ICMS Highlights

Edition 1
September 2013

The fabric of life

INTERVIEW
/ Frank Baaijens

STORM

INTERVIEW
/ René Janssen

& more...

Institute for Complex Molecular Systems

TU/e Technische Universiteit **Eindhoven** University of Technology

Where innovation starts

ICMS Highlights

Dear reader,

Since the start of the Institute for Complex Molecular Systems in 2008, many striking results in science have been achieved and numerous lectures and workshops crossing the boundaries of disciplines have been organized.
Our members have published a large number of interdisciplinary papers in top Journals. We are also proud of the Gravity Grant (26.9 MEuro), that was awarded to researchers from ICMS, Institute for Molecules and Materials (Nijmegen) and Stratingh Institute (Groningen).
In the summer of 2012 ICMS moved to the renovated Ceres building. After settling down we have started an evaluation process on how to get even more out of the current setting, with many excellent scientists, dedicated experimental facilities and outstanding students connected.
Coming years ICMS will focus on two lines of research: functional molecular systems and bio-inspired engineering. We are very happy that Frank Baaijens will join the ICMS Board as associate scientific director. He will give direction to the bio-inspired engineering research.
The relationship with industry will be strengthened further to guarantee a good match between science and innovation. The education program for our master and PhD students will be broadened with professional and leadership skills to prepare them even better for a career in academic or industry science.
This is the first edition of ICMS Highlights, a magazine that will be published twice a year. It will give you insight into the progress made in science and in our organization. But most of all, our members will be in the spotlight – they are the heart of ICMS.

We hope you will enjoy reading,

Sagitta Peters
Managing director

Bert Meijer
Scientific director

Calendar

September 16, 2013, 11.30 hr
'Aan de Dommel' lecture by prof.dr.ir. Wil van der Aalst TU/e
Location: Zwarte Doos

October 4, 2013, 15.00 hr
'Aan de Dommel' lecture by prof.dr.ir. René Janssen TU/e
Location: Zwarte Doos

October 14, 2013, 11.00 hr
Lecture by dr. Sebastian Seiffert
Location: Ceres 0.31

October 28, 2013, 14.00 hr
'Aan de Dommel' lecture by prof.dr. Takuzo Aida
Location: Ceres 0.31

November 21, 2013, 10.30 hr
'Aan de Dommel' lecture by prof.dr.ir. Maarten Steinbuch TU/e
Location: Ceres 0.31

December 19, 2013, 11.30 hr
'Aan de Dommel' lecture by prof.dr.ir. Anthonie Meijers TU/e
Location: Zwarte Doos

January 23 & 24, 2014
ICMS Outreach Symposium
Location: Zwarte Doos

Content

Edition 1
September 2013

/ Frank Baaijens

The promise of bio-inspired engineering

In the last two decades, technology and biology have merged into bio-engineering, producing challenging questions and promising possibilities. An even fresher discipline is bio-inspired engineering, i.e. using nature as a source of inspiration and applying technology to create new technical concepts and applications in fields such as energy and healthcare. The last-mentioned subject is prof.dr.ir. Frank Baaijens' area of interest. From September 1 onwards he will use his expertise in bio-inspired engineering as associate scientific director of ICMS. His goals: connect brilliant scientists to explore and solve challenging (bio-) engineering questions.

Bio-engineering

Frank Baaijens: “Bio (inspired) engineering is a very complex scientific area. We now often approach it at the molecular level. Technology has evolved over the last years setting new standards in imaging and measuring at the molecular scale. The quality of models and simulations has improved enormously. Nowadays research groups are able to build complex molecules and small molecular systems. All this paves the way for bio (inspired) engineering.

The last months I encountered several inspiring studies in this area while working at the Wyss Institute (Harvard, Boston). For instance, I met a research group working on DNA origami. They are able to take the complex DNA-strands apart and rebuild them into new forms. They are now producing tiny simple 3D objects of DNA-material, but who knows, tomorrow they might be building little bio-factories performing autonomous recovery operations somewhere in the human body.”

Bio barriers

Bio-inspired engineering is a promising field, delivering a world of new possibilities to technology and - in the end - answers to pressing societal issues. Naturally, there are also hurdles to be taken. Frank Baaijens: “Fundamental knowledge and understanding of the biological processes is crucial. That is what I have experienced in my work. We have got to understand exactly what’s going on, make quantitative what we know qualitatively. Furthermore we have to look at all levels - molecular, cellular, tissue - in coherency. Sometimes we can understand things on a molecular level, but this doesn’t mean we understand things on the level of organs or the body as well. One of our major challenges is to effectively connect the different length and time scales. This is also subject of our work at ICMS.”

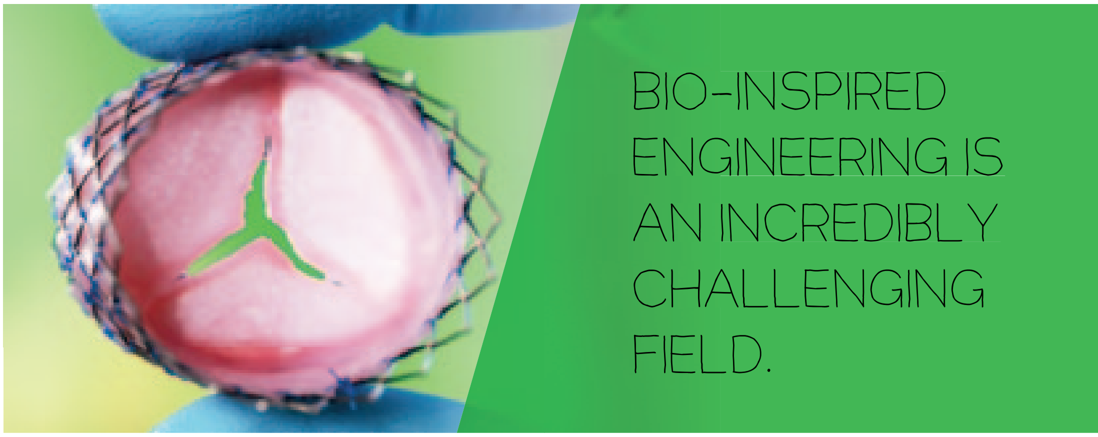
The institute

The Institute for Complex Molecular Systems encourages cross-fertilization between scientists. By bringing different disciplines together, with complex molecular systems as a common denominator, new ideas and concepts emerge. Frank Baaijens: “I think ICMS may claim a leading international position. We connect the best researchers from TU/e (and beyond) in dedicated research programs. Together we can expand our knowledge and build on true scientific achievements in this field. The institute has a recognizable signature and performs relevant research. It can contribute significantly to the international

visibility of the TU/e. As associate scientific director I will be responsible for our activities in bio-inspired engineering. And that's a thrill. We have a team of incredibly talented scientists aboard. It will be very interesting to work with them. And we don't start from scratch; we will build on research already in progress. This bio-inspired line of research that studies shapes and functionality in nature and use these principles to solve engineering problems.
We work on biomaterials and their use in regenerative medicine, aimed at the repair and regeneration of diseased or damaged tissues and organs. Our research on protein engineering enables visualization of molecular processes at the sub-cellular level as well as the three dimensional organization of engineered tissues. The investigation of protein-protein interaction may open new avenues for the pharmaceutical treatment of diseases.
An emerging area is called Organs-on-a-Chip. Here we mimic functions of tissues and organs at a small scale (a chip). The goal is to study the behavior of - and interaction between - the tissue samples under well-controlled conditions all at high throughput. We are particularly interested in the effect of interventions (e.g. mechanical, pharmaceutical or radiation) on cell and tissue functionality and tissue-tissue interaction.
Finally, we work on improving medical diagnosis. Techniques that can detect extremely low concentrations of protein in blood or plasma in order to develop very sensitive instruments.
In brief, we conduct interesting and relevant research at ICMS. And the good thing is that all the research areas can be connected very well."

