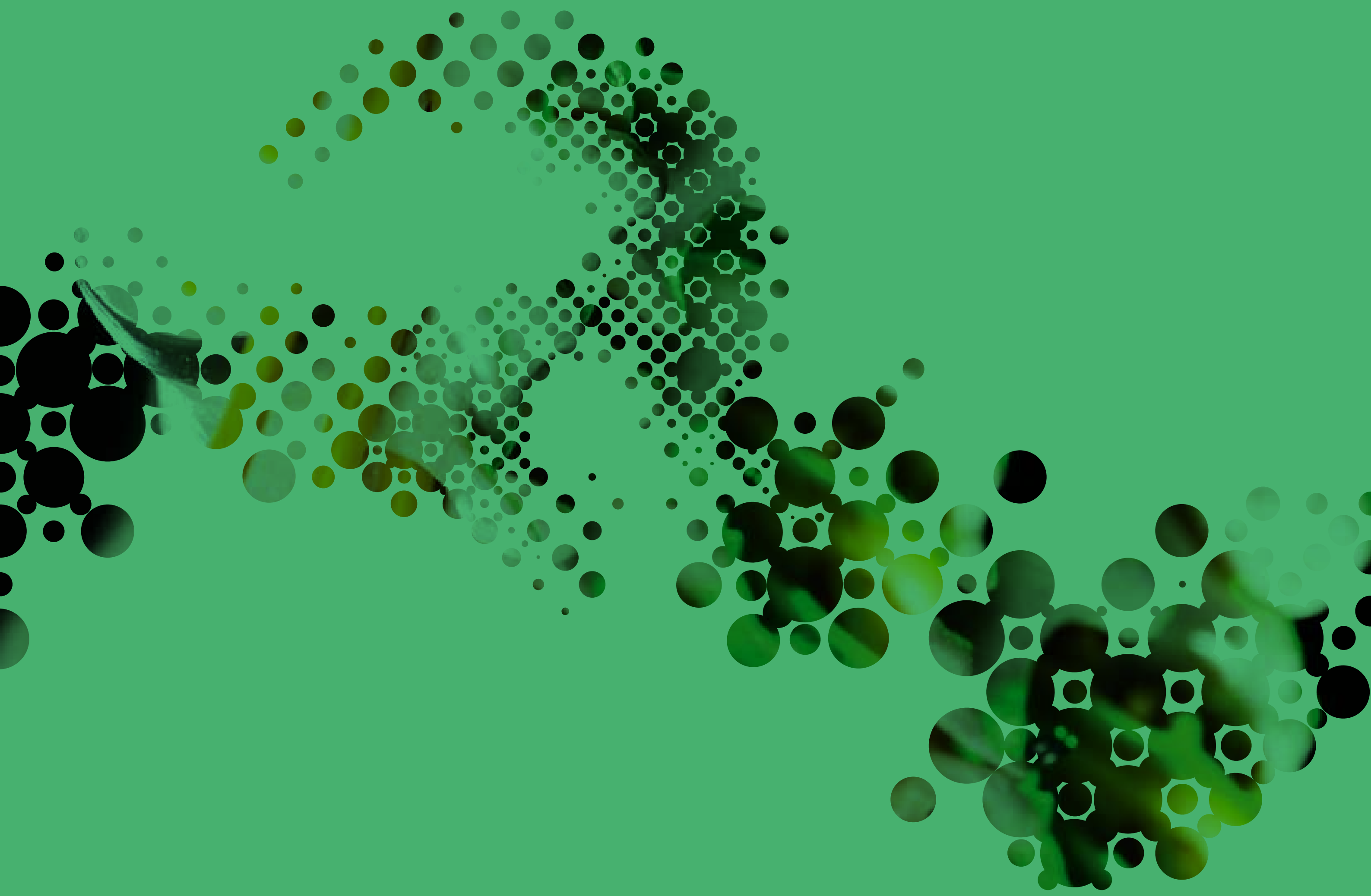
DPI's Managing Director Jacques Joosten indicates that DPI can and will contribute to solving the problem in all possible ways. For example:

- The properties of polymers so that they can be recycled more easily
- Developing polymers based on renewable raw materials
- Investigating whether certain synthetics can be made biodegradable for applications in which this is meaningful
- Investigating whether banning disposable plastic is sensible or not
- Contribute to education and training of people so that they behave in a socially responsible way with both raw materials and plastic products
- Developing plastics with alternative non-toxic additives to be used as flame retardants, softeners, artificial dyes.

"Polymers are only fifty, sixty years old. There are many possibilities and there is much freedom in modelling them: simple things, but also complicated projects and artistic design. What drives DPI is socially responsible production. I see plenty of possibilities for that. We are only at the beginning," says Joosten.

Bio-Inspired Polymers

The Bio-Inspired Polymers (BIP) programme aims 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 such as self-assembly and biocatalysis.



Scientific Chairman Appointment

In September 2009 Professor Gerrit Eggink was appointed Scientific Chairman of the Technology Area Bio-Inspired Polymers. Gerrit Eggink has been involved in DPI since 2003 and is currently working at Food & Bio-based Research Wageningen UR.

Cross Technology Area Bio-Based Polymer programme

DPI is planning to set up a programme across Technology Areas. The first workshop was held in Eindhoven on 10 November 2009 with a follow-up workshop planned in the autumn of 2010. The goal of these workshops is to establish future research lines and themes to set up a Bio-Based Polymers programme within DPI.

Bio-Inspired Polymers
Bridging the gap

A new biocompatible and biodegradable polymer was the starting point of a DPI project to investigate the possibility of repairing the damage to peripheral nerves. While damaged nerve ends do grow again, you have to force them to do that in the right direction. Biodegradable scaffolds can help.

Professor Marco Marcus starts by explaining how he became involved in this project. “During my studies I worked for a while in the United States where we developed the Actiq lolly as a means to administer a painkiller, fentanyl. Initially there was some opposition to this form of medicinal administration but in the end it was a very successful project. Now it is a 700 million dollar business. When I returned to the Netherlands I became involved in a project with Dolphys Medical, among others, that was examining controlled release of painkillers. I was enouraged to take part due to my experience in bringing research results to a commercial success as we had done in the US. During one of the project meetings I met professor Cor Koning of the Chemical Engineering and Chemistry Department of the Eindhoven University of Technology and, as these things go, during drinks after the meeting he told me about a new biocompatible polymer material that his group had developed. We brainstormed about what we could do with it. The first ideas involved repairing damaged Achilles tendons and using it as a suture material. The project proposal was written within a week, the project was approved and soon we had a PhD and a postdoc working on it.”

Push and pull

It is interesting to notice that in formulating this project both ends of the value chain – the academics that invented and developed the material and the doctors in hospitals who are going to use it – played a role. In most other project proposals it is more push than pull. Marcus hurries to mention that not he is the end user but the hospital surgeons. Anesthesiologists are often involved in research projects spreading into other fields of medicine. He agrees that the success percentage of projects that have the whole value chain involved from the beginning is high.

With the end of the four-year project in sight, the possible applications have changed from the tendons and suture material to nerve repair. Practically all patients arriving at accident and emergency suffer from nerve damage in one form or another. Curing and rehabilitating them is very

> “I succeeded in finding a copolymer system whose degradation speed can be altered.”
>
> **Inge van der Meulen**

Discussion partners

Inge van der Meulen studied organic chemistry at the Eindhoven University of Technology. She is a PhD student of professor Cor Koning in the department of Chemical Engineering and Chemistry and is doing her research project, High Molecular weight aliphatic polyesters by enzymatic polymerisation for medical applications, in collaboration with the Department of Anesthesiology laboratory of University Maastricht Medical Centre under the supervision of professor Marco Marcus. She will defend her thesis at the end of 2010.

Ron Deumens studied biology at Radboud University in Nijmegen, the Netherlands. His main interests are related to neuroscience. During his study he did an internship at University Maastricht which became a PhD project by natural extension in the anesthesiology laboratory. Currently he is working as a postdoc in the field of biomaterials for repairing damaged nerves and alleviation of pain.

Marco Marcus is a professor at the Department of Anesthesiology of University Maastricht Medical Centre in the Netherlands. As such he is involved in what is called peri-operative care, all the peripheral aspects of an operation, so not only anesthesia before but also pain control after the operation. His group is researching biocompatible and biodegradable polymers that neurosurgeons and plastic surgeons can use to repair the peripheral nervous system.


Marco Marcus, Inge van der Meulen and Ron Deumens

expensive. Not many neurosurgeons and plastic surgeons operate in this risky field, and if they do, they tend to use a part of a peripheral nerve not needed as badly as the damaged one as a patch. But such nerves are few and far between, so an alternative solution is highly desirable and, moreover, will save society a lot of money.

