Edition 16 June 2021

ICMS Highlights

BREAKING THE BARRIER:
TRACKING THE MOVEMENT OF CANCER CELLS

ICMS PHD OUTREACH PROGRAM

MEASURING MATERIALS
UNDER EXTENSIONAL FLOW

ICMS
INSTITUTE FOR COMPLEX MOLECULAR SYSTEMS

TU/e

INTRODUCTION

ICMS Highlights

It is with great pleasure that we look back on the online ICMS Annual Symposium 2021. More than 320 participants from both academia and industry exchanged knowledge and know-how in the fields of advanced materials and engineering health. Young scientists shared and discussed their research with other participants using their digital posters and pre-recorded pitches. We would like to thank you all for your contributions, which made this symposium a beautiful event!

Looking ahead, two initiatives are in the making to further boost science communication amongst PhD students and postdocs at the TU/e and within the ICMS community. The PhD platform is organized by and for the ICMS community and they are looking for your active participation. The postdoc initiative engages with all TU/e departments and is supported by the TU/e institutes ICMS, EIRES and EAISI. More information about these initiatives can be found in this edition of the Highlights.

We also would like to mention that we are very happy to announce the appointment of Roderick Tas, a member of the Voets Research Group, as an ICMS Fellow. He combines many disciplines to visualize and understand the architecture of complex biological assemblies at the nanoscale. Furthermore, one of the ICMS focus areas, materials for regenerative medicine, has launched the HybridHeart project for master students. This project aims at the development of a soft biocompatible artificial heart.

We hope your will enjoy reading about the great science and inspiring news that this issue of ICMS Highlights has in store for you.

For more information on our community please also visit our LinkedIn page.

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Scientific director

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Managing director

Calendar

Please check our website for our upcoming events.

www.tue.nl/icms

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 twice a year.

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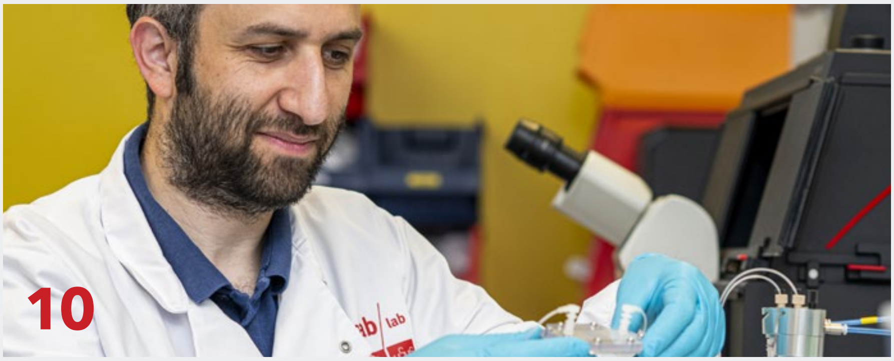
Content



COVER Artist impressions of interactive surface modifications (front) and cells on a scafold (back).

ADVANCED ANALYSIS OF COMPLEX MOLECULAR SYSTEMS

Paula Vena and Laura van Hazendonk

Smart experimental design enables comprehensive model for collagen self-assembly

Master student Laura van Hazendonk won the 2020 AkzoNobel Graduation Award for Chemistry and Process Technology, granted by the Royal Holland Society of Sciences and Humanities. What started as an MSc assignment to develop a multiscale collagen hydrogel, resulted in a comprehensive systems approach to experimentation: automated, data driven and enabling statistical quantitative analysis. An approach that will benefit not only collagen research, but other experimental settings as well.

So, there you are, a MSc student starting your project. Under the supervision of assistant professor Heiner Friedrich and PhD student Paula Vena, in the Physical Chemistry group of Remco Tuinier. The task at hand: guide molecular collagen self-assembly into micrometer-sized fibers, forming a hydrogel. With the additional challenge of realizing a gradient in hydrogel morphology – think fiber diameter and pore size. The outlook: devise a scaffold for tissue engineering. Collagen is the most abundant compound in the supportive, fibrillar matrix of human tissue, such as skin or bone. A collagen hydrogel could mimic such a matrix and thus act as a scaffold to induce repair of damaged tissue – or even grow replacement tissue in the lab.

Of course, you start studying the literature. The basics are simple enough. Chemists can tune the formation of the collagen hydrogel by adjusting variables such as pH, salt concentration or temperature. But then you encounter some peculiarities. Where one researcher finds an elevated pH to increase fiber diameter, another reports exactly the opposite. And it's not just pH. With other parameters, you find even more contradictory results. Are you going to let that knock you out of the game? Not Laura van Hazendonk. "The overall picture was indeed rather confusing," she says. "But that only motivated me. I wanted to study all relevant parameters in such a way that the interdependencies were revealed."

DIVERSE AND COMPLEX

Paula Vena explains the confusion: "The world of collagen is very diverse. It's a protein that can be obtained from a variety of sources such as rats, cows, pigs, and various types of fish and sea sponges. Most research is focused on the system at hand and usually in a very result driven manner. What you find in literature often describes a specific collagen to be used in a specific manner to produce hydrogels for a specific application. You can't repeat that with another collagen or in other conditions and expect the same results. There are simply too many differences; at the molecular level as well as the system level. So, Laura was right in wanting to comprehensively map out the relationship between the relevant aspects of collagen self-assembly and the desired hydrogel morphology." The question then is how to achieve just that. Van Hazendonk: "An approach of trial and error and some educated guessing would not suffice. It's too complex for such an approach to yield really insightful results." She decided to develop an effective statistics-based research planning tool to arrive at the smallest possible number of experiments, with the greatest possible reliability. Furthermore, she proposed to perform both sample characterization and data analysis in an automated manner. "I expected this approach to produce the right data to build a comprehensive model for collagen hydrogel formation," Van Hazendonk says. "Thankfully, I was able to convince the research team of this."

A COMPREHENSIVE MODEL

"I have to say that Laura is quite a convincing person," Vena shares. "With that I mean that she doesn't say things lightly, she thinks about what she proposes and can be trusted in her opinion. On the other hand, as a supervisor I want the students to really own their project. When Laura proposed to take this route, it indeed made lots of sense and she immediately had me on board."

To study the kinetics of gel formation, Van Hazendonk designed automated turbidity measurements on collagen samples assembled in a 96-wells plate. For morphological analysis, the team brought Thermo Fisher Scientific in, so that they could use an automated scanning electron microscope to analyze up to 36 samples in the same run. After 48 hours of automated data collection, 300 images per sample were obtained. Van Hazendonk developed a Matlab script for image analysis with respect to fiber diameter

"I EXPECTED THIS APPROACH TO PRODUCE THE RIGHT DATA TO BUILD A COMPREHENSIVE MODEL FOR COLLAGEN HYDROGEL FORMATION"

and pore area. Subsequent statistical analysis established which factors had the largest effect on collagen morphology. Moreover, it proved possible to identify confounding parameters.

As a result, a comprehensive model could be developed for rationally designing collagen gels. "In fact, there's a rather large design space regarding morphology and assembly kinetics," Van Hazendonk says. "This can be used for tailored application in bioprinting, tissue engineering or drug delivery. I really hope that other people will pick up on this and continue our work."