Living heart valve

The research of Frank Baaijens is focused on regenerative medicine in particular. Within the project 1Valve his team develops a degradable prosthetic heart valve. Once implanted into the body, the valve attracts cells from the body, which develop into a new heart valve. The prosthetic valve becomes redundant and slowly degrades. 1Valve is already operational in a Petri dish (under laboratory conditions). Baaijens: "We try to team up with



the forces of nature as closely as possible, mimicking the required biological processes. The support, the scaffold, is a very porous bioactive material that needs to function as a heart valve at the time of implantation. Furthermore the scaffold has to dissolve at the right time without causing any complications. And it gets really challenging once the biological process is introduced. We must attract the required cells at the right time and in the right place. We use specific biological signals that also occur in other places in the body to accomplish this. This requires fundamental understanding of cell behavior and cell-cell and cell-matrix interaction within the tissue. You can imagine, this is a delicate process which must be carried out properly every single time."
The 1Valve project involves a consortium of research organizations. The research is funded by CVON (Cardiovasculair Onderzoek Nederland), which in turn is funded by the Nederlandse Hartstichting (Dutch Heart Society). Baaijens: "We gathered budget for five consecutive years of research. Soon after the end of this period we hope to be able to start with our first clinical trials."

Challenging and relevant

Baaijens: "Bio-inspired engineering is an incredibly challenging field. I find it scientifically very interesting because of the complexity of linking the diverse technical and medical disciplines. And in the end: if you manage to create something new - like a living heart valve - it will have great impact on a large group of patients. This is the side of science where I find my personal drive."

THESES ICMS

January 2013 – August 2013

1 **Responsive surface topographies**
Danqing Liu

January 31, 2013
Promotor:
prof.dr.ir. J.M.J. den Toonder

2 **Microscopic interpretation of wasserstein gradient flows**
Michiel Renger

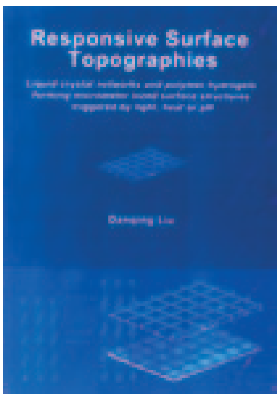
February 21, 2013
Promotor:
prof.dr. M.A. Peletier

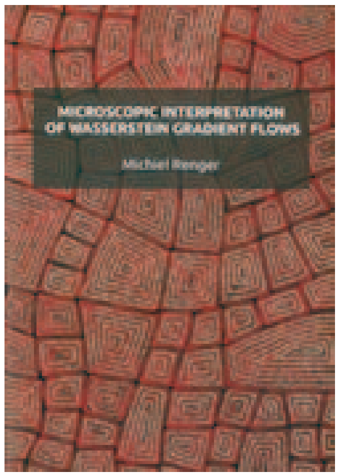
3 **Chemical biology approaches for nuclear receptors**
Sascha Fuchs

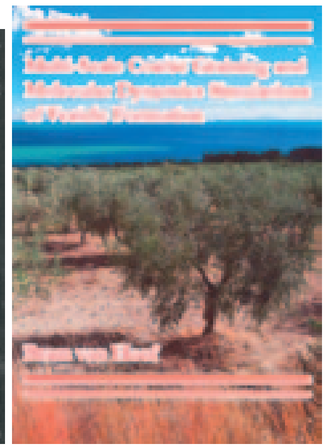
February 27, 2013
Promotor:
prof.dr.ir. L. Brunsveld

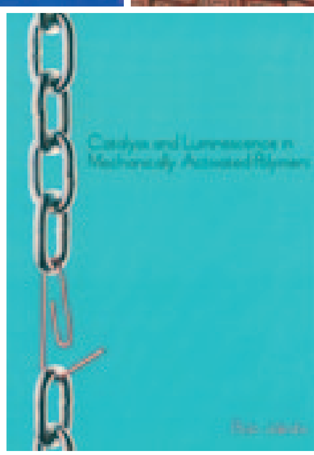
4 **Multi-scale coarse graining and molecular dynamics simulations of vesicle formation**
Bram van Hoof

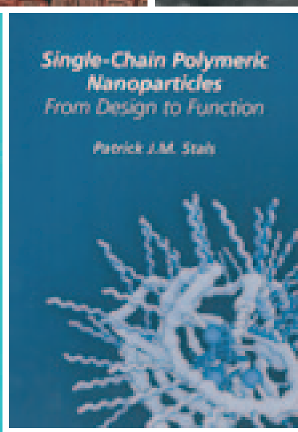
March 27, 2013
Promotores:
prof.dr. P.A.J. Hilbers
& prof.dr. R.A. van Santen

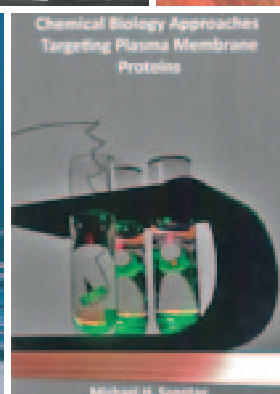












5 **Catalysis and luminescence in mechanically activated polymers**
Bob Jakobs

April 16, 2013
Promotor:
prof.dr. R.P. Sijbesma

6 **Single-chain polymeric nanoparticles From design to function**
Patrick J.M. Stals

June 25, 2013
Promotor:
prof.dr. E.W. Meijer

7 **Chemical biology approaches targeting plasma membrane proteins**
Michael H. Sonntag

June 27, 2013
Promotor:
prof.dr.ir. L. Brunsveld

NEWS, AWARDS & GRANTS

TAKUZO AIDA

first International ICMS Chair

Prof.dr. Takuzo Aida has been awarded the first International ICMS Chair in Chemistry for his major achievements in the field of functional supramolecular polymers.

Currently, prof.dr. Takuzo Aida (1956) is director for Riken Advanced Science Institute and Full Professor of the Department of Chemistry and Biotechnology, School of Engineering at the University of Tokyo. His research interests include electronic and optoelectronic soft materials, bioinspired dendritic macromolecules, molecular and biomolecular machines, and biorelated molecular recognition and catalysis. He has received many awards including the American Chemical Society Award in Polymer Chemistry in 2009.
He will stay at Eindhoven from October 18 till October 30, 2013.

ERC Advanced Grant for

RENÉ JANSSEN

Prof.dr.ir. René A.J. Janssen has been awarded an Advanced Grant of the European Research Council (ERC), worth 2.5 million Euros. The project of René Janssen and his group Molecular Materials and Nanosystems aims at the research and development of new principles to turn solar energy into fuels. prof.dr.ir. René A. J. Janssen is professor within the Department of Applied Physics and the Department of Chemical Engineering and Chemistry of the TU/e and has been appointed as University Professor since 2013.

TU/e Doctoral Project Award 2013 for

MAARTJE BASTINGS

Dr.ir. Maartje Bastings has received the TU/e Doctoral Project Award 2013 on July 5, 2013, for her thesis entitled Dynamic Reciprocity in Bio-Inspired Supramolecular Materials. The TU/e Doctoral Project Award 2013 consists of a certificate and an amount of 5,000 Euros awarded to the best TU/e doctoral project, completed in 2012. Maartje is a former member of ICMS and the Department of Biomedical Engineering. From November 2012 onward, Maartje is working as a postdoctoral fellow at the Wyss Institute / Harvard University in Boston, USA.

CERES

is Building of the Year

TU/e's Ceres building was named as Building of the Year by the Royal Institute of Dutch Architects (BNA) on May 16th. The building is home to the Institute for Complex Molecular Systems. A total of twelve buildings was nominated for the award. Ceres was designed by diederendirrix architects, Rob Meurders and Bert Dirrix.