> "In large projects, like those of DPI, I can take up the discussion and contribute my knowledge."
>
> **Ron Deumens**

Scaffolds

Inge van der Meulen is the PhD student doing the research work. "I started with the material that professor Marcus and professor Koning talked about during drinks. It was biocompatible, that was already known, but it did not degrade fast enough in the body. My first task was to improve on that by incorporating comonomers. I succeeded in finding a copolymer system whose degradation speed can be altered by the ratio of comonomers incorporated in the polymer." Ronald Deumens, the postdoc involved in the project, explains the present application of the material. "Surgery of periphery nerves is very risky. If you have a nerve with a gap in it you can take both ends and stitch those together but you can only do that successfully if the gap is very small. If you have to stretch the nerves to bring the ends together it will not work. Experiments with silicon tubes in which the nerve ends can grow in the right direction are promising. But going towards the middle where both ends meet, the nerve will contain only few nerve fibers and, thus, will be very thin and vulnerable. So the idea is now to make a kind of scaffold from this new material inside such a tube to attract growth-supporting cells from both nerve ends so that the nerve fibers can regenerate into the appropriate direction within this scaffold and eventually reconnect. We want to make these scaffolds from this new biopolymer. These porous structures will contain pores oriented in the right direction." Apparently, if you do not induce nerve fibers to grow in one direction they fan out in all directions, grow into knots and fire spontaneously causing pain sensations.

The plastic complies with all the biocompatible and biodegradable requirements and all that Van der Meulen has to do is to make the porous structures. She is busy doing that and is confident that she can meet all the requirements set by Deumens. The nice thing about these growth-supporting cells and nerve cells is that they also grow in a Petri dish so that you do not need to do initial experiments to test the materials and the structures in living creatures. When asked for a prediction about when the material can actually be used in patients, Deumens says, "First we test the material in Petri dishes, then in animals and eventually in patients. The whole trajectory will take five years, I guess. It is a bit of a pity that this project ends when we have the material and are ready to test it. We will have to think about a successor." Marcus adds, "A successor needs relatively little money and the best thing would be if this project can be continued in some way. If we have to go and find another sponsor it will cause a big delay."

> “Give the researchers involved a share in the eventual business success. That speeds up things substantially.”
>
> **Marco Marcus**

Missing link

Even though the start and end of the value chain are presently involved, there is still a missing link: who will produce this material when research has resulted in a proof of principle? A big chemical company like DSM? Or a start-up company, maybe related to DSM? A good thing would be if all the knowledge that Van der Meulen has acquired in the process will be retained for such a company. For that to happen she could work in the respective company or transfer her knowledge to others. In particular during the start-up phase there is a need to go back to the basic science for any suggested change of a non-scientific nature.

Marcus comments, “The problem with large companies is that they want success fast, but to develop materials to be used inside patients takes time. To develop a new medicine takes 14 years, so this is a relatively fast development.” He comes up with a creative way to speed up the development process substantially. “Give the researchers involved a share in the eventual business success, 1% or so of the royalties, not a one-off amount patent-related payment.” This is also an approach he learned during his stay in the US.

All discussion partners agree that the atmosphere and the environment that DPI creates in these projects is fruitful. Deumens puts it like this: “In DPI meetings the chemists express their expertise in such a way that I can take up the discussion and contribute my knowledge. Such things you only find in large projects, like those of DPI.” Marcus has a point of criticism though, more for himself than for DPI. “I have not attended enough DPI meetings for my own liking. Of course, I am very busy, but still it can be very stimulating to attend. Incorporating one or two days of my time in a project can be settled financially with the university. So that I feel more obliged to come to the meetings. Or DPI can call me and say that they count on me being there, that it is important also for end users to attend the meetings. If all representatives of the whole value chain are present, you will have a completely different discussion. People from different backgrounds have different ways of thinking and when you come together, it can result in very surprising ideas.”

It is all about bridging the gap, not only that in damaged nerves but also the gap between both ends of the value chain and that between the medical world and polymer chemistry.

Objectives

Bio-Inspired Polymers can be produced from natural or synthetic recources. They can be produced through cemo, enzymatic or microbial catalysis. The structure-property relationships of the novel materials are studied to elucidate why they exhibit these unique properties, with the scale of the synthesis developed such that tangible amounts of materials will become available for testing. The aim is also to demonstrate the potential for scaling up.

Facts and figures

Partners from industry

- DSM
- Evonik
- Food and Biobased Research Wageningen UR
- FrieslandCampina
- Océ Technologies
- Teijin Aramid

Partners from the research world

- Eindhoven University of Technology
- Food and Biobased Research Wageningen UR
- Friedrich-Schiller-University Jena
- Loughborough University
- Max-Planck Institute fur Polymer Forschung
- Polymer Technology Group Eindhoven
- University Maastricht
- University of Leeds

Budget and organisation

Total expenditure in 2009 was € 1.76 million (budget € 1.85 million). About € 60k was spent on equipment. The total number of FTEs allocated at the end of 2009 was 16.8 (27 researchers), but not all vacant positions have been fulfilled. In 2009 Dr. Peter Nossin was Programme Area Coordinator and Professor Dr. Gerrit Eggink acted as Scientific Chairman.

Publications and inventions

The research programme of the Technology Area generated three scientific publications and one thesis in 2009.

Detailed information on page 83.

Large-Area Thin-Film Electronics

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.

Large-Area Thin-Film Electronics
Functional films, more than mere materials

The mobility of charge carriers in organic semiconductor materials is now approaching that of amorphous silicon, with good performance feasible. So the time has come to find a way to produce them in a reliable, reproducible, fast and cost-efficient process. Printing from solutions is a promising option.

Derivatives of a semiconducting organic material called TIPS pentacene have successfully been used to demonstrate working organic transistors. It is the organic semiconductor material with the highest charge carrier mobility at the moment and a good candidate for use in large-area applications such as flexible displays, plastic photovoltaic cells and RFID tags. The prerequisite for such applications is a reliable, reproducible, fast and cost-efficient technology for the deposition of this material on large substrates. Printing from a solution is the best option and, therefore, the goal of the project discussed.

Project leader Dick Broer, a DPI veteran involved in many projects, sums up the successive phases in this project: "Firstly, there is the choice of the active material: which derivative of TIPS pentacene will have the best properties. Then we have to choose the solvent and the polymers that influence the rheology of the blends so that they can be used as a coating. This work is being done by a PhD student at Imperial College London, in Natalie Stingelin's group. The next step towards using these blends in a printing process, is to investigate the flowing behaviour and evaporation process, a task for the researchers in Anton Darhuber's group. Since the mobility of the charge carriers depends on the crystallisation direction, a postdoc in my group is studying how that can be optimised. These three groups are very complementary, approaching the problems from their own expertise. The Holst Centre then takes the process a step further towards industrialisation and, finally, materials suppliers, including Evonik, supply the materials to the end users. These are the device makers who supply their customers with flexible displays, RFID tags, organic photovoltaic cells and other flexible circuitry." It is a project with a long value chain and a lot of different partners involved.

Ready-to-use

Heiko Thiem is happy that Evonik is involved in this project. "We want to supply our customers with a functional ink so that they can substitute their expensive sputtering process with a cost-efficient printing process. Not a powder customers still have to use to make their own dispersions to fit their applications but ready-for-use inks for printing layers with well-defined thicknesses and optimum performance. We cannot investigate all aspects ourselves, we simply do not have the expertise nor all the

Discussion partners

Natalie Stingelin has been a lecturer in Organic Functional Materials at the Department of Materials of Imperial College in London since January 2009. She had previously worked at the Philips Research Laboratories, Eindhoven, the Cavendish Laboratory of the University of Cambridge and at Queen Mary, University of London. Her current research interests encompass the broad field of organic functional materials.

Anton Darhuber is a professor in the Applied Physics department at Eindhoven University of Technology. After working at Princeton University he came to Eindhoven in 2007 to build up a new research group in the field of micro- and nanofluidics.

Dick Broer is a professor in the Chemical Engineering and Chemistry department of Eindhoven University of Technology. He began as a part-time professor in 1996 and in 2009 he became full-time professor. From 1973 until 2009 he was a polymer scientist at Philips Research in Eindhoven.

Charlotte Kjellander has been working at Holst Centre in Eindhoven since 2008 as a researcher in the field of organic transistor technologies. Before that time she did her PhD project with DPI at Eindhoven University of Technology in Dick Broer's group and worked for a while at Philips Research Laboratories in Eindhoven.

Heiko Thiem has been a project manager in the area of printed electronics with Evonik Industries for four years. He is responsible for funded projects, for communication and for Evonik's relations with companies and institutions. He is a DPI programme committee member on behalf of Evonik and sees to it that projects go in the right direction and deliver results in time.


Anton Darhuber and Charlotte Kjellander

> “More understanding will help us to adapt our processes to new and better materials.”
>
> **Charlotte Kjellander**

different printing technologies at our disposal. Not only do we have the basic science of the materials and their deposition, but Holst Centre takes the process one step further towards a real industrial process, scaling it up and making it a more reliable process. And that’s great.” Anton Darhuber chips in. “Scaling up is indeed not a task for universities involved in such projects. It is too expensive for us and not a topic that facilitates scientific publications.” That task is, of course, exactly the mission of Holst Centre. Charlotte Kjellander comments: “We in our turn depend on the fundamental knowledge developed at the universities and hope that by gaining more understanding about the fundamental science, we can easily adapt our processes to new and better materials. I am sure better materials will come.”