SMART EXPERIMENTATION

The jury of the 2020 AkzoNobel Graduation Award for Chemistry and Process Technology was not only impressed with the results from the high throughput measurements, but also with Van Hazendonk's smart experimental design. "I have to give credit to Mohammad Moradi, a postdoc in the group, who suggested me to dive into this," she says. "It's so easy to just turn on a machine and collect thousands and thousands of data points, but you can get quickly lost in data. A smart experimental design really can save lots of time and effort." According to Heiner Friedrich, Van Hazendonk's work is an excellent example of a systems approach to experimentation. "I am curious to see how in the future automated sample handling and screening, possibly with support from artificial intelligence, will change our abilities to discover new materials and the rules governing their assembly over multiple length scales."

ICMS Annual Symposium 2021: A wave of inspiration

Waves can take many forms. They can be gentle and soothing, when you're relaxing at the shore on a warm summer evening. They can be exhilarating for surfers and adventurous swimmers. And they can be downright intimidating when they turn into tsunamis.

The "wave of inspiration" that hit the participants of the 2021 ICMS Annual Symposium on March 25, had elements of all three examples. There were familiar faces and projects – albeit that these were different for every participant. To balance the familiar, the program was diverse enough to contain something new, mind-blowing and perhaps even a little intimidating for everyone. But overall, the wave created an exhilarating experience. With so many different topics, approaches and promising applications "on stage," the day provided plenty of stimulating ideas and insights for all. Exactly what a scientific symposium is supposed to.

Key publications

NOVEMBER 2020 – MARCH 2021

01. ACID-ACTIVATABLE TRANSMORPHIC PEPTIDE-BASED NANOMATERIALS FOR PHOTODYNAMIC THERAPY
B. Sun, R. Chang, S. Cao, C. Yuan, L. Zhao, H. Yang, J. Li, X. Yan, J.C.M. van Hest
Angew. Chem. Int. Ed. 59, 20582–20588 (2020)

02. BIASING THE SCREW-SENSE OF SUPRAMOLECULAR COASSEMBLIES FEATURING MULTIPLE HELICAL STATES
N.J. Van Zee, M.F.J. Mabesoone, B. Adelizzi, A.R.A. Palmans, E.W. Meijer
J. Am. Chem. Soc. 142, 20191–20200 (2020)

03. DIRECT INK WRITING OF A LIGHT-RESPONSIVE UNDERWATER LIQUID CRYSTAL ACTUATOR WITH ATYPICAL TEMPERATURE-DEPENDENT SHAPE CHANGES
M. del Pozo, L. Liu, M. Pilz da Cunha, D.J. Broer, A.P.H.J. Schenning
Adv. Funct. Mater. 30, 2005560 (2020)

04. DYNAMIC SPATIAL AND STRUCTURAL ORGANIZATION IN ARTIFICIAL CELLS REGULATES SIGNAL PROCESSING BY PROTEIN SCAFFOLDING
B.C. Buddingh', A. Llopis-Lorente, L.K.E.A. Abdelmohsen, J.C.M. van Hest
Chem. Sci. 11, 12829–12834 (2020)

05. FRAGMENT-BASED STABILIZERS OF PROTEIN-PROTEIN INTERACTIONS THROUGH IMINE-BASED TETHERING
M. Wolter, D. Valenti, P.J. Cossar, L.M. Levy, S. Hristeva, T. Genski, T. Hoffmann, L. Brunsveld, D. Tzalis, C. Ottmann
Angew. Chem. Int. Ed. 59, 21520–21524 (2020)

06. HIGHLY ORDERED 2D-ASSEMBLIES OF PHASE-SEGREGATED BLOCK MOLECULES FOR UPCONVERTED LINEARLY POLARIZED EMISSION
M.H.C. van Son, A.M. Berghuis, F. Eisenreich, B. de Waal, G. Vantomme, J.G. Rivas, E.W. Meijer
Adv. Mater. 32, 2004775 (2020)

07. LIGHT-ACTIVATED SIGNALING IN DNA-ENCODED SENDER-RECEIVER ARCHITECTURES
S. Yang, P.A. Pieters, A. Joesaar, B.W.A. Bogels, R. Brouwers, I. Myrgorodska, S. Mann, T.F.A. de Greef
ACS Nano 14, 15992–16002 (2020)

08. MECHANOTRANSDUCTION IS A CONTEXT-DEPENDENT ACTIVATOR OF TGF-BETA SIGNALING IN MESENCHYMAL STEM CELLS
S. Vermeulen, N. Roumans, F. Honig, A. Carlier, D.G.A.J. Hebels, A.D. Eren, P. ten Dijke, A. Vasilevich, J. de Boer
Biomaterials 259, 120331 (2020)

09. MULTIMODAL IMAGING OF BACTERIAL-HOST INTERFACE IN MICE AND PIGLETS WITH STAPHYLOCOCCUS AUREUS ENDOCARDITIS
P. Panizzi, M. Krohn-Grimberghe, E. Keliher, Y.-X. Ye, J. Grune, V. Frodermann, Y. Sun, C.G. Muse, K. Bushey, Y. Iwamoto, M.M.T. van Leent, A. Meerwaldt, Y.C. Toner, J. Munitz, A. Maier, G. Soultanidis, C. Calcagno, C. Perez-Medina, G. Carlucci, K.P. Riddell, S. Barney, G. Horne, B. Anderson, A. Maddur-Appajaiah, I.M. Verhamme, P.E. Bock, G.R. Wojtkiewicz, G. Courties, F.K. Swirski, W.R. Church, P.H. Walz, D.M. Tillson, W.J.M. Mulder, M. Nahrendorf
Sci. Transl. Med. 12, eaay2104 (2020)

10. PROGRAMMED SPATIAL ORGANIZATION OF BIOMACROMOLECULES INTO DISCRETE, COACERVATE-BASED PROTOCELLS
W.J. Altenburg, N.A. Yewdall, D.F.M. Vervoort, M.H.M.E. van Stevendaal, A.F. Mason, J.C.M. van Hest
Nat. Commun. 11, 6282 (2020)

11. SYNTHESIS OF COMPLEX MOLECULAR SYSTEMS–THE FORESEEN ROLE OF ORGANIC CHEMISTS
T. Schnitzer, G. Vantomme
ACS Cent. Sci. 6, 2060–2070 (2020)

12. THIOSQUARAMIDE-BASED SUPRAMOLECULAR POLYMERS: AROMATICITY GAIN IN A SWITCHED MODE OF SELF-ASSEMBLY
V. Saez Talens, J. Davis, C.-H. Wu, Z. Wen, F. Lauria, K.B. Sai Sankar Gupta, R. Rudge, M. Boraghi, A. Hagemeijer, T.T. Trinh, P. Englebienne, I.K. Voets, J.I. Wu, R.E. Kieltyka
J. Am. Chem. Soc. 142, 19907–19916 (2020)

13. A MODULAR APPROACH TOWARD PRODUCING NANOTHERAPEUTICS TARGETING THE INNATE IMMUNE SYSTEM
M.M.T. van Leent, A.E. Meerwaldt, A. Berchouchi, Y.C. Toner, M.E. Burnett, E.D. Klein, A.V.D. Verschuur, S.A. Nauta, J. Munitz, G. Prevot, E.M. van Leeuwen, F. Ordikhani, V.P. Mourits, C. Calcagno, P.M. Robson, G. Soultanidis, T. Reiner, R.R.M. Joosten, H. Friedrich, J.C. Madsen, E. Kluza, R. van der Meel, L.A.B. Joosten, M.G. Netea, J. Ochando, Z.A. Fayad, C. Perez-Medina, W.J.M. Mulder, A.J.P. Teunissen
Sci. Adv. 7, eabe7853 (2021)