In its report, the jury praises the transformation of the Ceres building. "Diederendirrix architects have given the former boiler house a new life in a way that's extremely intelligent, discrete en highly effective. The jury is very impressed, and regards the transformation from a boiler house into a pleasant, light area for people to work in as an absolute tour de force, with no out of place signs of all the work that has been done on the building."

Ceres (which stands for Central Energy and REgulator Station) was officially opened in October 2012. Until 2006 it provided TU/e with hot water and heating. The historical and industrial character of Ceres has remained largely intact, as has the 70 meter high brick chimney which stands next to the building. The Catalyst and MetaForum buildings at TU/e were also on the list of participants; the latter received an honorable mention in the South Region.

LORENZO ALBERTAZZI

first ICMS Fellow

Because of his excellent scientific track record in an interdisciplinary field of science and engineering, dr. Lorenzo Albertazzi has been awarded an ICMS Fellowship. The ICMS Fellowship gives young scientists maximal possibilities to grow and to define their own academic career within an existing research group. In the next three years Lorenzo will work in the group of Bert Meijer connecting supramolecular biomaterials with biophysical techniques including super resolution microscopy (STORM).

ECHO STIP grants for

TOM DE GREEF & ILJA VOETS

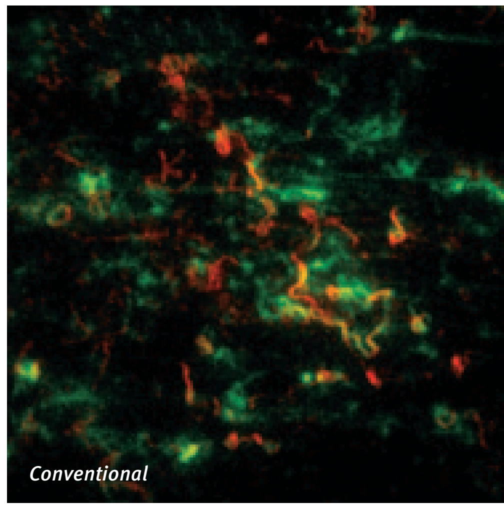
The Netherlands Organization for Scientific Research (NWO) has awarded dr.ir. Tom de Greef and dr.ir Ilja Voets both an ECHO-STIP grant of 260,000 Euros. Ilja Voets has received the grant for her planned research on supramolecular colloids: multivalent particles with switchable and orthogonally selective 'sticky' interactions. Tom de Greef will work on engineering synthetic cell-free biochemical circuits using a molecular networking strategy.

STORM

reveals hidden features of supramolecular polymers

In the hands of the first ICMS fellow, Lorenzo Albertazzi (see page 9), in the group of Bert Meijer the challenge has been taken up to image self-assembled structures in such a way that the underlying behavior of these molecules can be understood.

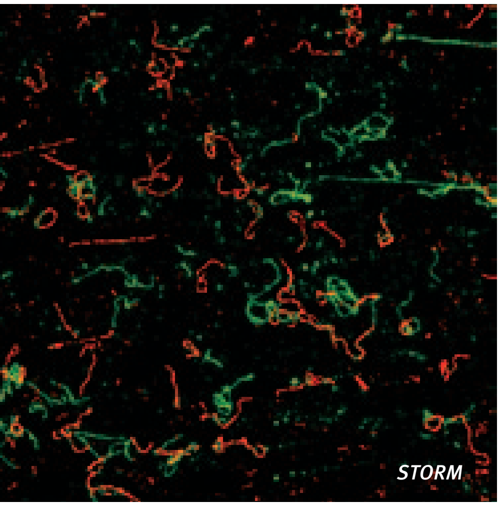
After ample discussion, one has decided to use STORM, Stochastic Optical Reconstruction Microscopy. However, up to now this method only had been used for describing biological phenomena.



Images of BTA fibers. Left with a conventional microscope; right a STORM image revealing the individual fibers by super-resolution.

Resolving processes

In the past decade with STORM many issues in biology have been resolved. It has been shown how clathrin-coated vesicles travel over the microtubules during endocytosis. The distribution of actin over neuronal axons has been proven to be at fixed intermittent rings, contrary to the general assumption that actin would align along the axon-axis. The burning question within ICMS is whether STORM can also be used for synthetic structures?



Flexibility revealed

The first choice of molecules to test this novel technique on is the, by now well-known, self assembling molecule BTA (1,3,5-benzenetricarboxamide). And indeed, through STORM the rod-like structures of self-assembled BTA molecules can be visualized. The super-resolution images show fiber structures that are significantly more flexible than previously demonstrated using electron microscopy (EM). This clear difference underscores that studying molecular behavior without perturbing the sample is crucial in visualizing its true morphology. High-resolution techniques like EM and AFM (atomic force microscopy) all have in common that the samples have to be chemically fixed and/or dried, with a change in structure as result. STORM allows for imaging molecules in solution only adhered to a (glass) surface to limit movement. Moreover multicolor imaging is possible allowing the simultaneous imaging of different species (i.e. different BTA monomers or different assemblies) in the sample.

Work in progress

The images obtained by STORM present a challenge as well. Instead of a picture based on pixels, the image is now a collection of points. This fundamental difference renders standard image analysis software useless and requires the development of tailored software to enable a quantitative understanding of the super-imaged synthetic fibers. Within the capable hands of ICMS researchers, this work is currently in progress.

Background of STORM?

STORM has been developed only lately as one of the techniques to overcome the physical resolution limit that has been set by Ernst Abbe in the late 19th century. His formula, $D=\lambda/2NA$, describes among others how resolution in microscopy is limited by the diffraction of light. The clear physics of this has hampered research in the field of optics resolution enhancement, as the law is rock solid.

Super-resolution is emerging

Lately, the field of optics has moved to bypass the physical resolution limit, thereby obtaining so-called super-resolution. The different approaches to overcome Abbe's law can roughly be divided in two groups. One group achieves super-resolution deterministically; here STED (Stimulated emission depletion) is a leading example. The other group of super-resolution techniques is represented by STORM. In this group photoswitchable dyes enable single molecule imaging as the number of emitting dyes is controlled by a temporal stochastic process.

FACTS

$D=\lambda/2NA$

was published in 1873 by Ernst Abbe

Standard visible light resolution is

~ 250 nm

Microscopy becomes Nanoscopy

STORM resolution is

~ 20-50 nm

"…. mutual inspiration **between** *ICMS AND* **industry** through our ***industrial consortium***"

Sagitta Peters, managing director

Reaching out

NEXT OUTREACH SYMPOSIUM, JANUARY 23&24, 2014

With the establishment of an industrial consortium ICMS reaches out. Mutual benefits are being sought by combining industrial research and development with more fundamental sciences. While the industrial members stay up to date with the most recent developments, ICMS scientists get inspiration for their research.

The industrial consortium currently comprises four members. With them, ICMS has been working intensively to compile the best package favoring all parties. ICMS will further expand the consortium in the near future. Members are being located in the Netherlands as well as in neighboring countries, at a close enough range to easily attend meetings and enable face-to-face contact. As part of the membership company co-workers can visit lectures and workshops, use the Advanced Study Center, participate in courses and access ICMS' state-of-the-art infrastructure.

To further promote knowledge exchange, ICMS organizes the yearly Outreach Symposium, which will be held again on January 23 - 24, 2014 (see also the Calendar). Access to the symposium is only for ICMS consortium partners. During the Outreach Symposium both the companies and ICMS members will present on ongoing research, enabling an exchange of knowledge and ideas. ICMS' outstanding master and PhD students and postdocs have the opportunity to learn about these companies and meet their researchers, and vice versa. In this way we facilitate matchmaking between companies and possible future co-workers as well.