Cooperation

When many different partners are involved in a project, cooperation can be complicated. This is not the case here. Indeed, it is very much appreciated. The short distance between Holst Centre and the university, for instance, enables the exchange of information on a daily basis and students to easily use equipment at both sites. “I can send over our PhD student to Eindhoven to come and work with you,” Natalie Stingelin suggests to Charlotte Kjellander, “and that will also help to intensify the contacts.” London is relatively close by, geographically speaking. Kjellander appreciates the proximity: “Of course, if you have partners geographically further away, it is still possible to cooperate, but it is always nice to speak to someone face to face. And because I meet people regularly in person, it is also easier to pick up the phone and discuss small things with them. Without the DPI network that threshold would be higher. When I did my PhD work in a DPI project, it was useful to see that the fundamental work we did at the university was indeed used. Now I am on the other side of the fence grateful for the fundamental research and putting it to good use.” Darhuber sometimes feels a push from industrial partners to address empirical and technological issues before the more time-consuming fundamental questions, but considers a continued dialogue about research results and directions as highly fruitful.

None of the discussion partners finds the number of industrial partners involved in LATFE a problem. There are now two materials companies, one end-user and one research institute as members of LATFE. “The more, the better, that is … as long as they have complementary expertise,” Stingelin says. However, Thiem sees a bit of

> “In The Netherlands we are good at connecting fundamental knowledge to technology.”
>
> **Anton Darhuber**

"The three university groups in this project have complementary expertise."

Dick Broer

a problem if the numbers grow too much. "I very much value our open discussions with leading experts in the field but when you have too many partners, and especially materials companies that will ultimately be our competitors, you cannot always say what your real interests are. I think there is an optimum number, between five and ten companies."

Cooperation in the project and also in the relatively small Technology Area of Large-Area Thin-Film Electronics is good but cross-fertilisation between the different technology areas could be improved. This is the observation of some discussion partners. Stingelin: "If you are aware of what is going on in other fields, you can contribute your expertise. That is something I am eager to do because I will always learn something in the end myself. I appreciate information about the other areas in a condensed form since we all have little time. It can also lead to the involvement of other experts of Imperial College working in the field who are not yet part of DPI projects." Imperial College is considered a hotspot in organic electronics in the United Kingdom.

Asia

A question raised by John van Haare, Programme Area Coordinator of Large-Area Thin-Film Electronics, concerns the competition with Asia where the end users of the technology are situated and where major companies, with large research departments, and big knowledge institutes are working towards the same goal. Will they not beat us? Kjellander: "I think with DPI as the bridge between universities and the industry we can compete with Asian companies and institutes." Thiem underlines this: "We certainly have to be aware of what is going on in Asia. I would say that we can only be successful if we provide an advanced material development. We can only do that when we work together. One company on its own can never compete with large Asian companies." Darhuber adds: "From my somewhat limited and academic perspective, I observe that university-industry cooperation and efforts to connect scientific and technological innovation are less of a presence in Asia than in Europe."

Thiem has the last word, thinking about the future. "Once the printing technology has been developed, applications with thin-film transistors – displays, backplanes, E-paper – will be possible within two or three years. While organic light-emitting diodes require high-throughput processes and thus more time, they will be feasible in five or six years. RFID tags will take a little longer."

"I appreciate condensed information about the other areas. It can lead to the involvement of other experts."

Natalie Stingelin

Objectives

Whereas Functional Polymer Systems (FPS) focuses on materials development and initial device performance, Large-Area Thin-Film Electronics (LATFE) is the obvious next step in the value chain and the fundamental knowledge generated should facilitate the reliable production of organic electronic 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 realise 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 the right deposition method choices 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) with 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 uncomprehended failures. New device architectures allowing more robust processing and production and improving yield without affecting device performance (efficacy, homogeneity of light output) are very desirable.

Facts and figures

Partners from industry
- Philips
- OTB Group
- TNO

Partners from the research world
- Eindhoven University of Technology
- Imperial College London
- University of Algarve
- University of Cologne
- University of Groningen

Budget and Organisation
Total expenditure in 2009 amounted to € 0.83 million (budget € 1.23 million). The total number of FTEs allocated at the end of 2009 was 8.4 (12 researchers). Total expenditure on equipment is amounted to €111k. During 2009 Programme Area Coordinator Dr. John van Haare was actively engaged in increasing critical mass of the Technology Area and granting projects after proper industrial evaluation and peer review.

Publications and inventions
In the start-up phase of the TA LATFE many contributions to scientific symposia in the form of posters and presentations were made. The projects currently running will certainly generate scientific publications in 2010.

Detailed information on page 83.

Emerging Technologies
Push and pull

If researchers at universities have a conceptually new idea they can approach DPI and convince them to pursue it. If such projects do not fit in an existing Technology Area, they can be absorbed in the Corporate Research programme and eventually grow into a new technology area. A recent example is the Bio-Inspired Technology Area, which developed out of Corporate Research. But what if industry has a good idea?

DPI is organised to stimulate technology push by way of its Technology Area Corporate Research: researchers with a good idea can submit a proposal to the DPI Corporate Research Programme Committee without first organising a consortium of companies interested in it and in that way get funds to do a project. But until recently there had been little focus on market pull – industry has an idea about a new technology. To remedy this DPI has set up the new Technology Area called Emerging Technologies (EMT).

Companies can approach DPI with a proposal for a new subject to work on. They subsequently find an academic partner, who writes a project proposal that is treated in the normal DPI way, including external reviewers who give their opinion on the scientific quality of the proposal. If that is positive – there is, of course, no Programme Committee – the Executive Board of DPI decides whether the project can be started.

Projects are just like other DPI four-year projects, for instance, but after two years a decision will be taken whether another two years will be granted or not. A condition that has to be met at that time is that, apart from the industrial party that started the project, at least one other industrial party must have shown interest and is willing to participate. The intellectual property (IP) that is generated in the first two years of the project is owned by all partners of DPI, the same as with projects in the Corporate Research Technology Area. After two years, the project can move into a separate Technology Area and IP is treated the same way as in other technology areas.

In 2009 one project was started in this Technology Area. It is about water-soluble polymers to be used for enhanced oil recovery. It is known that adding polymers to the water used to get oil from a well to the surface helps to enhance the oil recovery from an existing well. This project focuses on investigating structure-performance relationships and new polymer structures to improve this mechanism. Shell initiated this project being carried out at the University of Groningen.

Two other possible projects that are presently being discussed with industry following the establishing of EMT concern special barrier films and coatings, and composites. But there are more opportunities that support the mission of DPI: to study and develop new and emerging sustainable polymer technologies in cooperation with industry and academia.

First DPI Fellow
Theo Dingemans

Polymers that can take the heat....

Polymers that can resist temperatures up to 400ºC and can be processed with existing methods will open up a new field of applications. Theo Dingemans, professor at Delft University of Technology, the Netherlands, wants to bring DPI to the top of this field of high-performance polymers.

Theo Dingemans explains his ambition. “It is possible to design high-performance polymer composites suitable for application at very high temperatures, for instance in airplanes and electronic devices. These composites make use of a unique class of liquid-crystal polymers and have outstanding structural properties. Some of these materials can couple these structural properties with a specific function and can be used in membranes for gas separation or in polymer-based photovoltaic cells. The development of such materials is a blind spot in the Netherlands and I want to change that by bringing DPI to the top in the field of high-performance polymers.”

Rising star

Dingemans is a rising star in polymer research in the Netherlands. He was appointed associate professor at Delft University of Technology in 2003 at the departments of Aerospace Engineering and Applied Sciences. In September 2009 he was also appointed Antoni van Leeuwenhoek Professor. Before 2003 he worked at NASA where he initiated research into a new class of liquid-crystal aromatic polymers, a field on which he is now building his research group in Delft. Dingemans: “Contrary to many commonly used polymers, these polymer chains consist of rigid benzene-based molecules. The high binding energy of the molecules make them thermally stable. The challenge, on the other hand, will be to make them processable.”

In aviation in particular there is great demand for new polymers to replace the synthetic polymers currently used. These polymers are crystalline, disintegrate at temperatures higher than 150ºC and are affected by solvents. According to Dingemans, the Netherlands has every chance to play a leading role in the 60 billion-euro market for high-performance polymers, a market expected to grow to 80 billion euros by 2015.

Dingemans wants to collaborate in the field of high-performance polymers with other groups inside and outside DPI. “These materials show great promise when combined with membrane technology, photovoltaic cells and other functional applications. I will do my best to bring these materials to new applications and new business. I am glad that DPI gives me this chance.”

Corporate Research

The role of the Corporate Research Programme is 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.