14. ASSEMBLY OF DYNAMIC SUPRAMOLECULAR POLYMERS ON A DNA ORIGAMI PLATFORM
J. Schill, B.J.H.M. Rosier, B. Gumi Audenis, E. Magdalena Estirado, T.F.A. de Greef, L. Brunsveld
Angew. Chem. Int. Ed. 60, 7612–7616 (2021)

15. COMPETITION BETWEEN CHIRAL SOLVENTS AND CHIRAL MONOMERS IN THE HELICAL BIAS OF SUPRAMOLECULAR POLYMERS
M.L. Sleczkowski, M.F.J. Mabesoone, P. Sleczkowski, A.R.A. Palmans, E.W. Meijer
Nat. Chem. 13, 200–207 (2021)

16. CONSEQUENCES OF CHIRALITY IN DIRECTING THE PATHWAY OF CHOLESTERIC HELIX INVERSION OF PI-CONJUGATED POLYMERS BY LIGHT
C. Kulkarni, R.H.N. Curvers, C. Vantomme, D.J. Broer, A.R.A. Palmans, S.C.J. Meskers, E.W. Meijer
Adv. Mater. 33, 2005720 (2021)

17. COOPERATIVITY BETWEEN THE ORTHOSTERIC AND ALLOSTERIC LIGAND BINDING SITES OF ROR GAMMA T
R.M.J.M. de Vries, F.A. Meijer, R.G. Doveston, I.A. Leijten-van de Gevel, L. Brunsveld
Proc. Natl. Acad. Sci. U. S. A. 118, e2021287118 (2021)

18. HOW REACTIVITY VARIABILITY OF BIOFUNCTIONALIZED PARTICLES IS DETERMINED BY SUPERPOSITIONAL HETEROGENEITIES
R.M. Lubken, A.M. de Jong, M.W.J. Prins
ACS Nano 15, 1331–1341 (2021)

19. OLIGODIMETHYLSILOXANE-OLIGOPROLINE BLOCK CO-OLIGOMERS: THE INTERPLAY BETWEEN AGGREGATION AND PHASE SEGREGATION IN BULK AND SOLUTION
B.A.G. Lamers, A. Herdlitschka, T. Schnitzer, M.F.J. Mabesoone, S.M.C. Schoenmakers, B.F.M. de Waal, A.R.A. Palmans, H. Wennemers, E.W. Meijer
J. Am. Chem. Soc. 143, 4032–4042 (2021)

20. OXIDATIVE STRESS IN PANCREATIC ALPHA AND BETA CELLS AS A SELECTION CRITERION FOR BIOCOMPATIBLE BIOMATERIALS
M.M.J.P.E. Sthijns, M.J. Jetten, S.G. Mohammed, S.M.H. Claessen, R.H.W. de Vries, A. Stell, D.F.A. de Bont, M.A. Engelse, D. Mumcuoglu, C.A. van Blitterswijk, P.Y.W. Dankers, E.J.P. de Koning, A.A. van Apeldoorn, V.L.S. LaPointe
Biomaterials 267, 120449 (2021)

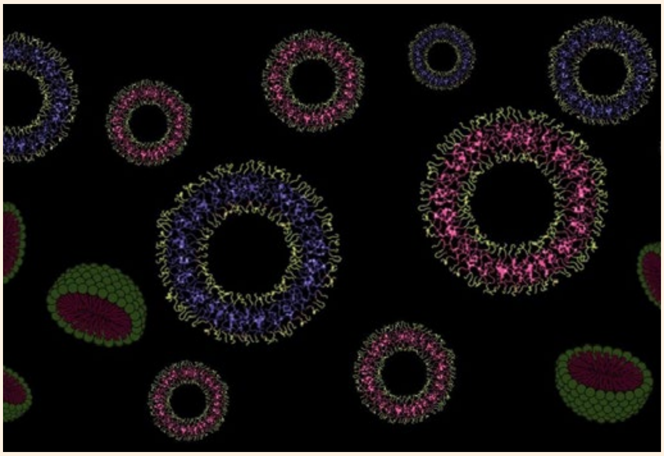
News, awards & grants

Nanoparticles, from hype to actual clinical product

DEVELOPING AN EFFICIENT, SCALABLE AND HIGHLY CONTROLLED MANUFACTURING PROCESS.

PhD candidate Jaleesa Bresseleers, of the TU/e department of Biomedical Engineering, investigated a robust and scalable manufacturing process for nanocarriers and their building blocks. With these insights, the road to widely available clinical applications for nanocarriers has become much shorter.

It's common to read about amazing new drugs and therapies in the newspapers, only to have them disappear from the scene, never to be heard of again. The same usually happens for novel therapeutic nanoparticle formulations, usually nanocarriers that can be imagined as tiny balloons with a drug inside. One reason for this is that during scale-up toward industry applications, it is found that these formulations can't be reproducibly and cost-effectively produced on a large scale, or even at all.



Since nanocarriers are built from multiple tiny building blocks, Jaleesa Bresseleers studied how these building blocks and their formulation and processing parameters correlate to the resulting nanocarrier characteristics.

Regenerative heart valves and blood vessels a step closer

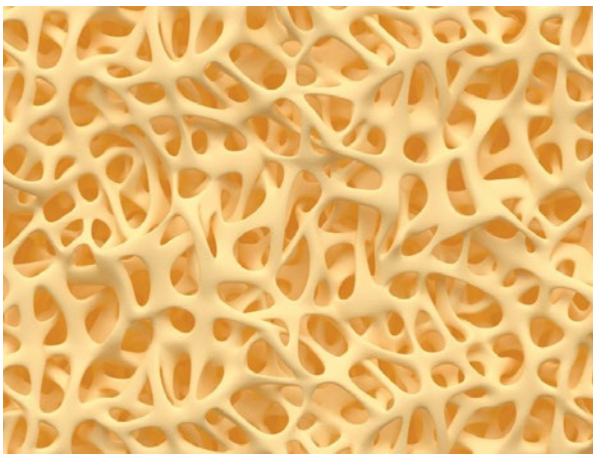
Source: Shutterstock.

A NUMBER OF YEARS OF CAREFUL LABORATORY TESTS HAVE NOW LED TO THE FIRST PRE-CLINICAL TESTS OF IMPLANTABLE BIODEGRADABLE HEART VALVES AND STENTS.

Non-degradable prostheses for cardiovascular tissues can be used to replace heart valves and blood vessels, but they can't stay in the body permanently. In two recent papers, TU/e researchers in collaboration with a number of clinical partners, the Dutch Heart Foundation, and TU/e spin-off companies Suprapolix, Xeltis, and STENTiT have shown how replacement stents and heart valves made from biodegradable materials can be a permanent solution as they help the body to replace damaged tissues. It's the first time that these biodegradable heart valves and stents from their research have been evaluated in a pre-clinical setting.