DSM BRIGHT SCIENCE. BRIGHTER LIVING. سابك sabic SupraPolix SyMO-Chem

The FABRIC of LIFE

Our bodies are held together by collagen. This is a protein that forms fibers that weave together to form the materials that shape and support us, such as skin, bone, and blood vessels. On smaller scales, but following a similar design principle, the skeleton of a cell is formed by a network of stiff, connected protein polymers.

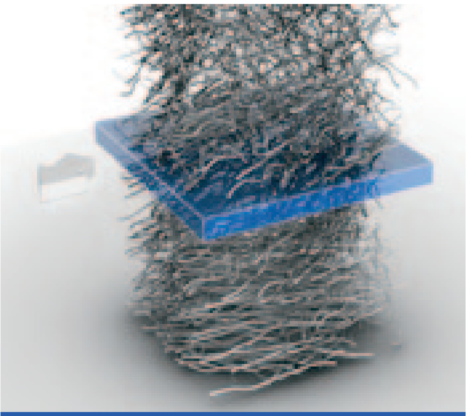
These protein materials present some truly remarkable mechanical properties. Many of them may be very soft, but they strengthen dramatically when strained. A deeper understanding of these and other properties could aid in the prevention for instance aneurysms, resulted by collagen failure. Biological materials also inspire the design of novel synthetic materials, which might be engineered to display similar properties.

Stronger under stress

During each heartbeat, the aorta expands to accommodate the influx of blood. Then, it contracts to help propel the blood downstream. During this cycle, the blood pressure doubles or even triples. If the aorta was made of just any soft material, it would overexpand and likely burst. Fortunately, the blood vessel wall responds to the increasing pressure by stiffening. This makes the material stronger as it is strained, limiting its expansion. This functional feature is also found in natural collagen gels and cytoskeletal meshes - much simpler structures compared to the aorta. A better understanding of this behavior in such simple systems may lead to new strategies to combat life-threatening conditions such as the formation of aneurysms, but it may also inspire the design of new synthetic materials.

How it works

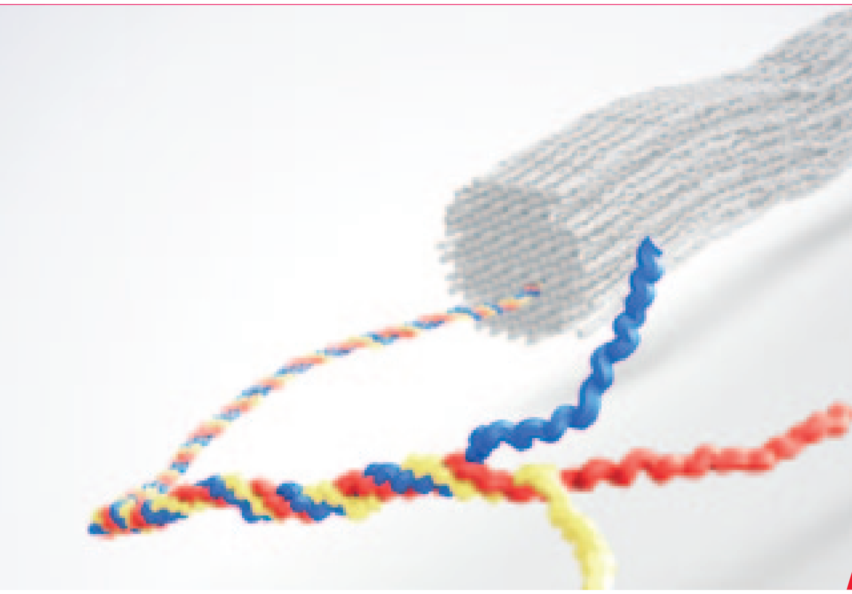
It was always thought that the aorta's strain stiffening was caused by certain proteins or other active, regulatory mechanisms, activated when the material is deformed. Cornelis Storm discovered that even "dead" (reconstituted) biomaterials exhibit similar nonlinear elasticity without any external agent. This means that the stiffening arises from its internal structure. Storm showed that, in particular, the filaments in the material are important. Their length and the nature of the interconnections between them determine the degree of stiffening. Thus, it is the network-like structure, combined with the properties of each filament individually, that is responsible for the remarkable reaction to stress. This explanation is far simpler than previously thought, and has opened up the possibility of mimicking this remarkable behavior in artificial materials.



Watch our computer animation
youtu.be/Yopic3wUdJw

Mimicking nature

Constructing an artificial network of filaments is still no easy task. In nature, different biological molecules string together to form collagen fibrils. Growing them artificially requires a similar process, with shorter molecules concatenating into longer chains. The challenge is to direct this so-called self-assembly toward the desired structure of filaments and connections.



> TO UNDERSTAND THESE MATERIALS, YOU NEED TO CONFRONT MODEL CALCULATIONS WITH REAL MATERIALS. BUT IT IS STILL A CHALLENGE TO MEASURE THEIR PROPERTIES
>
> Cornelis Storm, assistent professor Applied Physics

FACTS

Collagen =
30%
of the human body

Structure =
RIGHT-HANDED TRIPLE HELIX

Basic unit is
300 nm
long

More about this research:

Y. Chen, A.J.H. Spiering, S. Karthikeyan, G.W.M. Peters, E.W. Meijer & R.P. Sijbesma (2012). Nature Chemistry, 4(7), 559

A.R. Cioroianu, E.M. Spiesz & C. Storm (2013). Biophysical Journal, 104(2), 511a

To design, synthesize, and characterize these materials is the ambition of a collaborative research project involving four ICMS groups: Rint Sijbesma in Chemical Engineering and Chemistry, Hans Wyss and Gerrit Peters in Mechanical Engineering, and Cornelis Storm in Applied Physics.
The project brings together all of the necessary areas of expertise: chemical synthesis and self-assembly, as well as computational modeling and advanced mechanical characterization, both microscopically and macroscopically.

Seeing the action

One of the challenges in the project is to monitor the exact microstructure of the materials that are formed. The disordered, three-dimensional pattern of crisscrossing filaments is difficult to quantify with classical techniques. A recent breakthrough in the lab of Sijbsema will prove extremely useful: a delicate chemical process makes network materials light up where they are strained, which makes the forces directly visible and helps locate the precursors of fracture.

What's the use?

Biomimetic materials hold great promise for medical applications. They may be used to facilitate wound healing, to provide lifelike environments for cell culture and study, to provide vectors for controlled drug release or to act as scaffold materials for implantation surgery. One of the most exciting prospects is that through the use of self-assembly, the biomimetic may be engineered to assemble on-site, on-cue, within the body. This is due to the fact that they are exquisitely sensitive to temperature and the composition of the surrounding medium, and heir assembly may be triggered by injection or external stimulation. In short, biomimetic materials provide the benefits of a lifelike environment in a range of medical, diagnostic and research settings, combined with the advantages that precision control over assembly and properties through synthesis offers. Cornelis Storm and co-workers are working hard to make these miracle materials a reality!