Start-up of Bio-Related Materials (BRM) Programme

Science clusters its strengths to push the boundaries of polymer research. Physicists and chemists joined forces to work on a programme in the field of bio-inspired polymers that is being funded by the Foundation for Fundamental Research on Matter (FOM), Dutch Polymer Institute (DPI) and Top Institute Food & Nutrition (TIFN). The aim of this collaboration is to learn how to better understand and control the organisation of natural and bio-inspired polymers. This can help enhance the quality of foods, new ingredients and plastics.

New Scientific Chairman

The Technology Area Corporate Research has welcomed Professor Martien Cohen-Stuart as new Scientific Chairman in succesion of Professor Thijs Michels.

Corporate Research
The link between theory and practice

Two former DPI researchers in the Corporate Research Technology Area, both still involved in DPI, one as industrial contact person, the other as a project leader, reflect on their past and present roles.

In the Corporate Research area, having as part of its mission to provide enabling science to all other Technology Areas, models are more common than in these other areas. The background of today's discussion partners already reflects this. Both are relatively young scientists at the beginning of their careers, one in industry at the end of the value chain, the other at a university at its beginning. Both have been working, and still are working, in the field of modelling polymer systems. They agree that modelling always has to have a strong link to experiments. As Tom Engels explains, "If you do not see for yourself what is happening in the process, you have no idea what to expect and do not know which relevant phenomena you have to incorporate in your models. So either you do experiments yourself or you must have a strong link to the experimentalists in your field of research." Jasper van der Gucht adds, "In literature you sometimes find results of people who develop models in isolation. You can only wonder about their conclusions and I also have my doubts about the relevance of the work they are doing."

Apparently, also in Corporate Research, by nature the DPI Technology Area with the most theoretical impact, the link to practical problems must be present. It also shows in the character of the work Engels does at DSM. When he compares it to his work at the university, it is still related to models but less to the development of models and more to model implementation. "Scientific progress leads to new insights that, in turn, cause models to become more advanced. We look to what extent these models are applicable to our materials portfolio. And we do this in direct contact with our application development department, which asks us for new fundamental insights to help solve practical problems. We form the link between DSM as the materials producer and the end user."

Threshold

The only way for companies to distinguish themselves is by being leading both in the materials and in customer application support. However, since it is not feasible to cater for everything alone, companies certainly need to be aware of the latest developments and have people in house that are able to judge the value of models. DSM offers Engels enough opportunity to visit universities to keep himself and, through him, his company well informed. He regularly visits Han Meijer's group and DPI meetings enable him to establish contacts with other universities. In that respect he sees a difference with his PhD work. The threshold for getting into contact with

Discussion partners

Jasper van der Gucht is assistant professor at Wageningen University, the Netherlands. After he finished his PhD-project in DPI's Corporate Research Technology Area in 2004 at the same university, he worked for two and a half years at the Institut Curie in Paris, France, in the field of polymers in living matter. In 2006 he returned to Wageningen and worked there first as a postdoc researcher and since 2007 as assistant professor. His work is related to both experiments and models of polymer networks based on weak interaction. His main interest is in the physical properties of the polymers but, of course, there is strong interaction with the people who synthesise the materials. He is the academic contact person for a number of DPI projects, most of which are in this field.

Tom Engels finished his PhD in Han Meijer's group at the Eindhoven University of Technology, the Netherlands, in 2008. His work was related to the modelling of the mechanical properties of polymer glasses and their performance in applications. In particular, he investigated the influence of processing conditions such as the mould temperature in injection moulding on the performance of polymer products. Currently, he is head of the Materials Science Centre of DSM and is involved in investigating the mechanical properties of polymers in general and in applications. Although most of the work is again related to mechanics and modelling, the direct interaction with the chemists who synthesise the polymers is much stronger than during his PhD work. He is the industrial contact person for a number DPI projects.

Tom Engels and Jasper van der Gucht

people he meets through DPI is now assurringly low. "During your PhD project, you tend to be so focused on your specific subject that you are not so open to others. Now I am, I have to be, and because of the regular DPI meetings the threshold for getting into contact with whoever I want is very low."

When asked about his contacts and DPI's role in them, Van der Gucht says, "When I did my PhD, DPI was the sole means of getting into contact with others in the value chain. Companies tend not to contact us directly, which is quite understandable since our fundamental work puts us at the very beginning of the value chain and so the direct link to applications is not all that easy to find. Still, through DPI we find out what others do and this has resulted in cooperation, usually with other university groups. These contacts are becoming more intensive."

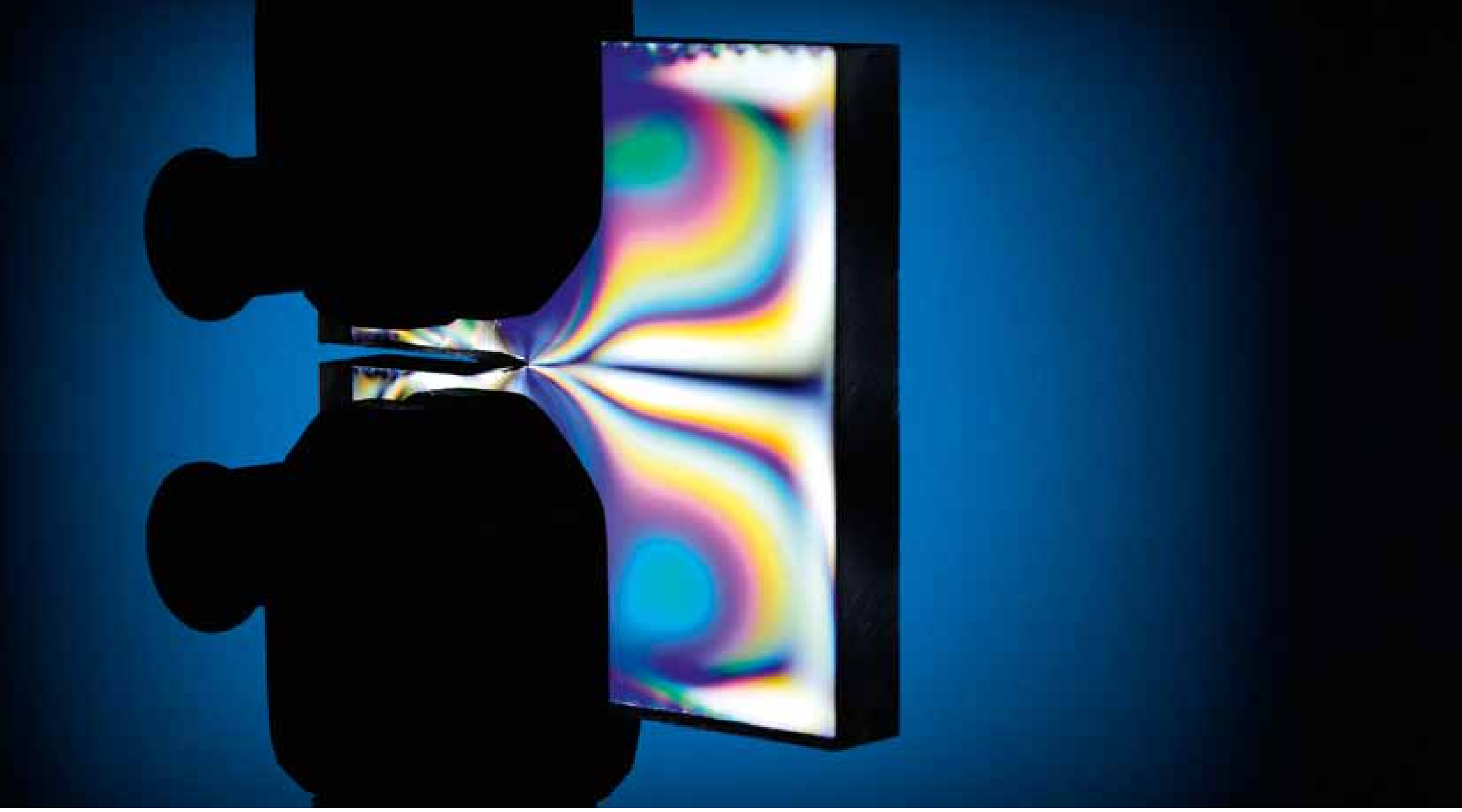
Things go faster in industry, Engels notes – they have to go faster. When he had contacts with a company about commercialising the model he had developed during his PhD work, he really appreciated the fact that his work would end up directly in a product that others would use. After the first beta release a corporate takeover followed by the crisis put everything on hold. That is industry – all or nothing. But now, looking at this from an industrial standpoint, he understands this better. At university you have ample time to examine a subject from all angles and if it does not bring what you had expected, so be it. In industry you try to find out whether you may be taking the wrong path to solving a problem long before that. Engels: "The value chain is a chain, with a beginning and an end, for a reason. The people you need at the beginning and at the end are different, and they must stay at their respective ends. It does not benefit industry when universities develop tangible products. That's the corporate domain. Universities have to develop the fundamental insight, the tools with which we can tackle the problems and find solutions." As Van der Gucht adds, "That's exactly the reason I stayed in science. Our work contributes to products, but we do not develop them."