Researchers grow most lifelike woven bone yet starting from cells

FIRST BONE ORGANOID WILL GREATLY INCREASE UNDERSTANDING OF BONE FORMATION AND BONE DISEASES.



Researchers from Eindhoven University of Technology and Radboudumc have interwoven various bone cells into an "organoid" that can independently make new, hard bone tissue. It's the most complete 3D model of bone formation to date. The 3D model allows for the study of the key biochemical processes in unprecedented detail and could help in cracking the many mysteries surrounding bone formation. Moreover, the lab-grown bone is particularly suitable for testing and designing new treatments for bone diseases such as osteoporosis or osteogenesis imperfecta.

Organ-on-a-chip project receives huge grant to make the leap from lab to fab

NWO PERSPECTIVE GRANT OF 4.8 MILLION FOR MULTIDISCIPLINARY CONSORTIUM, LED BY TU/E PROFESSOR JAAP DEN TOONDER, TO DEVELOP MUCH-NEEDED UNIVERSAL STANDARD FOR THE PHARMACEUTICAL INDUSTRY.

Scientists are pushing ahead building "organ-on-chips," small chips with human cells, for example, for studying cancerous metastases in the bloodstream or the development of scar tissue. Or for testing the effect of drugs or food outside a human body. To take the step to industry, a collective of research groups, companies and research institutes, brought together by the organ-on-chip consortium hDMT, are building a universal standard, supported by a NWO Perspective grant of nearly five million. The ultimate goal: to link multiple organ-chips together to simulate the whole body.

Jaap den Toonder. Photo: Public Cinema

ALLIANCES

Breaking the barrier: Tracking the movement of cancer cells

Sertan Sukas

When cancer cells start to spread through the body, the patient's prospects seriously deteriorate. Understanding how cancer cells manage to escape and roam around freely, requires detailed insights into the way they penetrate the epithelial barrier. In a joint IBEC/ICMS project, postdoc Sertan Sukas managed to develop a unique device that enables the study of cellular movement in conditions that mimic those in the blood vessels. This novel technique enables, for the first time, not only the combination of shear and pressure, but also the independent control of these crucial parameters.

"THE CONTRIBUTION AND EFFECT OF SHEAR AND PRESSURE HAS NEVER BEEN RESOLVED BEFORE"

In this article, we celebrate the innovative work undertaken as part of the collaboration between the Institute of Bioengineering in Catalonia (IBEC) and ICMS. In one of three joint projects, postdoc Sertan Sukas (Biomedical Engineering/ Mechanical Engineering) is developing a microfluidic circulatory mimicking device which is designed to uncover important information about how cancer traverses the lining of vessels and spreads through the body. The project is supervised by Vito Conte, assistant professor Synthetic Morphogenesis (Biomedical Engineering and IBEC) and Jaap den Toonder, professor of Microsystems (Mechanical Engineering). Playing into the technological strength of TU/e to develop the device and the biological experience of IBEC to test its application, this collaboration makes for a powerful partnership.

THE GREAT ESCAPE

Endothelial cells are the barrier cells between blood vessels and tissue; they determine what gets into and what escapes from the vessels. When cancer cells break away from a primary tumor site and enter the bloodstream, they spread via the circulatory system and can find their way to other organs causing secondary tumors, also known as metastases. Conte and Den Toonder had the idea to develop a device that could interrogate the way cancer cell mechanics influence how cells are able to traverse the endothelial layer and go on to cause devastating metastatic disease. To be able to penetrate the endothelial layer, the cells need to physically push themselves through. This process of exiting the endothelia layer is called extravasation. Sukas: "We had to create a device that would mimic the circulatory system, allowing us to place the cancer cells within it and study the extravasation process."

UNIQUE DEVICE

In the first stage of device development, a soft substrate bed for the endothelial cells was created, giving the cells an environment that mirrors the human body. This substrate also performs the function of the stroma, which is supporting the framework of the vessel. Importantly in this case, the substrate is also able to quantify mechanical interactions. The next challenge was to create the conditions within the vessel to mimic blood flow. So, the device needed to be capable of producing and controlling two key mechanical functions: shear force and pressure loading. Studying the impact of both shear and pressure is a unique aspect of this project, says Sukas. "Most microfluidic devices are designed to only control shear force. But just focusing on the effects of shear neglects how much pressure is generated and the subsequent effect that this pressure has on the way the cells move."

Using a combination of microfluidics and Traction Force Microscopy, a technique to determine the dynamic interactions between cells and their underlying matrix, Sukas created a unique device that not only generates both shear and pressure, but is also capable of decoupling these parameters and controlling them independently. "Since we can independently control shear and pressure, we can create shear force and pressure loading independently from each other at physiological levels, thus mimicking the conditions within the blood vessel," Sukas explains. Excitingly, this appears to be the first device of its kind, says Conte. "According to the literature, the contribution and effect of shear and pressure has never been resolved before, so we are thrilled that we have been able to achieve this insight through the project."

DISEASE MECHANICS

Having created a robust and functioning device that mimics the forces at play in blood vessels, Conte remarks: "What is important now is to put the technology through its paces with various biological functions and to conduct experiments with other cell models." This is where the expertise of the IBEC colleagues comes in. IBEC's strength in life sciences will enable the team to test the limits of the device and understand its application potential. Their dream is for this innovative device to advance the study of disease mechanics at the cellular level. In doing so, it can play its part in developing much-needed new treatments and therapies.

New ICMS Fellow: Roderick Tas

Roderick Tas

"I have been at TU/e and ICMS since 2019, when I joined the group of Ilja Voets as a postdoc. To me, receiving the ICMS Fellowship feels like an additional recognition and it emphasizes my affiliation with the institute. As a Fellow, I will become more involved in the ICMS infrastructure and organization and I look forward to sharing my ideas on what we can achieve as a research community. The Fellows also act like a kind of ambassadors and represent ICMS within and outside the university and I think, as a postdoc, it is an interesting step in your career development."

CYTOSKELETON

"During my biology studies at Utrecht University, I attended a presentation by Lukas Kapitein on his research into the cytoskeleton and I was immediately taken by the complexity of this structure, but also by the way the architecture of the system regulates molecular transport within the cell. The function of the cytoskeleton is not only defined by the specific molecular components, but also by their organization. Specific molecules need to be organized in a specific way to make the system work. I was fascinated by all this and decided to pursue a PhD in the Kapitein group, focusing on using superresolution microscopy to study the cytoskeleton in brain cells."

SINGLE MOLECULE

"Currently, I work on ice-binding proteins using various single-molecule techniques, including superresolution microscopy. Now, the big challenge is to study multiple molecules at the same time on the highly sensitive ice-water interface to really figure out how the systems works. Can we translate what we see on the single molecule level to the complexity of the system? That will require new tools and techniques, which I like to work on because I can bring different areas together, such as biochemistry, molecular biology, biophysics and advanced technology like superresolution microscopy. ICMS offers the perfect environment for this type of research, because here you work surrounded by creative scientists with so many different backgrounds. Every day, you talk to people working on different topics. It generates a continuous flow of new and exciting ideas."

Postdocs in the spotlight

Visibility is essential for scientists at any stage, but particularly for young researchers who are just starting to build their career. The brand new Postdoc Paper Award offers postdocs a chance to take the stage and share their work with a broader audience.