ICMS TOP PUBLICATIONS

February 2013 – August 2013

1. *I.J. de Vries-van Leeuwen, D. da Costa Pereira, K. Flach, S.R. Piersma, C. Haase, D. Bier, Z. Yalcin, R. Michalides, K.A. Feenstra, C.R. Jimenez, T.F.A. de Greef, L. Brunsveld, C. Ottmann, W. Zwart, and A.H. de Boer*
Interaction of 14-3-3 proteins with the Estrogen Receptor Alpha F domain provides a drug target interface
Proc. Nat. Ac. Sci. U.S.A. 110, p. 8894–8899 (2013)

2. *F. Rodríguez-Llansola and E.W. Meijer*
Supramolecular Autoregulation
J. Am. Chem. Soc. 135, 6549-6553 (2013)

3. *M. Geers, R. Peerlings, M.A. Peletier and L. Scardia*
Asymptotic behaviour of a pile-up of infinite walls of edge dislocations
Arch. Rational Mech. Anal. 209, pp. 495-539 (2013)

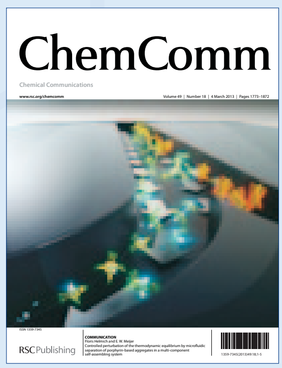
4. *E. Huerta, P.J.M. Stals, E.W. Meijer and A.R.A. Palmans*
Consequences of folding a water-soluble polymer around an organocatalyst
Angew. Chem. Int. Ed. 52, 2906-2910 (2013)

5. *L. Albertazzi, F.J. Martinez-Veracoechea, C.M.A. Leenders, I.K. Voets, D. Frenkel and E.W. Meijer*
Spatiotemporal control and superselectivity in supramolecular polymers using multivalency
Proc. Nat. Ac. Sci. U.S.A. 110, 12203-12208 (2013)

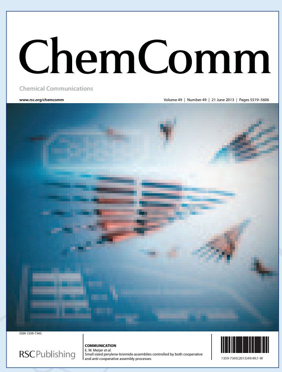
6. *R.E. Kieltyka, A.C.H. Pape, L. Albertazzi, Y. Nakano, M.M.C. Bastings, I.K. Voets, P.Y.W. Dankers and E.W. Meijer*
Mesoscale modulation of supramolecular ureidopyrimidinone-based poly(ethylene glycol) transient networks in water
J. Am. Chem. Soc. 135, 11159-11164 (2013)

7. *P.J.M. Stals, Y. Li, J. Burdynska, R. Nicolaÿ, A. Nese, A.R.A. Palmans, E.W. Meijer, K. Matyjaszewski and S.S. Sheiko*
How far can we push polymer architectures
J. Am. Chem. Soc. 135, 11421-11424 (2013)

8. *M.M.C. Bastings, S. Koudstaal, R.E. Kieltyka, A.C.H. Pape, Y. Nakano, D. Feyen, F.J. van Slochteren, P.A. Doevendans, J.P.G. Sluijter, E.W. Meijer, S.A.J. Chamuleau and P.Y.W. Dankers*
A fast pH-switchable and self-healing supramolecular hydrogel carrier for guided, local catheter-injection in the infarcted myocardium
Adv. Healthcare Mater. (2013), in press.

9. 

F. Helmich and E.W. Meijer
Controlled perturbation of the thermodynamic equilibrium by microfluidic separation of porphyrin-based aggregates in a multi-component self-assembling system
Chem. Commun. 49, 1796-1798 (2013)

10. 

R. van der Weegen, P.A. Korevaar, P. Voudouris, I.K. Voets, T.F.A. de Greef, J.A.J.M. Vekemans and E.W. Meijer
Small sized perylene-bisimide assemblies controlled by both cooperative and anti-cooperative assembly processes
Chem. Commun. 49, 5532-5534 (2013)

This overview lists publications in high end journals with ICMS as affiliation.

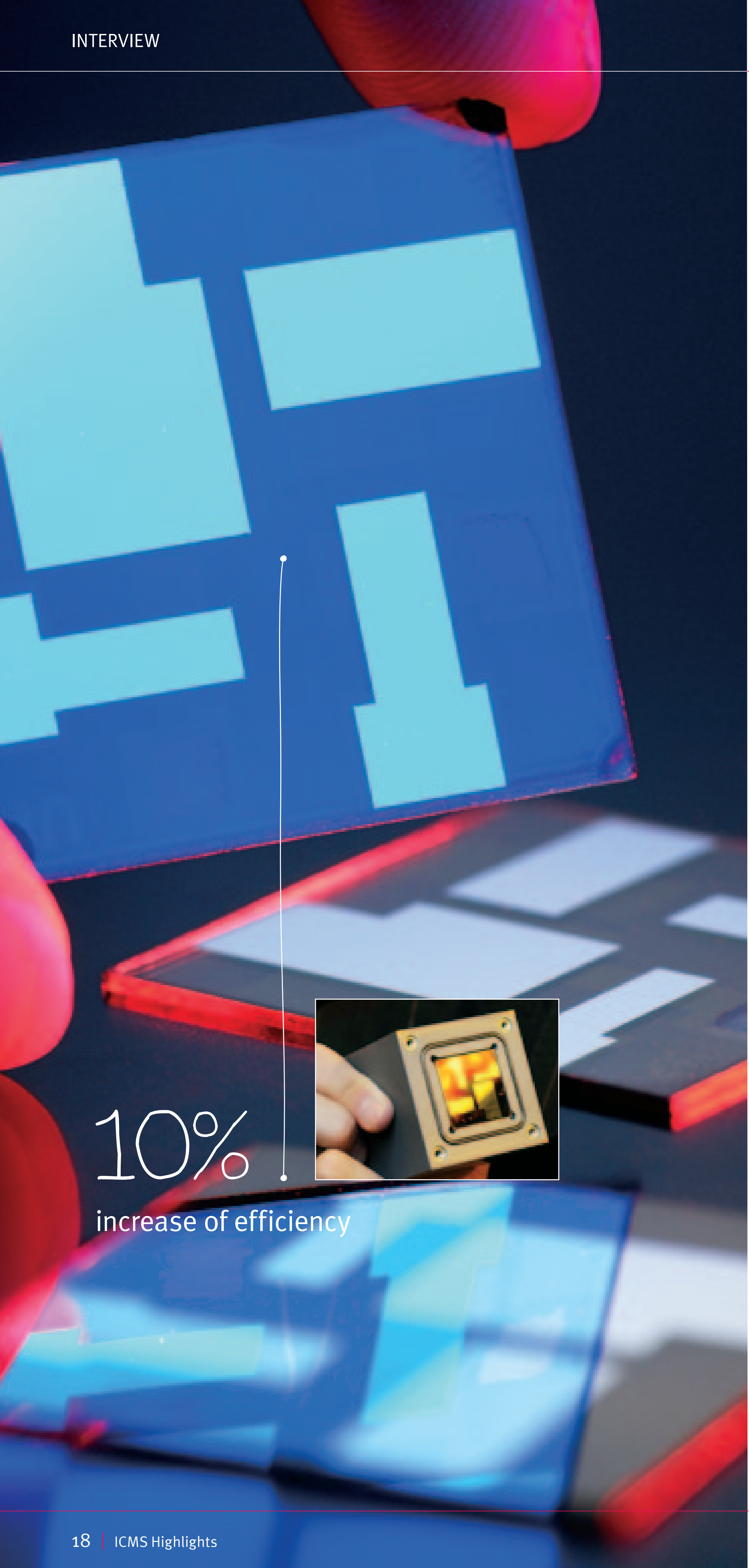
/ René Janssen

Understanding nature and outperforming it

"Many people find that nature has everything sorted out right. But in many ways it hasn't. Think of trees, almost every tree goes into hibernation and loses its leaves. Why? What's the point? A tree should be productive: make apples!"

These are the words of René Janssen, University Professor at TU/e and performing research on functional materials based on molecules. His research is contributing - among others - to the further development of plastic solar cells. A brief conversation about his work, the field of functional materials and the role technology plays in our world.

"WHAT DRIVES ME, IS EVERYTHING THAT CAN'T BE DONE YET



Functional materials are materials with a function other than construction. For example: materials exhibiting electrical, optical or magnetic properties. The research groups ‘Macromolecular and Organic Chemistry’ and ‘Molecular Materials and Nanosystems’ at which René Janssen conducts his research, are both engaged in the development of new functional materials.