Output

For universities the results of projects are publications; for industry results help make a product, business or money, if you like. The interests of both parties do not always run parallel. Companies may want to keep promising results to themselves while scientists want to talk about them to colleagues at conferences. Both Engels and Van der Gucht are of the opinion that the stricter rules at DPI – the decision to publish or not must be taken within a few weeks – helps to ease this tension. Companies that do not always want to provide all the information they have about a subject in a DPI project are difficult to work with. Engels puts it like this: "You cannot cooperate on the basis of incomplete information. You have to trust each other. This is an extra reason for DPI projects to avoid applications and concentrate on developing tools and insight. Universities have to make sure that they call the tune, not industry. The risk that

"Our work contributes to products, but we do not develop them."

Jasper van der Gucht



a project goes too far in the direction of one specific application should be avoided." Van der Gucht is keen to confirm his industrial colleague's opinion. The output of DPI projects for industry includes the highly educated researchers who can be recruited by industry, something that both Van der Gucht and Engels appreciate from their respective standpoints.

Cooperation between industrial and academic partners is usually restricted to DPI meetings but could be intensified by doing experiments together. Van der Gucht: "We have specific equipment while the equipment at industrial labs is sometimes quite different. Doing experiments together not only extends the possibilities but also helps to intensify the contacts." Monique Bruining, DPI's Programme Area Coordinator, suggests, "Maybe we should incorporate working on site in industry in the projects to optimise synergy between industry and the academic environment."

Reflecting on these ideas, Engels suggests something like a Yellow Pages of equipment and experts that you can use to access the broad variety of expertise and know-how available within the DPI community. When thinking about more improvements in DPI's way of working Van der Gucht says: "More cross fertilisation between the different Technology Areas could be supported by making it possible to attend the meetings or lectures of other Technology Areas in parallel sessions. We have the annual meeting where everybody attends, but lectures there are more general interest. However, I do realise the possible difficulty of organising it in that way." A regular newsletter with information about what is going on in other Technology Areas could perhaps help.

"Universities develop fundamental insight and tools that industry can use to tackle problems and find solutions."

Tom Engels

Objectives

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. Several sub-clusters have been designated.

Subprogrammes

Enabling Science

- Polymer characterisation: surfaces and interfaces (applying mainly microscopic techniques) and molecular characterisation (SEC techniques on cross-linked architectures and networks amongst others, and analysis of molar mass 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 requirements of sustainability, durability and bio-related polymer systems.

Infrastructure

Corporate Research also strengthens the research infrastructure by investing in equipment, 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.

Bio-Related Materials (BRM) programme

Together with FOM, DPI and TIFN we have established an Industrial Partnership Programme on bio (-related) materials. This programme aims to understand how to get from the scale of complexes and aggregates to the mesoscopic scale, taking account of both the time-dependent interactions and structures in their chemical detail and the resulting dynamic and spatially varying mesoscale physical properties.

Facts and figures

Partners from industry

- All DPI partners take part in Corporate Research

Partners from the research world

- Delft University of Technology
- Deutsches Kunststoff Institut
- Eindhoven University of Technology
- FOM
- Leibniz-Institut für Polymerforschung Dresden
- Polymer Technology Group
- Radboud University Nijmegen
- Stellenbosch University
- TIFN
- University of Amsterdam
- University of Groningen
- University of Naples Federico II
- University of Twente
- Wageningen University

Budget and organisation

Total expenditure in 2009 was € 1.81 million (budget € 2.53 million). An amount of € 281k was spent on equipment. A total of 12.8 FTEs were allocated, distributed over 28 researchers. Dr.Ir Monique Bruining was Programme Area Coordinator.

Publications and inventions

The research programme of the Technology Area generated one thesis and 17 scientific publications.

Detailed information on page 83.

Towards (more) valorisation of research

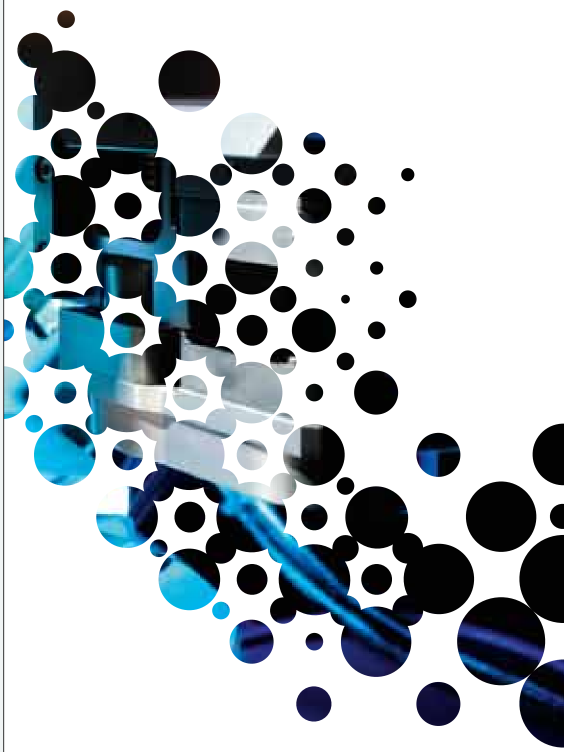
On 9 September 2009 DPI Managing Director Jacques Joosten and DPI Value Centre Managing Director Arie Brouwer signed a contract regarding the valorisation of research. Although the main goal of DPI's research programme is not to build up a large patent portfolio, this academic research with a focus on industry needs has, since the early days of DPI, led to many inventions that have resulted in patent applications (some of which have been granted). The first claimants to this intellectual property (IP) are the partner companies of the Technology Areas where the invention was created, and the knowledge institute involved. In the event that the partners see no fit with their own business and show no interest in purchasing the patent application, parties outside the DPI community can be approached to explore the business opportunities further.

That is where DPI Value Centre steps in. It selects the most promising technologies and investigates business opportunities to make a deal with a company to further the development and commercialisation of the technology created within the DPI research programme. In order to facilitate this, DPI and DPI Value Centre have now signed an Evaluation License and Option Agreement, giving DPI Value Centre the exclusive right to evaluate and test the technologies and, upon positive evaluation, purchase them from DPI. Currently DPI Value Centre is using its licence to investigate business opportunities in the areas of liquid-crystal applications and the catalysis of polyolefins.

The DPI Value Centre is, along with DPI, one of the main executors of the Polymer Innovation Programme of the Dutch Ministry of Economic Affairs. DPI Value Centre is an independent foundation whose main goal is to help companies with innovations related to polymers, for example, by giving (start-up) companies advice in technology development, new business creation and managing a patent portfolio. It is linked to DPI and, amongst other things, shares with DPI a mutual network and knowledge base. The main target group of DPI Value Centre are small and medium-sized companies.

Citation Impact factor and Journal Impact factor

Every two years the Dutch Observatory of Science and Technology (NOWT) surveys the Citation Impact factor. Annually DPI calculates its own average Journal Impact factor. Both scores have increased since the last score determination, to 2.19 for the Citation Impact and 4.18 for the average Journal Impact factor.



Citation Impact factor

The Dutch Polymer Institute scored a Citation Impact factor of 2.19 for its scientific publications. This means that the quality of DPI publications is twice the average in the field. In 2008 DPI scored a Citation Impact factor of 2.08.

Jacques Joosten, Managing Director, is very pleased with the results achieved. “The report shows that it is possible to achieve top scientific results based on application inspired problems. Of course, the academic partners have achieved this great result and it shows we have the right partners in our network.”

Journal Impact factor

In 2009 DPI publications let to an averaged Journal Impact factor score of 4.18, a figure that confirms a continuation of the upward line in the Journal Impact score. The factor is a score calculated according to the value attributed of the scientific journals that contain the articles.

Since 2004, when DPI started with a averaged Journal-Impact factor of 3.16 this score has increased annually. The number of scientific publications in 2009 increased slightly compared to the previous year, from 165 in 2008 to 176 articles. Neither the Large-Area Thin-Film Electronics nor Emerging Technologies Technology Areas had any scientific publications in view of the fact that they had just been launched.