Even though a postdoc position can be found on the resume of almost any academic, it somehow remains quite an invisible step in the building of a scientific career. "Postdocs are an in-between career group that is a bit overlooked," says Maria Pastrama, postdoc in the Orthopedic Biomechanics group at the Department of Biomedical Engineering and acting president of the TU/e's Postdoc Association (PDA). "Events or activities specifically geared towards postdocs are rare. The postdoc stage is a niche that does not have a real place in the academic career path."

Pastrama's view is shared by Florian Lemaitre, postdoc in the Photonics Integration group at the Department of Electrical Engineering and board member of PDA. "Postdocs need the visibility and that becomes even more important when you are aiming for an academic career." So, when ICMS approached PDA for suggestions on activities for postdocs, the idea for an award came up. Pastrama: "We know what it is like to be a postdoc and we have the contacts with the postdoc community within TU/e. That is our motivation to organize this competition."

FIRST AUTHOR

The initiative has meanwhile broadened within TU/e and now also includes the Eindhoven Artificial Intelligence Systems Institute (EAISI) and the Eindhoven Institute for Renewable Energy Systems (EIRES). All postdocs affiliated to TU/e are invited to submit a recent, first-author paper, accompanied by a short abstract. Papers that discuss results obtained while working at another university are also eligible. "Postdoc contracts are short, while the review process at journals can take a long time," Lemaitre explains.

The selection process is divided into two rounds. First, a jury of TU/e faculty selects ten participants. Next, all participants are invited to the second round, where the selected ten will be revealed and will be asked to pitch their work live on stage. The scores of both the expert jury and the audience will be combined to generate the numbers 1 (€500), 2 (€250) and 3 (€100). "Nice amounts," says Pastrama, "and the winning papers will also be actively promoted through the institutes' and university's social media channels, thereby increasing the researchers' visibility."

Contact: postdoc_association@tue.nl

ADVANCED ANALYSIS OF COMPLEX MOLECULAR SYSTEMS

Next level colloids: 3D structured hybrid materials

Colloidal systems are everywhere. Think paint, for instance. Upon drying, a mixture of microscopic particles, colloids, in a solvent transforms into a protective polymer layer. Likewise, there are many more applications where a colloid system is the starting point for the creation of novel, functional materials. Obtaining structured materials from colloids has become a central research topic in academia and industry. ICMS researchers have now taken this to the next level with the creation of hybrid designer materials through supracolloidal self-assembly.

In a paper in Nature Materials, postdoc researcher Mohammad Moradi and PhD candidate Deniz Eren (Physical Chemistry/Remco Tuinier group) present a hybrid supracolloidal system consisting of polymer spheres covered with smaller silica nanoparticles. They use this system to produce three-dimensionally structured materials in which a crystalline polymer phase is intertwined with smaller silicon particles in a semi-crystalline lattice.

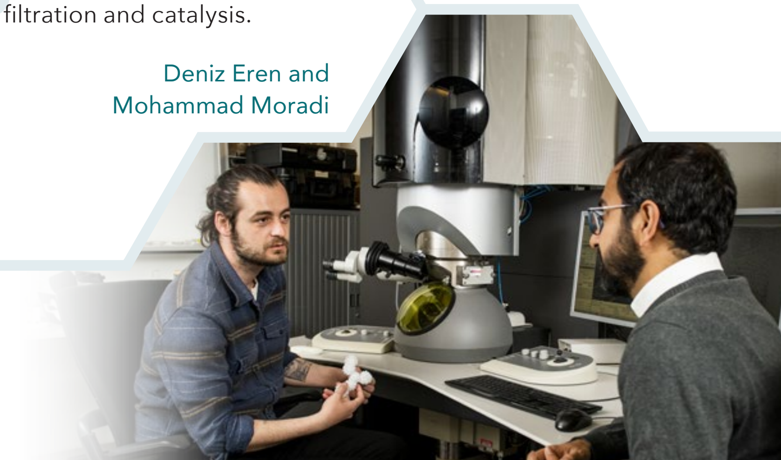
CHARGE-SWITCHABLE PARTICLES

Where most colloidal systems result in thin layers, Moradi and Eren were able to produce 3D-structured materials. They used charge-switchable silica nanoparticles that were three to five times smaller than the oppositely charged polymer spheres. When switching the silica charge by dropping the pH, the silica particles and polymer spheres cluster to form a supracolloid dispersion. Upon drying, a structured, hexagonally packed hybrid material emerges – but only when the dispersion of the supracolloids is retained, which depends on the ratio of the components, the charge density and the ionic strength. The Nature Materials paper presents a generalized model for using this approach to arrive at structured multi-component materials.

It took tenacity and a few serendipitous moments to get this far. At first, producing the supracolloids seemed impossible. Even after several hours, there was no sign of well-structured self-assembly. But then Moradi's first son was about to be born and he had to rush to the hospital, leaving the samples in the lab. When he returned three weeks later, he discovered that perfect supracolloids had formed. Another hiccup occurred when during drying of the dispersions, the structured arrangement disappeared. Only after MSc student Sebastian Rzadkiewicz discovered a tiny amount of double crystalline material in a corner of a sample, the proof of a 3D structure was obtained. It turned out that the supracolloids had to be more repellent. The third important breakthrough occurred when Eren managed to speed up the drying process. Now, satisfying amounts of the structured hybrid material are available in a matter of minutes.

Further research established that the silica structure remains stable after polymer removal by a temperature treatment, resulting in structured nanopores in a silica network. The research, carried out in close cooperation with the Center for Multiscale Electron Microscopy at TU/e, thus provides new opportunities for designing and producing tailored hybrid nanomaterials for use in diverse fields such as optoelectronics, energy storage, membrane filtration and catalysis.

Deniz Eren and Mohammad Moradi



M.-A. Moradi, E.D. Eren, *et al.*, "Spontaneous organization of supracolloids into three-dimensional structured materials," *Nat. Mater.* 20, 541–547 (2021). DOI: 10.1038/s41563-020-00900-5

Alex Joesaar works on the construction of artificial protocells that can communicate using DNA-based signals. "Living cells have many components and that makes them very complex. It's hard to isolate one specific functionality." He recently obtained his PhD in the Synthetic Biology group of Tom de Greef (Department of Biomedical Engineering). "In the future, synthetic cells could potentially be used for degrading toxic products in the environment or the synthesis of complex molecules."

Protocells start talking

"We created a system that consists of synthetic capsules or 'protocells' roughly the size of living cells," Joesaar explains. "These can mimic primitive forms of cellular communication." To enable the communication between protocells, Joesaar and colleagues needed to create a DNA-based protocol for molecular communication. "The binding between DNA strands is very programmable and predictable. This is very appealing since we can easily create new orthogonal systems using different DNA sequences."

PREDICTABLE BEHAVIOR

This flexibility allows the construction of logic circuits out of DNA. "In the protocells, we encapsulated DNA duplexes that are not fully complementary, but contain a single-stranded DNA overhang. This part is free to interact with any other DNA. If an input strand diffuses from the exterior into the protocells and is complementary to that overhang sequence, it can push away the existing binding partner, which in turn is released and creates an output signal. The length of the DNA and the distance between the protocells control the strength and speed of this interaction. We can fine-tune these parameters using a mathematical model to predict the system's behavior." The more complex diffusion-based communication systems are bidirectional. "We have developed a system that contains two populations of protocells: one population sends a signal and the other population responds with an inhibitor."