Model-devices

René Janssen: “Our work concentrates in the pre-application stage. Currently we are developing a number of what we call ‘model devices’ for applications such as solar cells, transistors, sensors and light emitting diodes. It is our aim to gather fundamental knowledge and thorough understanding about the materials and the principles behind. Subsequently our studies can be used for future applications. At this moment we are quite successful with our work around plastic solar cells. As energy is one of the major societal issues, our research gains a lot of attention. Recently we have reached an interesting point: the past two years we have managed to increase the efficiency of plastic solar cells from 1% to about 10% (light energy transformed into electricity).” René Janssen’s study of thin-film photovoltaic solar energy takes place within Solliance, an alliance between TU/e, ECN, Holst Centre, imec and Forschungszentrum Julich. The program produces impressive results, affirming an international leading position.

The next step

René Janssen: “With about 10% efficiency we are able to realize a nice yield. It allows us to play up front in the Solar Champions League. However, the return on solar cells is a moving target.

When we started our study, the silicon cell (traditional solar cell technology) was very expensive. Meanwhile, the price dropped by a factor of ten. So reducing cost is not the primary reason anymore for anyone to step into plastic solar cells. I am afraid that's the nature of the game. It's not just if you can, it is also when you can. It makes the game exciting and challenging. For now, we continue to work on these solar cells. I think we can reach efficiencies of 15 to 20% in the near future.
To me the next step in solar energy is: Solar Fuels. To make a device that can transfer solar energy directly into fuel. For example based on water or even better, CO_2. Nature has given us oil, which is a particularly concentrated form of energy. I think oil will still be needed for a long time to come. Can you imagine an electric airplane taking-off? With the enormous weight of the batteries? No way, it will need kerosene to do so. However, the process of making oil is particularly inefficient. You need sunlight, a huge amount of certain plants and - most important - a hundred million years. Can we efficiently capture sunlight and turn it almost directly into an effective fuel? That's a very challenging question to me."

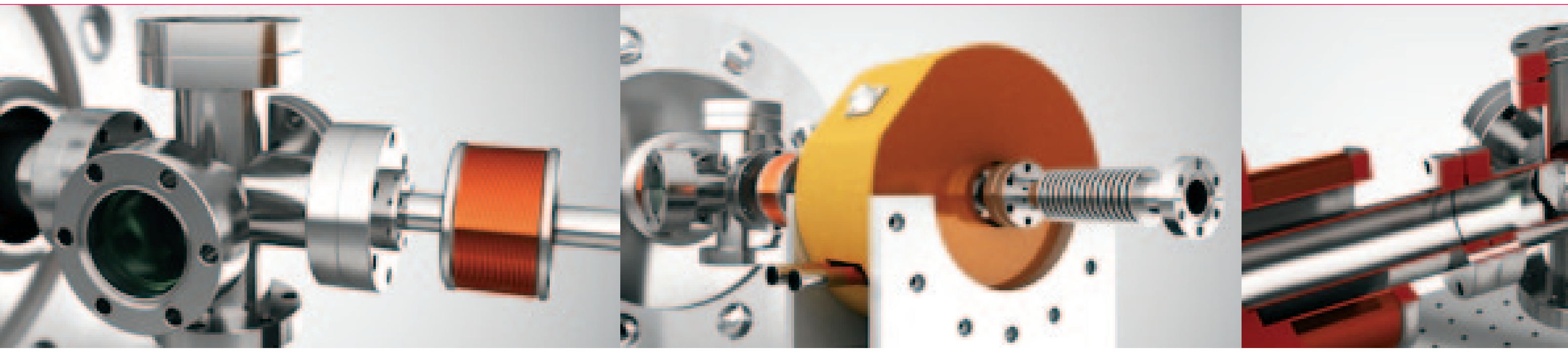
Added value of the institute

In the past year the team of René Janssen started to collaborate with ICMS. In cooperation with the group of Bert Meijer (TU/e) it subscribed to the Gravity-program of Ministry of Education, Culture and Science with a research proposal around Functional Molecular Systems. The partners in this research program - Nijmegen University, Groningen University and TU/e - want to increase knowledge in the field of organic functional molecules. Examples of research lines are functional molecular motors (inspired by the movement of muscles)and molecular self-assembly (the self-organizing ability of molecular systems).
René Janssen: "These studies touch the side of traditional technical disciplines and the field of bio-inspired engineering. Therefore we found it relevant to accommodate our part of the program within ICMS. I do not have a background in biology. We are working merely on materials, in which the complexity comes from the devices that use several functional layers interacting with each other. The bio-component may well lead to some inspiring cross-breeding."
Within ICMS scientists work on various aspects of molecular systems. The goal of the institute is to promote ideation and solution-oriented research via the bringing together of various technical disciplines.
René Janssen: "Think of the solar cell again. That is a system that captures light and converts it to electricity. You can also create a camera based on this principle. Perhaps this is a step towards an artificial eye. I am not saying it will work, but the point is that ICMS provides a platform where these ideas can grow. That's the added value of the institute. You're connecting to colleagues from other disciplines, trying to understand their work. And it is precisely in those areas - where there's something in between - these are the areas where you can really achieve something."

Better than nature

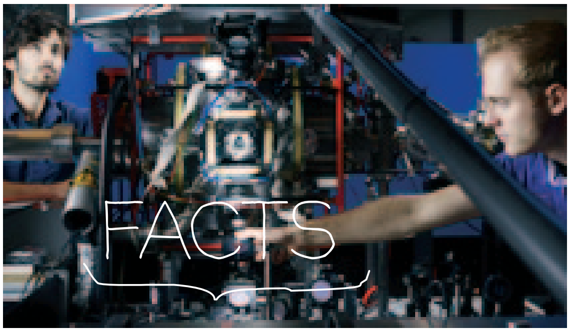
René Janssen: "Nature is not necessarily my source of inspiration. I like to outperform nature. As human beings we are capable of that. I mean: we can fly further than any bird, we have more calculating power, and thanks to the wheel we can move over land faster than any other being. Nature has gone through a certain development, which is important for where and what we are now. But that doesn't mean that nature has always chosen the best solutions. It was 'survival of the fittest', which makes survival more important than optimization. Technology supports the latter. We are no longer cavemen, feeling bad about an unsuccessful hunt. Technology has brought well-being, health, longer life, better nutrition. Paradoxically, the major challenges resemble our challenges at beginning of creation: energy, water, food and health. You've got to get that sorted out first, the rest will follow.

Ultimately our planet is our limitation. This planet and the sun - our only energy source - determine our playground. Everything we do must be balanced with what earth can provide. By now, we have gathered a reasonable amount of intelligence so we can influence nature quite a bit, but we make big mistakes as well. My challenges are to understand molecules and their behavior and to invent new things on top of that: materials, applications and technologies that bring us a step ahead."



Seeing molecular motion

It would be wonderful to shoot a film of molecules in action. You would need a camera with a field of view of a few nanometers and frames of a hundred femtoseconds. Up to now, the only instrument that came in the the vicinity of such a precision was an XFEL, a giant x-ray laser, which costs a few 100 million Euro. Even at this price, not all materials are captured well. X-rays are best for bulk materials. Thin membranes, and certain proteins alike, are still hard to picture with this costly instrument.



Electrons produced by
100 kV
electron gun

Exposure time
100 fs

Speed of electrons is
1/2 SPEED
of light

ICMS cooperates with the research group Coherence and Quantum Technology, which developed a unique imaging instrument, which uses highly compact, coherent and dense electron pulses. Particle physicists always thought that huge accelerators were needed for such pulses. However, a special geometry does the trick on a tabletop. The instrument is now marketed worldwide. A new, even more coherent version will be used to study fragile proteins.