Output per area 2009

Polyolefins

Projects

#387: Advanced characterization of Ziegler-Natta catalysts on flat surfaces

#547: Experimental and computational study of high pressure fluidization of polymeric materials

#632: Experimental and computational study of dense gas-fluidised beds with liquid injection

#633: Understanding structure/performance relationships for non-metallocene olefin polymerization catalysts

#634: Characterization of the specific density of semi-crystalline polymers

#635: Measuring active site concentration of olefin polymerization catalysts

#636: The study of the role of the support, support preparation and initial conditions on olefin polymerization

#637: Role of entanglements on the flow behavior of polyolefins

#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 systems

#641: High-Troughput Computational Pre-Screening of Catalysts

#642: Development of High-Temperature 2-Dimensional Liquid Chromatography for the Characterization of Polyolefins

#644: High Throughput Experimentation Approaches to Ziegler-Natta-type catalytic olefin polymerizations

#646: New Functionalized Materials by Rh and Pd Mediated Carbene Homo-Polymerization and Olefin/ Carbene Co-Polymerization

#674: Rheology Control by Branching Modeling

#706: Intrinsic effect of catalyst immobilization techniques on catalyst activity and selectivity

#707: Advanced Static and Dynamics Modeling of Heterogeneous Ziegler-Natta Catalytic Systems

#708: Structure-property relations of olefinic block copolymers

#709: Integrated Models for PolyOlefin Reactors

#710: Linking chemically specific structure information to physical properties of polyolefins

#711: Mass transfer & kinetics in heterophasic copolymerization of propylene

#712: Elucidation and control of the active surface structure and chemistry in MgCl2-supported Ziegler-Natta catalysis: an integrated experimental and computational approach

#714: Putting values to a model for Flow Induced Crystallization

Theses

S.N. Keelapandal
Fines generation in polyethylene polymerization

M.D. Daftaribesheli
Comparison of catalytic ethylene polymerization in slurry and gas phase

J. Flapper
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#637: Y.D.M. Champouret, A.V. Pandey, S. Rastogi
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Performance Polymers

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#356: Investigations on Blending, Reinforcement and Curing in EPDM/ NR/ BR Rubber Compound for the Tire Side-Wall Application

#432: Improved catalysts for controlled propene oxide polymerization

#537: Sub-micrometer thermoplastic vulcanizates (2)

#580: Modification/ Crosslinking of saturated elastomers using functional-ised azides

#581: Long-term heat (thermo-oxidative) stability of engineering plastics

#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

#584: Micro Friction and Wear of Polymers

#585: The “sticky blocks” concept, furnishing EPs with enhanced processability

#614: Consequences of molecular degradation in load-bearing components

#616: Flow of particle filled viscoelastic fluids in complex geometries

#623: Fundamental aspects of Nanocomposites

#647: New Functionalized Materials by Rh and Pd Mediated Carbene Homo-Polymerization and Olefin/Carbene Co-Polymerization

#648: Graphene-based nanocomposites- A study on the potential of grapheme nanosheets as an alternative low-cost filler for multi-functional polymeric materials

#649: Thermoplastic elastomers via living radical graft polymerzation from Functional elastomers

#650: Molecular Modelling of Cavitation in Polymer Melts and Rubbers

#651: Smart Surface Modifiers for Engineering Plastics

#652: Rubber/silica nano-composites via reactive extrusion

#653: Biodegradable Thermoplastic Polyurethanes from Renewable Resources

#654: Effects of the nano-scale structure of polymer surfaces on their adhesion and friction

#656: Green Rigid blocks for Engineering plastics with enhanced performance

#664: Sustainable elastomers and Thermoplastics by short fibre reinforcement

#671: Optimized plastication in extruders for better economy and product properties

#696: Self healing thermo-plastic polymers based on in-situ solvent deployment

#697: Creating multiple distributed healing in fibre composites using compart-mented liquid filled fibres

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H. Zhang
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S.J. Ilinca
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Wear 267 (1-4), 669-678

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Surface Properties of Poly(ethylene oxide)-Based Segmented Block Copolymers with Monodisperse Hard Segments
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Sub-micrometer thermoplastic vulcanizates obtained by reaction-induced phase separation of miscible mixtures of poly-(ethylene) and alkyl methacrylates
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F. Lahmar, C. Tzoumanekas, *D.N. Theodorou, B. Rousseau*
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A. Marcellan, O. Bondil, C. Boue, A. Chateauminois
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M. Mikrut, A. Wilk, J.W.M. Noordermeer, G. Verbeek
Silicone Rubber Tack I: Relation to Network Structure
Journal of Adhesion 85 (7), 395-412

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A.A. Verhoeff, R.H.J. Otten, P. van der Schoot, H.N.W. Lekkerkerkert
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E. Vinken, A.E. Terry, A.B. Spoelstra, C.E. Koning, S. Rastogi
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Analytica Chimica Acta 654, 11-19

W. Daud, H.E.N. Bersee, S. J. Picken, A. Beukers
Layered silicates nano-composite matrix for improved fiber reinforced composites properties
Composites Science and Technology 69 (14), 2285-2292

J. Devroede, R. Duchateau, C.E. Koning
The Synthesis of Poly(butylene terephthalate) from Terephthalic Acid, Part II: Assessment of the First Stage of the Polymerization Process
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G. Van Lier, G. Van Assche, H.E. Miltner, N. Grossiord, C.E. Koning, P. Geerlings, B. Van Mele
Theoretical analysis of carbon nanotube wetting in polystyrene nanocomposites
Physical Chemistry Chemical Physics 11 (47), 11121-11126

R.A. Orza, P.C.M.M. Magusin, V.M. Litvinov, M. van Duin, M.A.J. Michels
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C. Tzoumanekas, F. Lahmar, B. Rousseau, D.N. Theodorou
Onset of Entanglements Revisited. Topological Analysis
Macromolecules 42 (19), 7474-7484

T.A.P. Engels, L.C.A. van Breemen, L.E. Govaert, H.E.H. Meijer
Predicting the long-term mechanical performance of polycarbonate from thermal history during injection molding
Macromolecular Materials Engineering 294(12), 829-838

T.A.P. Engels, B.A.G. Schrauwen, L.C.A. van Breemen, L.E. Govaert
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Filed patent applications

#583: S.G. Vaidya, S. Rastogi
Preparation of a conductive polymer composition

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

Reported inventions

#580: A.J. Zielinska, J.W.M. Noordermeer, M. van Duin, A.G. Talma, P. Kraan
Crosslinking of thermoplastic vulcanizates

#583: S.G. Vaidya, S. Rastogi
Preparation of a conductive polymer composition

#648: D. Tang, D.J. Mulder, C.E. Koning
Biodegradable termoplastic polyurethanes

#648: E.E. Tkalya, S. van Berkel, C.E. Koning
Graphene-polymer nano-composites

#653: S. Thiyagarajan, D.S. van Es, J. van Haveren, L. Gootjes, W. Vogelzang
Biodegradable termoplastic polyurethanes

#656: L. Jasinska, J. Wu, D.S. van Es, C.E. Koning
Biobased building blocks for engineering plastics

#656: J. Wu, D.S. van Es, J. van Haveren
Biobased building blocks for engineering plastics

Functional Polymer Systems

Projects

#518: Singlet to triplet exciton formation in polymeric light-emitting diodes (LED/FET)

#522: Towards a Push-and-Pull Muscle Fibre: An Electroactive Polymer Composite

#524: Polymer-fullerene solar cells and low band-gap donor materials for photovoltaics (combined #524 and #527)

#529: Conductive block copolymer systems with extremely low wt% of Carbon Nanotubes

#530: Photo-Embossing of Polymeric Bi-Layers with Dual Functionalities

#532: Polymer MEMS- an integrated approach towards activated surfaces for micro-fluidic 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 inter- and /or intramolecular 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 polymerzinc oxide solar cells from novel organozinc precursors

#661: Structurally defined conjugated dendrimers and hyperbrached polymers in solar cells

#677: Understanding inter-actions between polymer surfaces and proteins: towards a ideal polymer biosensor substrate material

#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: Photoembossed gratings for efficient light harvesting in organic solar cells

Theses

E.C.P. Smits
Ambipolar and self-assembled organic electronics

M.C. Hermant
Manipulating the percolation threshold of carbon nanotubes in polymeric composites

K. Hermans
Latent structured thermally developed reliefs

M.M. Mandoc
Device physics of all-polymer solar cells

M. Lenes
Polymer: fullerene solar cells

A.P. Zoombelt
Pi-Conjugated Polymers for Photovoltaics

F. Fahrni
Magnetic polymer actuators for microfluidics

Scientific publications

K. Asadi, Y. Wu, F. Gholamrezaie, P. Rudolf, P.W.M. Blom
Single-Layer Pentacene Field-Effect Transistors Using Electrodes Modified With Self-assembled Monolayers
Advanced Materials 21 (41), 4109--4114

J.C. Bijleveld, M. Shahid, J. Gilot, M.M. Wienk, R.A.J. Janssen
Copolymers of Cyclopentadithiophene and Electron-Deficient Aromatic Units Designed for Photovoltaic Applications
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R.J. de Vries, S.L.M. van Mensfoort, V. Shabro, S.I.E. Vulto, R.A.J. Janssen, R. Coehoorn
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Micro-fluidic actuation using magnetic artificial cilia
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W.J. Grzegorczyk, P. Ganesan, T.J. Savenije, S. van Bavell, J. Loos, E.J.R. Sudholter, L.D.A. Siebbeles, H. Zuilhof
Photoconductance of Bulk Heterojunctions with Tunable Nanomorphology Consisting of P3HT and Naphthalene Diimide Siloxane Oligomers
Journal of Physical Chemistry C 113 (18), 7863-7869