MORE WORK

"Making this system reusable is something we haven't achieved yet," says Joesaar. "We end up in an equilibrium state were the DNA is completely hybridized and not reactive anymore. If we want to repeat the experiment, we need a new set of protocells. Our idea is that eventually we can build systems that remain out of equilibrium and are reusable." Looking at the bigger picture, engineering synthetic cells from scratch will require more work. "There is a lot of research on the various functionalities, such as communication, metabolism and movement. I think the biggest challenge is putting them all together."

Alex Joesaar

Patricia Dankers

In March, Patricia Dankers learned that she was one of the recipients of the Ammodo Science Award for Fundamental Research 2021. "A real honor," says Dankers. "Not only for me, but for my whole group. All scientific areas are eligible for this award, so being selected is really a wonderful recognition of our fundamental work and the results we have achieved as a group."

"WE ARE NOW EXPLORING THE POSSIBILITIES"

Patricia Dankers ventures into the world of plants

Every two years, eight mid-career scientists – covering all academic areas – are selected for this €300,000 prize. The award is an initiative of the Ammodo Foundation and the Royal Netherlands Academy of Arts and Sciences (KNAW). Those who assume that she will use the prize money to continue along the same research lines are in for a surprise. "I want to start a project on plants, in particular creating matrices to culture plant cells," Dankers explains.

Plants? What about all the promising progress in biomedical materials? "I'm not leaving that area, but I have been thinking about plant research for a while now and when the first lockdown hit us in the spring of 2020, just like many people I spent a lot more time in my garden. That accelerated my thoughts on how our work on synthetic matrices could be used to develop new methods to grow plant cells."

Dankers envisions a matrix-like material similar to what Matrigel is for culturing animal cells. "Now, researchers have to fully grow a plant to study, for example, the effects of genetic modification. When we can create a way to culture plant cells, we can speed up this process while at the same offering more control of the conditions. Together with scientists who are more at home in plant research, we are now exploring the possibilities."

MATERIALS
FOR REGENERATIVE
MEDICINE

Inflammation is a good start

Anthal Smits

Our immune system protects us by attacking anything that is non-self. Including implants that are needed to restore vital functions. No wonder that for long, evading the immune system was seen as the key to avoid rejection. But following extensive studies of how our bodies deal with an implanted material, new strategies have emerged. The immune system is no longer perceived as a threat, but as an essential partner in making the body deal with the new and “strange” material. By studying how immune cells respond to synthetic materials, Anthal Smits aims to ensure a better integration and processing of biomedical implants.

"INFLAMMATION IS THE FIRST RESPONSE AND IT IS EXACTLY WHAT WE NEED"

The COVID-19 pandemic leaves no doubt that a better, deeper and broader understanding of our immune system is paramount. For Anthal Smits, that is no news. The immune system was already a key topic in his research, with or without viral threats. Smits, assistant professor of Immunoregeneration in the Soft Materials and Mechanobiology group (Biomedical Engineering) studies how the immune system responds to degradable implants used in regenerative medicine, such as heart valves and blood vessels. "Our aim is to develop regenerative materials that gradually get replaced by the body's own, functional tissue," he says. In that process, the immune system is a key player and Smits wants to understand its role and in particular, how its actions can be put to good use. That is a relatively new strategy in the field. "For long, the assumption has been that an implant should evade the immune system as much as possible. We now know that you need the immune system to achieve the desired clinical outcome."

GARBAGE MEN

The secret? Inflammation. We often think of inflammation as a bad sign, but it is simply the way the immune system responds to anything that is seen as an intruder, whether it is a deadly virus or something as mundane as a little wooden sliver in your finger. Or, in Smits' research, a synthetic heart valve. "Also here, inflammation is the first response and it is exactly what we need. Inflammation is the start of the whole process of repair, healing and formation of new, functional tissue." His particular interest is in the macrophages, the immune cells that are often described as the body's garbage men. "Macrophages are important 'cleaners', but they also initiate inflammation and the subsequent repair and healing process. Moreover, macrophages degrade the implant, while they are also responsible for terminating that process." A central question is how mechanical factors affect the macrophages' behavior and regulation. "Tissues such as heart valves and blood vessels experience high mechanical loads, so our implants have to be quite robust. We know that certain cells in our body need mechanical loads to mature and function. But we know very little about the effect of mechanical loads on macrophages, which is relevant because they infiltrate the implanted materials and are thus subject to strain and pressure. Our research has demonstrated that macrophages 'feel' the stretch and that they don't like it too much. High strain, even when still physiologically acceptable, induces an inflammatory response."

NEW ARCHITECTURE

The results of a long-term study with degradable heart valves in sheep, which were published end of 2020, demonstrate the relevance of more insight into the mechanics-macrophage interplay. "We mimicked the well-defined structure of native heart valves to ensure the formation of functional tissue. But it turned out that, unexpectedly, our materials underwent complete remodeling. Apparently, the macrophages sensed the structure of the material, leading to a completely new architecture that did not resemble the microstructure of native heart valves." But the valves still functioned and the sheep survived, so does it really matter? "That is a recurring discussion. Of course, you may say that is doesn't matter as long as the valve operates as it should. Our concern is that a valve with a different structure may function fine for a while, but that problems will occur at some point, because the improper structure of the new valve is in the long run unable to deal with the mechanical load and that leads to malfunction."

MECHANICAL IMPACT

To understand the impact of mechanics on macrophages, Smits and his team study their behavior under different conditions. "Next to animal studies, we do a lot of in vitro work, in which we grow macrophages from human blood on our biomaterials in various configurations and subject them to different mechanical stimuli. That way, we examine the effect of the material's structure on the macrophages' behavior and vice versa. What does a macrophage 'feel' and how does it respond? The mechanical load is not the same throughout the valve, so it is interesting to see if that is reflected in the degradation and regeneration process. Where does the degradation start? In the center or at the fringes? Always in the same spot or is it a random process? That is what we want to find out. So we can direct the macrophages towards the right balance between breaking down the implants and building up the new tissue."

The circadian clock, the rhythmic beating of the heart; synchronized behavior is everywhere in life. Think also of the perfectly orchestrated movements of a shoal of fish or a flock of birds. It was the 17th century Dutch polymath Christiaan Huygens who first described the phenomenon when he observed that two pendulum clocks, mounted on a wooden beam, started moving in synchrony. Now, early in 21st century, the same has been observed and (almost) explained in soft, light-responsive polymers.

On polymers & pendulums

From left to right Henk Nijmeijer, Ghislaine Vantomme and Dick Broer

It all started, in the best scientific tradition, with an observation. In the fall of 2016, Ghislaine Vantomme and Anne Helene Gelebart, postdoc and PhD student at that time, were experimenting with light-responsive polymers. "In our group, we have long been working on materials that change shape influenced by light," says Dick Broer, professor of Functional Organics Materials and Devices. "We had developed polymer strips that exhibit sustained oscillatory behavior when exposed to light and then Ghislaine and Anne Helene noticed that two oscillating strips started to move in a synchronized manner. That drew our interest because synchronization points to some kind of communication between the strips. Apparently, these materials are capable of sensing each other. And that is of course very interesting and relevant when you are looking for new, programmable materials for soft robotics applications." The team recognized the importance of the observation, but was stuck on how to proceed. "We knew we had something, but we didn't know what to do with it," Ghislaine Vantomme adds. "The big question for us was how we could understand the physics and mechanics of this synchronization, but the dynamic aspects were so complex." Broer agrees: "We had no clear idea how to tackle this."