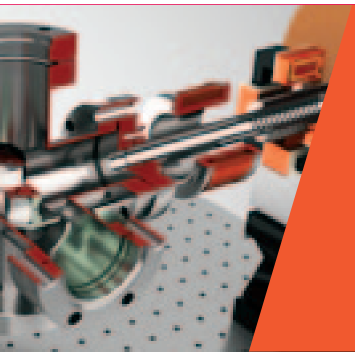
An impossible pulse

An electron beam is an excellent alternative to capture molecules in motion. Electrons behave like x-rays and make perfect pictures with one difference: they interact more strongly with matter. That's why electrons are best for picturing on thin materials and surfaces. This is routinely done with electron microscopes.

There is one drawback, however: electrons also interact strongly among themselves. They repel each other, which causes a fast flash of electrons to spread. Precision is lost, and the picture is blurred. That's why fast electron microscopes can't resolve the motion of the smallest structures.

The breakthrough: coherent pulses

The breakthrough came when Jom Luiten and co-workers studied electron interactions. When electrons would be arranged in a special geometry, many non-linear interactions between them would cancel each other out, they realized. The shape of a balloon filled with water would do the trick (a homogeneously filled ellipsoid). The electrons would still expand, but in a less chaotic manner, in a linear and predictable way. This makes it possible to compress the bunch



Watch our computer animation of the instrument at
youtu.be/aDsLZOv8unI

> NOBODY THOUGHT AN ELECTRON BUNCH COULD BE MADE WITH SUCH A SPECIAL SHAPE. BUT BEHIND A BLACKBOARD WE GOT AN IDEA.
>
> Jom Luiten, professor of Coherence and Quantum Technology

again, in the same controlled way as it expands. Electromagnetic fields provide the required push-back force. All of this can be done on a tabletop.
Jom Luiten and co-workers made the electron flashes with a femtosecond laser, firing on a cathode. To compress the electron bunch, they used magnetic lenses, known from electron microscopes, and a custom designed microwave cavity. The idea of using microwaves in this way is new. This setup compressed the bunch 100-fold. This means that the electron flash is much better focused, resulting in sharper images. All of this precision could be reached at a tiny fraction of the price of an XFEL. That's why the instrument was called a Poor Man's XFEL (PMX).

The reward: sharp images

The first images were made of a thin layer of gold, which is widely used to calibrate electron microscopes. The images are so-called diffraction patterns, from which the path of electrons and hence the structure of gold may be inferred.
That structure was not new, so soon the focus switched to novel materials. Graphene (extremely thin graphite) proved to be an interesting target. It was discovered a decade ago, and it has recently earned a Nobel Prize for its fascinating properties, but it is still poorly understood and has extremely fast-changing properties.
Soon, a worldwide interest in the instrument arose. Through the company Acctec, it is sold to labs worldwide. FEI, a producer of electron microscopes, now cooperates on the further development. Measurements have led to some high-profile papers. A recent paper in Nature includes a video, which shows the phase transition of an organic salt. Thanks to the Poor Man's XFEL, the molecules can be followed in a step-by-step manner (http://bit.ly/1c8id7o). It is the first femtovideo of an organic molecule.
However, the real proof of the instrument is the observation of complex and fragile materials. That's where Jom Luiten and his group started a fruitful cooperation with ICMS. The instrument is now used to study large biologic molecules and membranes, which have been made by colleagues. The first candidates are hydrophobins, proteins made by certain fungi. They can form a coating on nanomaterials, making these easier to solve in water. Within ICMS the formation of those coatings is studied.

The next breakthrough: even sharper

Some lack of sharpness remains in the pictures. This is caused by random thermal motions on the moment that the electron pulse is created. For really sharp images, you need an electron pulse that is like a laser, coherent and intense. That is: with all electrons moving in close order. Jom Luiten and his colleague Edgar Vredenbregt have now shown that this is possible. To make extremely coherent pulses, they have used an ultracold source, wherein every motion is frozen out. This holds the promise of pictures that are many times faster and sharper. Therefore, this exciting technique will be used to study proteins extensively at ICMS.

About laser-cooled pulses

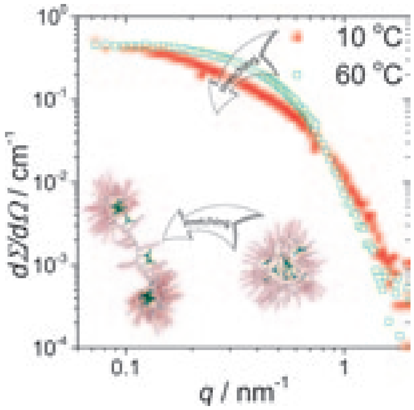
W.J. Engelen, M.A. van der Heijden, D.J. Bakker, E.J.D. Vredenbregt, and O.J. Luiten (2013), Nat. Commun. 4, 1693.

More about the instrument:

T. van Oudheusden, P. L. E. M. Pasmans, S. B. van der Geer, M. J. de Loos, M. J. van der Wiel, and O. J. Luiten (2010). Phys. Rev. Letters 105, 264801.

SAXS zooms into complex molecular systems

In the multi-equipped laboratory of ICMS, the small angle X-ray scattering (SAXS) instrument is dominating the dark lab. It is used intensively to uncover the internal structures of functional soft materials of biological and synthetic origin. Unlike visible light, X-rays are able to deeply penetrate into turbid materials such that their true structures may be observed.



FACTS

three decades of magnification

0.1 - 100 nm

Small to large magnification in one measurement

Contrary to the well-known X-ray crystallography, structure elucidation by SAXS does not require crystals to be formed. In fact, SAXS can be performed on crystalline materials and on structures in solution.

Journey into hierarchical architectures

The elegance of SAXS lies in the accessible range of length scales; as if the researcher embarks on a journey through several decades of magnification. Tracing the scattering pattern from low to high scattering angles in a single experiment, first reveals the total mass of supramolecular complexes, followed by their overall shape and surface structure when zoomed in to the maximum. Particularly powerful for complex multicomponent systems is the combination of SAXS and SANS (small-angle neutron scattering) utilizing isotopic substitution to highlight specific structural features.

Preservation of delicate equilibria

Using SAXS, structures can be studied in situ at interfaces and in bulk, in solution, and in gel samples. All of them in a wide range of temperatures, external fields, and even in custom-built devices such as shear cells and microfluidic chips. Delicate dynamic equilibria can be preserved without interference as samples need not be stained, labeled, dried or vitrified. Within ICMS Ilja Voets and co-workers are using SAXS in a large variety of studies on complex molecular structures, ranging from the dimerization of (anti-freeze) proteins and the flexibility of supramolecular fibers to the ordering and alignment of columnar liquid crystalline phases.

SAXS makes the difference

The power of scattering methods has been demonstrated when supramolecular polymers that fold into single chain nanoparticles were studied. The single polymer chains were decorated with discoted molecules. The assembly hereof resulted in chain stretching rather than the expected collapse, as was shown by SAXS. The next challenge is to find out why this happens and utilize it in the design of functional complex molecular systems.

Institute for Complex Molecular Systems

New technologies by mastering complexity

Mastering complexity requires a deep understanding on how matter – both natural and artificial – self-organizes into functional molecular systems.
The Institute for Complex Molecular Systems (ICMS) of the Eindhoven University of Technology (TU/e) was established in 2008 and brings together mathematics, physics, biology, chemistry and engineering to stimulate education and research in this emerging field of science. Interdisciplinarity is the core of ICMS; with the specialized input from leading specialists in different branches of science and engineering, new avenues are explored, where mastering complexity is the leading theme. The scientific agenda of ICMS consists of two lines of research:

1. Functional molecular systems (program leader prof.dr. E.W. Meijer)
2. Bio inspired engineering (program leader prof.dr.ir. F.P.T. Baaijens)

ICMS hosts the Advanced Study Center, a breeding ground for new interdisciplinary research.
It serves as an intellectual home to scientist from all over the world, hosting discussions on the theme of complexity. It is also the home of the Eindhoven Multiscale Institute (EMI) and the Eindhoven Polymer Laboratories (EPL).