K. Hermans, S.Z. Harnidi, A.B. Spoelstra, C.W.M. Bastiaansen, D.J. Broer
Rapid, direct fabrication of antireflection-coated microlens arrays by photoembossing
Applied Optics 47 (35), 6512-6517

M. Lenes, F.B. Kooistra, J.C. Hummelen, I. Van Severen, L. Lutsen, D. Vanderzande, T.J. Cleij, P.W.M. Blom
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J.D. Kotlarski, S.C. Veenstra,
J. Sweelssen, M.M. Koetse,
B. de Boer, P.W.M. Blom
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Organic Electronics 10 (7), 1275-1281

S.D. Oosterhout, M.M. Wienk,
S.S. van Bavel, R. Thiedmann,
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D. Hertel, K. Meerholz, E. Holder
Efficient Synthesis of Carbazolyl- and Thienyl-Substituted beta-Diketonates and Properties of Their Red- and Green-Light-Emitting Ir(III) Complexes
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S. van Bavel, E. Sourty,
G. de With, K. Frolic, J. Loos
Relation between Photoactive Layer Thickness, 3D Morphology, and Device Performance in P3HT/PCBM Bulk-Heterojunction Solar Cells
Macromolecules 42 (19), 7396-7403

S. van Bavel, E. Sourty,
G. de With, S. Veenstra, J. Loos
Three-dimensional nanoscale organization of polymer solar cells
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S.S. van Bavel, E. Sourty,
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Three-Dimensional Nanoscale Organization of Bulk Heterojunction Polymer Solar Cells
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Conductivity of Crosslinked Low Surface Energy Epoxy Coatings
Journal of Polymer Science Part B-Polymer Physics 47 (4), 366-380

A.P. Zoombelt, M. Fonrodona,
M.G.R. Turbiez, M.M. Wienk,
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A.P. Zoombelt, J. Gilot,
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Effect of Extended Thiophene Segments in Small Band Gap Polymers with Thienopyrazine
Chemistry of Materials 21 (8), 1663-1669

L.H. Fischer, M.I.J. Stich,
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M. Schaferling
Red- and Green-Emitting Iridium(III) Complexes for a Dual Barometric and Temperature-Sensitive Paint
Chemistry-a European Journal 15 (41), 10857-10863

M.C. Hermant, B. Klumperman,
C.E. Koning
Conductive Pickering-poly(high internal phase emulsion) composite foams prepared with low loadings of single-walled carbon nanotubes
Chemical Communications (19), 2738-2740

M.C. Hermant, B. Klumperman,
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C.E. Koning
Lowering the percolation threshold of single-walled carbon nanotubes using polystyrene/poly(3,4-ethylene-dioxythiophene): poly(styrene sulfonate) blends
Soft Matter 5 (4), 878-885

M.C. Hermant, M. Verhulst,
A.V. Kyrylyuk, B. Klumperman,
C.E. Koning
The incorporation of single-walled carbon nanotubes into polymerized high internal phase emulsions to create conductive foams with a low percolation threshold
Composites Science and Technology 69 (5), 656-662

M. Lenes, M. Morana,
C.J. Brabec, P.W.M. Blom
Recombination-Limited Photocurrents in Low Bandgap Polymer/Fullerene Solar Cells
Advanced Functional Materials 19 (7), 1106-1111

M. Mastalerz, V. Fischer,
C.Q. Ma, R.A.J. Janssen,
P. Bauerle
Conjugated Oligothienyl Dendrimers Based on a Pyrazino[2,3-g]quinoxaline Core
Organic Letters 11 (20), 4500-4503

S.G.J. Mathijssen, E.C.P. Smits,
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S.A. Ponomarenko, A. Moser,
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M. Kemerink, R.A.J. Janssen,
D.M. de Leeuw
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Nature Nanotechnology 4 (10), 674-680

Y.Y. Yimer, P.A. Bobbert,
R. Coehoorn
Charge transport in disordered organic host-guest systems: Effects of carrier density and electric field
Synthetic Metals 159 (21-22), 2399-2401

P. Zacharias, M.C. Gather,
A. Kohnen, N. Rehmann,
K. Meerholz
Photoprogrammable Organic Light-Emitting Diodes
Angewandte Chemie-International Edition 48 (22), 4038-4041

A.P. Zoombelt, M.A.M. Leenen,
M. Fonrodona, Y. Nicolas,
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Polymer 50 (19), 4564-4570

H.A. Every, L. van der Ham,
S.J. Picken, E Mendes
Spontaneous homeotropic alignment in films of rigid-flexible polyelectrolyte complexes
Soft Matter 5 (2), 342-345

D.S.H. Charrier, T. de Vries,
S.G.J. Mathijssen, E.J. Geluk,
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R.A.J. Janssen
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Organic Electronics 10 (5), 994-997

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H.P.A. Heuts, B. Klumperman,
A.M. van Herk, C.E. Koning
Influence of the molecular weight distribution on the percolation threshold of carbon nanotube-polystyrene composites
E-Polymers –

E. Sliwinska, S. Mansurova,
U. Hartwig, K. Buse, K. Meerholz
Effect of co-sensitization in new hybrid photo-refractive materials based on PVK polymer matrix and inorganic LiNbO3 nano-crystals
Applied Physics B-Lasers and Optics 95 (3), 519-524

C.A. Strassert, M. Otter,
R.Q. Albuquerque, A. Hone,
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Photoactive Hybrid Nanomaterial for Targeting, Labeling, and Killing Antibiotic-Resistant Bacteria
Angewandte Chemie-International Edition 48 (42), 7928-7931

P.A. Van Hal, E.C.P. Smits,
T.C.T. Geuns, H.B. Akkerman,
B.C. De Brito, S. Perissinotto,
G. Lanzani, A.J. Kronemeijer,
V. Geskin, J. Cornil,
P.W.M. Blom, B. De Boer,
D.M. De Leeuw
Upscaling, integration and electrical characterization of molecular junctions
Nature Nanotechnology 3 (12), 749-754

J. Perelaer, K. Hermans,
C.W.M. Bastiaansen, D.J. Broer,
U.S. Schubert

Photo-embossed Surface Relief Structures with an Increased Aspect Ratio by Addition of Kinetic Interfering Compounds
Journal of Photopolymer Science and Technology 22 (5), 667-670

Filed patent applications

#532: C.L. van Oosten, D.A. Nowak, C.W.M. Bastiaansen, D.J. Broer, Y. Han, R.P. Sijbesma, J.P. Teunissen, K. Pacheco
Multifunctional optical sensor

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

Reported invention

#624: F. Gholamrezaie, S.G.J. Mathijssen, E.C.P Smits, T.C.T. Geuns, P.A. van Hal, D.M. de Leeuw
Semiconducting self assembled monolayers

Coatings Technology

Projects

#439: Correlation of molecular changes, physical parameters and product properties of selected coatings in early stages utilizing a novel characterization approach

#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 (SF)-experiments and Scheutjens-Fleer (SF)-theory

#565: Thiol-ene based 2-pack-in-1-pot waterborne coating

#570: Self-Stratifying Antimicrobial Coatings (SAM Coat)

#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

#675: Drying of a waterborne coating: spontaneous phase inversion in jammed systems

#676: UV to daylight curing of organic coatings

Theses

J. Sprakel
Physics of Associative Polymers; bridging time and length scales

P. Malanowski
Weathering of aromatic polyester coatings

Scientific publications

P. Malanowski, S. Huijser, R.A.T.M. van Benthem, L.G.J. van der Ven, J. Laven, G. de With
Photodegradation of poly(neopentyl isophthalate) part I: Laboratory and outdoor conditions
Polymer Degradation and Stability 94 (11), 2086-2094

J. Sprakel
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Langmuir 25 (12), 6923-6928

J. Sprakel, E. Spruijt, J. van der Gucht, J.T. Padding, W.J. Briels
Failure-mode transition in transient polymer networks with particle-based simulations
Soft Matter 5 (23), 4748-4756

B.A.J. Noordover, A. Heise, P. Malanowski, D. Senatore, M. Mak, L. Molhoek, R. Duchateau, C.E. Koning, R.A.T.M. van Benthem
Biobased step-growth polymers in powder coating applications
Progress in Organic Coatings 65 (2), 187-196

A. Foyet, T.H. Wu, A. Kodentsov, L. van der Ven, G. de With, R. van Benthem
Impedance evaluation of permeability and corrosion of Al-2024 aluminum alloy coated with a chromate free primer
Progress in Organic Coatings 65 (2), 257-262

A. Foyet, T.H. Wu, L. van der Ven, A. Kodentsov, G. de With, R. van Benthem
Influence of mixing ratio on the permeability of water and the corrosion performance of epoxy/amine coated un-pretreated Al-2024 evaluated by impedance spectroscopy
Progress in Organic Coatings 64 (2-3), 138-141

P. Malanowski, S. Huijser, F. Scaltro, R.A.T.M. van Benthem, L.G.J. van der Ven, J. Laven, G. de With
Molecular mechanism of photolysis and photooxidation of poly(neopentyl isophthalate)
Polymer 50 (6), 1358-1368

Filed patent applications

#657: M.A. Cohen Stuart, F.A.M. Leermakers, M. Lemmers, J.H.B. Sprakel
Triblock copolymer gelators

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

Reported inventions

#657: M.A. Cohen Stuart, F.A.M. Leermakers, M. Lemmers, J.H.B. Sprakel
Triblock copolymer gelators

#658: Y. Li, R.A.T.M. van Benthem, J. van Haveren, C.E. Koning
Polyurethane dispersions

High-Throughput Experimentation

Projects

#400: New Thin Film and dot preparation techniques (inkjet and dispensing techniques), thin layer applications, mixing processes

#405: Development and application of new tools based on the AFM technology such as thermal spectroscopy, conductivity measurements, hardness and friction investigation etc.