“THE AIM WAS NOT TO MODEL THE CHEMISTRY, BUT TO FOCUS ON THE MECHANICS”

OPEN DISCUSSION

For Henk Nijmeijer on the other hand, synchronization displayed by “hard” materials in instruments like metronomes, was a very familiar topic. Nijmeijer is professor of Dynamics and Control at the department of Mechanical Engineering and studying complex dynamics of mechanical systems is at the heart of his research. But doing the same for a chemical system, that was something new. “Bert Meijer invited me to a very open ICMS discussion, and that is where we all met for the first time. The work on the light-responsive polymers was introduced and we were asked to think about how we could exploit this behavior and what we could do with these materials. An important question was how to analyze the complex dynamics of this system. I think that was the driver to ask us on board.” After that first gathering, things didn’t take off immediately. In part, that was due to practical reasons as Gelebart was busy finishing her thesis and Vantomme became assistant professor at TU/e. Vantomme: “But it also simmered in the background for a while, because at that stage it was not a real chemistry problem anymore. As for the physical and mechanical perspective, that needed to get going.” This raises an important point, when it comes to starting new collaborations and exploring new areas. “I can appreciate what I see, but I don’t know the chemistry,” says Nijmeijer. “A new collaboration takes time to understand each other’s language and learn about each other’s research. There is a very nice observation in the materials and their chemistry and there are interesting dynamics, but how do you bring that together? That is the challenge.”

Again, the ICMS environment proved to be a kick-starter. A subsequent meeting on soft robotics triggered a new round of discussions. Nijmeijer: “It was clear that we first needed to tackle the mechanics of the polymer system and we decided to recruit a student in mechanical engineering to work on a model that covers similar mechanics of oscillatory motions like we saw in Ghislaine’s experiments.” That is when Lars Elands and his supervisor Sasha Pogromsky (Mechanical Engineering) joined the project and things really got going. Importantly, the aim was not to model the chemistry, but to focus on the mechanics, says Broer. “There were existing models on the materials. Our system is driven by changes in molecular order. You excite one molecule and that affects other molecules in its direct environment, which induces strain and this whole sequence of events finally results in macroscopic changes in the material. What we needed from the model was to cover the dynamics of these events and then try to translate the mechanics to polymer science.” However, to explain the observed synchronization, something else needed to be considered as well, Nijmeijer emphasizes. “For me, it is always about the medium. How do systems communicate? How do they talk to each other? We know that when you put two pendulums on a flexible support, synchronization, either in-phase or anti-phase likely will occur. But how do you translate that to a polymer? What is the connection and how can we model the interaction between two polymer strips? Looking for the connection, or the medium, became the driver of the project.”

BROADER PERSPECTIVE

In this case, the medium was the material itself. Vantomme cut a rectangular piece of the polymer material lengthwise, but not completely through, leaving the two strips joined at one side. “We wanted to know the defining characteristics of the medium to allow synchronization to occur. For example, how flexible or stiff should it be?”, she points out. And once those are known, new questions immediately pop up, Broer foresees. “Can we change the connection? Use another material? What are the requirements of the connecting hinge to enable synchronized behavior, that is for us the essence of the

problem." And now there is a model of the observed synchronization in the two strips, as described in their recent Nature Materials paper. To what extent does it offer a general explanation of the phenomenon? Broer: "Well, enough to generalize for this system and for other materials that operate through changes in molecular order induced by changes in light, heat or perhaps electricity. What I find very appealing is that the model covers the collective behavior over different length scales and thus allows for a broader perspective on systems that 'talk' to each other, which is also relevant to examples of synchronization from the natural world." Nijmeijer agrees: "It is all about understanding the process of going from micro to macro. That is what we try to understand and that is directly related to all kinds of natural phenomena. One water molecule is not wet, but how many water molecules do you need for that? One brain cell cannot think, when does a thinking brain result from multiple brain cells? Such questions are a no-go in modeling terms, there is a numerical problem. Try modeling millions or billions of cells to see whether you get emergent behavior. You need a different approach and this new model fits very well with what we observe."

So, to recap: there was an observation that is now explained by a model. And now what? Broer starts to laugh. "I was wondering when that question would come. Well, what I would like to study is the effect of another actuating source than light. After all, we only use light to achieve the local heating in the material, which actually initiates the whole sequence of events. What happens if we put the strips on a wire and use electricity to heat the material? Another interesting option is to use other materials besides our much-liked liquid crystals. And there are ideas for trying to use this system for sensing applications. Can we make the medium sensitive to a certain chemical, so that it will affect the mechanical behavior of the arms. That could be a read-out. A system like that could be used to report on the properties of the medium or of the environment. Practical applications are still far off, but my first option would be to look at sensing."

CREATE A WAVE

Working on this project has generated plenty of inspiration for Nijmeijer to think about synchronization in new ways. "I am excited about any topic relating to synchronization and working on such a system with these dynamics, is really the kind of work I like most. There are still many challenges ahead. For example, what if you bring multiple oscillators together? We understand synchronization in metronomes in different set-ups quite well, but moving from individual oscillators to more than two is still very complex. This work on the polymer system might help us there." Another open question is what determines whether the strips move in-phase or anti-phase, says Vantomme. "We don't yet know when they start to move in synchrony. At first, they move each in their own rhythm and all of a sudden, the synchronized movement starts. For now, we concluded that when they are close by at that point, the strips move in-phase and when they're opposite of each other, their movement will be anti-phase." Control of the movement will become important when you move to larger numbers of oscillators, she says. "Let's say you want to use the strips to transport something by creating a wave, then you need to be able to orchestrate their movement."

Plenty of puzzles ahead, they all agree. Nijmeijer: "But this model really offers a framework to understand synchronization as a phenomenon, particularly concerning the medium. I think the medium was the real connection in this project." And humans are not exempt from all this, he says. "People also need to sit together for meaningful communication, it creates dynamic coupling. You cannot achieve that when everyone is just staring at their screen."

ICMS PhD Outreach Program

With the new PhD Outreach Program, the ICMS aims to energize the communication among the institute's youngest members. Levena Gascoigne (CEC), Mariska Brüls (CEC) and Martin Rutten (BMT) volunteered to organize a number of events to enhance scientific and social contact among the ICMS PhD students.