ICMS aims at offering an ideal training environment for all young students and scientists to prepare themselves for a future career in science and engineering in a world of increased complexity. Therefore, we offer the Graduate Program in Complex Molecular Systems (MSc and PhD).
The relationship with industry is strengthened via the Industrial Consortium – where science meets innovation.

More information can be found via our website www.tue.nl/icms. Please contact us via email icms@tue.nl or telephone +31 40 247 2482 with specific questions or remarks.

Editorial
ICMS Highlights is the half-yearly magazine of ICMS for ICMS members, colleagues, collaboration partners, policy makers and affiliated companies. ICMS Highlights is published in March and September.

Editorial staff
Sagitta Peters (editor in chief)
Moniek de Liefde (vice editor in chief)

Design and print
Zelv, Eindhoven

Illustrations and cover
ICMS Animation Studio

Article contributions
Moesasji & Bram Vermeer Journalistiek

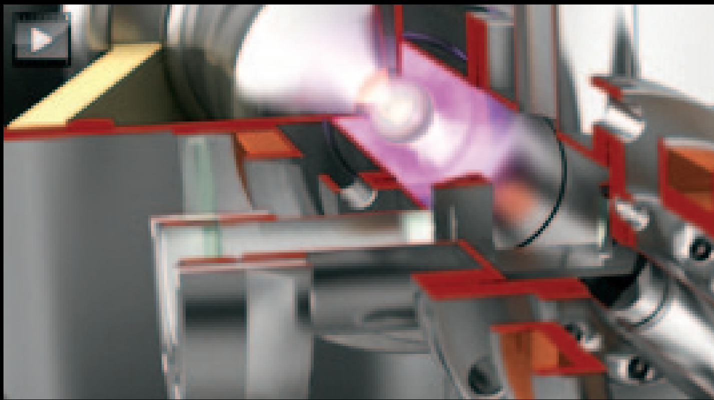
Photography
Bart van Overbeeke Fotografie

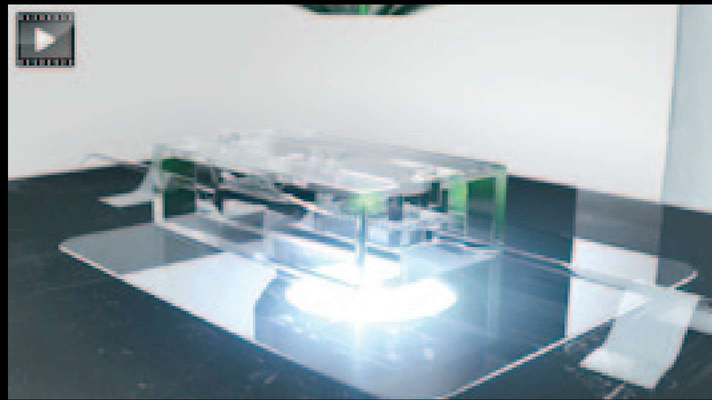
Contact
P.O. Box 513, 5600 MB Eindhoven
The Netherlands
Telephone: +31 (0)40 247 2482
Email: icms@tue.nl

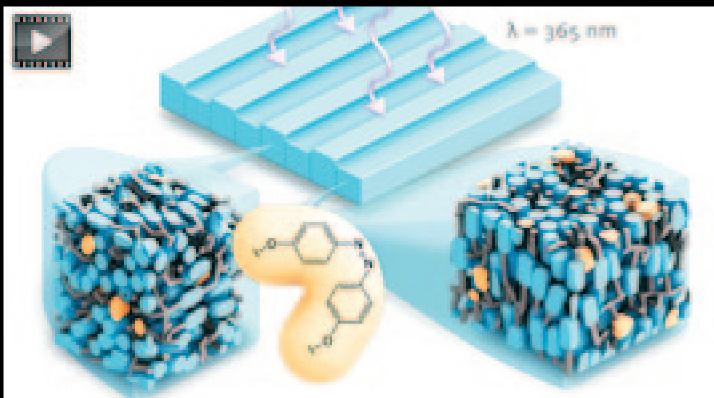
ICMS IN PRESS

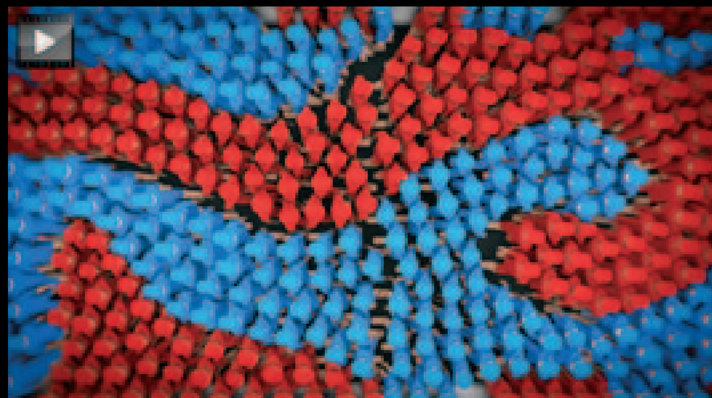

herontdekt biologie

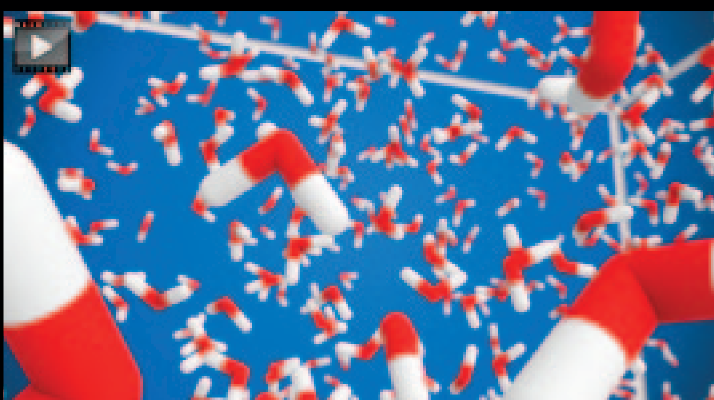
Ketelhuis TU Eindhoven nu onderkomen topinstituut

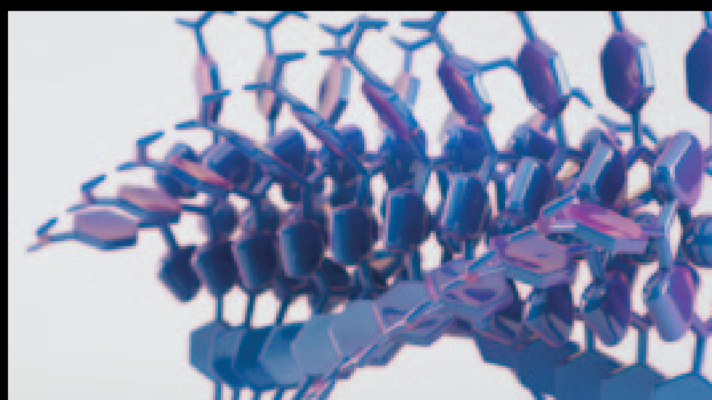


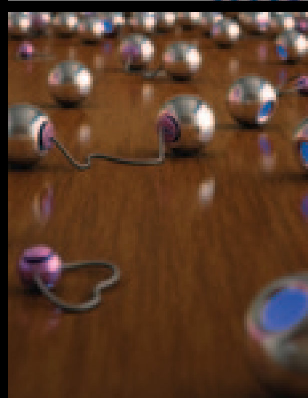












ICMStue - 21 video's

Subscribe 122

223 0

Please visit the ICMS Animation studio
www.youtube.com/user/icmstue