#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 and upgrade synthesizers/standard characterization (follow-up proposal for the core programme #360)

#500: Development of integrated knowledge capture systems for combinatorial materials and polymer research: a uniform platform approach for the HTE/CMR cluster

#501: Fast and automated development and optimization of polymeric materials by combinatorial compounding and high throughput screening

#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 at the Nanoscale

#543: Polymer manufacturing using new approaches

#546: Combinatorial discovery and optimization of photo-embossed polymeric bi-layers with dual functionalities

#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 investigations on well-defined (co)polymers with lower critical solution temperature (LCST) behavior

#613: Optimization of Acrylonitrile/Butadiene/ Stryrene (ABS) and Polycarbonate (PC)/ABS additive recipes by combinatorial compounding for UV stabilization

#619: Developing Polymer Ontologies

#620: Rapid-prototyping and inkjet printing using polyurethane precursons

#621: In-Stu preparatron of Polymer nanoblends

#622: Combinaterial screening of polymer solubility

#645: High Throughput Experimentation Approaches to Ziegler-Natta-type catalytic olefin polymerizations

#666: 3D Printing of Hydrogels Based 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

#669: HT Discovery of Polymers for Ambient Temperature H2 Storage

#670: Mechanical screening method a films for combinatorial compounding

#690: Libraries of poly (ethylene oxide)via parallel living anionic polymerization

Theses

J.M. Kranenburg
depth-sensing indentation and high-throughput experimentation on polymers and elastomers

C. R. Becer
Controlling Polymer Architectures

C. Ulbricht
Phosphorescent systems based on iridium(III) complexes

T. Erdmenger
Alternative routes and solvents in polymer chemistry - Microwave irradiation and ionic liquids

J. Perelaer
Microstructures Prepared via Inkjet Printing and Embossing Techniques

Scientific publications

C.R. Becer, R. Hoogenboom, U.S. Schubert
Click Chemistry beyond Metal-Catalyzed Cycloaddition
Angewandte Chemie-International Edition 48 (27), 4900-4908

A. Baumgaertel, C. Weber, K. Knop, A. Crecelius, U.S. Schubert
Characterization of different poly(2-ethyl-2-oxazoline)s via matrix-assisted laser desorption/ionization time-of-flight tandem mass spectrometry
Rapid Communications in Mass Spectrometry 23 (6), 756-762

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Clicking Pentafluorostyrene Copolymers: Synthesis, Nanoprecipitation, and Glycosylation
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Toward Main Chain Metallo-Terpyridyl Supramolecular Polymers: "The Metal Does the Trick"
Macromolecular Rapid Communications 30 (8), 565-578

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Tandem mass spectrometry of synthetic polymers
Journal of Mass Spectrometry 44 (9), 1277-1286

T. Erdmenger, C.R. Becer, R. Hoogenboom, U.S. Schubert
Simplifying the Free-Radical Polymerization of Styrene: Microwave-Assisted High-Temperature Auto Polymerizations
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C.A. Fustin, N. Lefevre, R. Hoogenboom, U.S. Schubert, J.F. Gohy
Surface micellization of poly(2-oxazoline)s based copolymers containing a crystallizable block
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J.F. Gohy, M. Chiper, P. Guillet, C.A. Fustin, S. Hoeppener, A. Winter, R. Hoogenboom, U.S. Schubert
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M. Gottschaldt, C. Bohlender, D. Muller, I. Klette, R.P. Baum, S. Yano, U.S. Schubert
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Prospects of Metal Complexes Peripherally Substituted with Sugars in Biomedicinal Applications
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P. Guillet, C.A. Fustin, C. Mugemana, C. Ott, U.S. Schubert, J.F. Gohy
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#501: M. Moneke, F. Becker, J. Barth
Apparatus for monitoring mechanical properties

#502: J.T. Delaney, U.S. Schubert
Printed structures on surfaces

#502: J.T. Delaney, U.S. Schubert
Electrically conducting surface structures

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

Reported inventions

#400/447: R. Eckardt, C.E. Hendriks, J. Perelaer, U.S. Schubert
Conductive polymer annealing

#502: A. Liberski, J.T. Delaney, U.S. Schubert
Miniaturization of reactions

#502: J.T. Delaney, A. Liberski, U.S. Schubert
Miniaturized hydrogel structures

#502: J.T. Delaney, A. Liberski, J. Perelaer, U.S. Schubert
Macroporous hydrogels

#502: A. Liberski, J.T. Delaney, J. Perelaer, U.S. Schubert
Printable conductive patterns

Bio-Inspired Polymers

Projects

#587: Keratins as cheap feedstock for novel self-organising oligomers and polymers

#599: Interaction of super-heated water with hydrogen bonded crystalline polymers: a computational approach

#602: Collagen inspired self-organizing materials

#603: Strengthening / Shielding of hydrogen bonding by Physical Process in the Presence of Salt or Ions

#604: Biomimetic polymers for the encapsulation of functional entities

#608: High molecular weight aliphatic polyesters by enzymatic polymerization for medical applications

#609: Advanced materials based on cellulose via novel reaction processes

#610: Combined MESAB/ MIMICKNAT proposal

#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 byenzymatic linking of food polysaccharides, food proteins and fatty acids

#688: Lessons from biomineralization: Self-Organizing and Mineralization-Directing Block Copolymers

#689: Bio-inspired hairy surfaces for actuation or sensing, produced with roll-to-roll technology

Thesis

J.A.W. Harings
Mediating and shielding of hydrogen bonding in amide-based (macro)molecules

Scientific publications

P.J. Skrzeszewska, F.A. de Wolf, M.W.T. Werten, A.P.H.A. Moers, M.A.C. Stuart, J. van der Gucht
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Thiol chemistry on well-defined synthetic polypeptides
Chemical Communications (24), 3612-3614

Large-Area Thin-Film Electronics

Projects

#618: Polymer light-emitting diodes with doped charge transport layers

#640: Engineering the morphology of organic (semi)-conductor layers

#659: Crosslinkable Semiconductors for Robust Polymer Electronics

#663: Initiated-chemical vapor deposition of polymer inter-layers for ultra high moisture diffusion barrier systems (POLYMOBAS)

#665: Composite stacked organic semiconductors: materials processing towards large area organic electronics

#704: Forming processes in metal oxide organic light-emitting diodes

Corporate Research

Projects

#446: Structured Fluids & Rheology in Processing

#578: Mechanical Properties without the Need of Mechanical Testing

#596: Chemically improved polysaccharides-detailed structure-property relationships

#597: Ultra-performance polymer separations

#598: Application of time resolved X-ray diffraction techniques for study on structural and morphological changes during polymerization and processing

#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 2-Dimensional Liquid Chromatograhpy for the Characterization of Polyolefins

#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

#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 visco-elasticy of elastomer-based nanocomposites

#702: Immobilization of molecular catalysts on well-defined flat model surfaces

#715: Novel Polyimide Architectures: Towards Membranes with Tunable Transport Properties

#717: All-aromatic heterocyclic liquid crystal polymers for photovoltaic applications

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#720: Nanomechanical characterization of supramolecular protein structures using atomic force microscopy

#721: Revealing the interplay between β-lactoglobulin unfolding, aggregation and cross-linking

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#723: Multiscale Structure and Mechanics of Collagenous Materials

#724: Molecular control over amyloid protein assembly by polyphenols

#725: Hybrid networks

#726: Cross-linked food proteins as hierarchical biopolymers

Thesis

P.J.A. Janssen
Morphology development in confined geometries

Scientific publications

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Structural Properties of Atactic Polystyrene of Different Thermal History Obtained from a Multiscale Simulation
Macromolecules 42 (1), 384-391

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Onset of Entanglements Revisited. Topological Analysis
Macromolecules 42 (19), 7474-7484

Emerging Technologies

Project

#716: Design of new chemical products (polymers and amphiphilics) for EOR

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 break-through 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.

Colophon

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