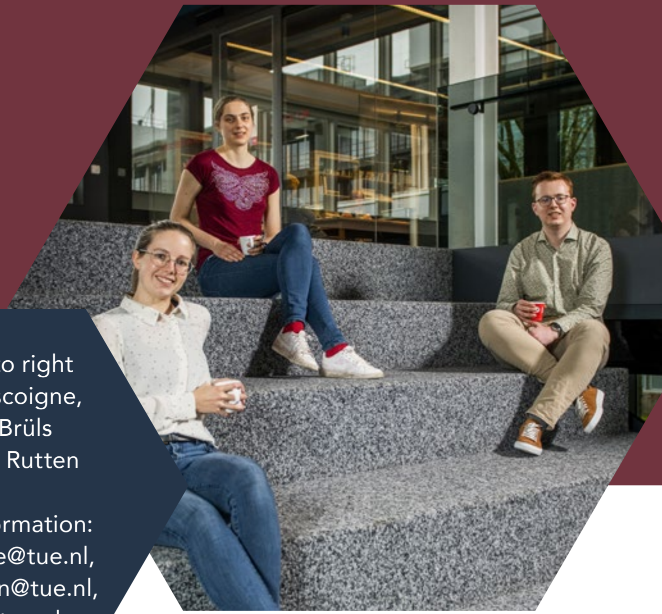
PhD students have benefited from the research environment fostered by ICMS, through exposure to multiple scientific disciplines, top-notch invited speakers, and cross-discipline collaborations. Martin Rutten can account for that himself, as he has collaborated with colleagues from Mechanical Engineering. But he also acknowledges that informal, cross-departmental contacts are mainly occurring when departments share working spaces. "We meet some people from other groups at symposia, but social interactions are mostly group-based and building-based," he specifies. "The three of us work in Ceres and get to see each other quite a bit," Levena Gascoigne agrees. "But that is not the case for many of our ICMS colleagues who are scattered all over campus." Coffee corners, lunch tables and Friday evening drinks are settings where students can spontaneously engage in scientific conversation. And then, as Gascoigne puts it, "ideas start to flow. Especially with people from other departments offering different perspectives." That way, researchers from different departments get to know each other personally and scientifically in an easy going manner. This is what the committee members want to boost among all PhD students within ICMS.

ACTIVITIES

The new PhD Publication Award seems the best way to achieve many goals at once. This biannual competition not only serves as a platform to meet fellow PhD students and learn about their research, but also to generate visibility for their own work. All submitted abstracts are listed on the ICMS LinkedIn page for public polling to select one finalist. "This way, everyone gets to showcase their work," Mariska Brüls points out. The four other finalists are selected by jury of PhD students. Following pitches by the five finalists, a TU/e postdoc jury will select the winner, who will receive €250 and will enjoy additional publicity for the article. Other scheduled activities include a LinkedIn workshop and near the end of the summer, the organizers have great hopes for a barbecue.

ORGANIZATION

Meanwhile, more PhD students have joined the team: Marrit Tholen (BMT), Max Schelling (AP), Anna-Maria Makri Pistikou (BMT) and Coen van der Gracht (ME). Colleagues from Mathematics and Computer Sciences are invited to join as well.



From left to right
Levena Gascoigne,
Mariska Brüls
and Martin Rutten

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MOLECULAR DEVICES

Towards the next generation of solar cells

Junke Wang and Kunal Datta

Together with colleagues at Solliance Solar Research, ICMS researchers have made significant progress in the development of next generation solar cells based on perovskite materials. In a paper in Nature Communications, they present a triple-junction perovskite cell with 16.8% conversion efficiency. Resulting from the PhD research of Junke Wang and Kunal Datta, these cells pave the way towards multi-layered perovskite tandem cells with record-breaking efficiencies.

Of course, silicon-based solar cells already cover many roofs and there are ample plans for solar farms to generate massive amounts of sustainable energy. Yet, there is still plenty of room for improvement. At the Molecular Materials and Nanosystems group led by René Janssen, researchers are pushing hard to develop the next generation of solar cells. These are based on perovskite materials; hybrid inorganic-organic crystalline compounds that can be easily manufactured from cheap raw materials and thus allow for rapid and cost-effective industrialized fabrication. "This combination of low cost, easy processing and high conversion efficiency would really bring solar energy conversion to the next level," says Kunal Datta. "It could provide a tremendous boost to realize the terawatt-scale solar industry that is essential for realizing the sustainable energy transition." Already start-up companies are exploring the opportunities of perovskites, he adds.

ABSORBING MULTIPLE COLORS

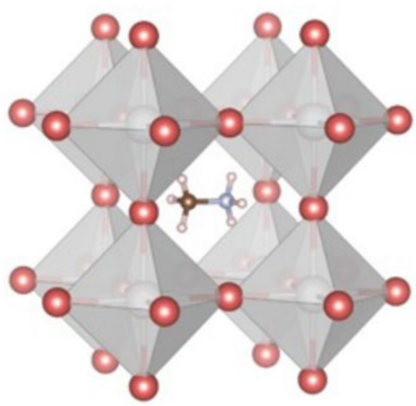
Junke Wang explains that solar cells using conventional crystalline silicon are already approaching their efficiency limit of 33 percent. "A strategy to go beyond that is to combine multiple light-absorbing layers that together can capture the full spectrum of sunlight. Perovskite offers a great way to do that since changing its chemical composition also changes the color of sunlight it absorbs." Combining multiple, different perovskite layers into one solar cell could – in theory – raise the conversion efficiency of a solar cell to a whopping 68 percent. "The concept of such tandem or multi-junction cells obviously reduces the cost per kWh," Datta says. "But then producing these cells should not require an intricate procedure, since that would counter the inherent benefits of perovskites."

"MULTIPLE LIGHT-ABSORBING LAYERS TOGETHER CAN CAPTURE THE FULL SPECTRUM OF SUNLIGHT"

The Nature Communications paper describes a simple, yet effective processing method to arrive at three distinct perovskite layers. At the heart is a two-step solution process where first, a solution of an inorganic halide compound is deposited to form a thin "precursor" layer. On top of that, a solution of an organic halide is deposited. A final thermal annealing process induces the formation (crystallization) of the actual perovskite layer whose composition depends on the contents of both solutions used in the two-step deposition process.

PROTECTIVE LAYER

Minimizing interference when repetitively using this procedure to deposit multiple perovskite layers proved a major challenge. Wang: "The problem is that the organic solvents we use to deposit the halide compounds will also dissolve a perovskite layer. So, we had to come up with a robust protective layer to preserve the integrity of an established perovskite layer during deposition of a new one. And of course, these layers themselves should not reduce the performance of the final solar cell." According to Wang, this turned out to be rather difficult. "At first we selected a deposition technology that in itself was damaging to the perovskite layer. Adding to this, the proposed protective layer introduced adversary electrical effects. It took us quite a long time to conclude that this approach would not yield any realistic device. Luckily, we then got in touch with colleagues at Solliance Solar Research at the Eindhoven High-Tech Campus, who proposed an alternative deposition technology. That enabled us to realize the protective layer and arrive at triple-junction devices with a very satisfying performance."



Crystal structure of a perovskite of the type $CH_3NH_3PbX_3$, where a central methylammonium cation ($CH_3NH_3^+$) is surrounded by PbX_6 octahedra. X represents halide ions (I, Br and/or Cl; depicted as red spheres). The ratio of I, Br and Cl determines the color of light that is absorbed by the perovskite. Replacing the lead (Pb) ion at the center of the octahedra with another metal such as tin also changes the absorption frequency.

RIVAL PERFORMANCE

Wang is proud that the 16.8% conversion efficiency of the triple-junction cell more than doubles figures reported earlier in literature. "This is quite a competitive field. Being one of the first groups to develop triple-junction perovskites is very satisfying. And in fact, we have only published proof-of-concept. We see many opportunities to go beyond 16.8%." After obtaining his PhD in December 2020, Wang is now improving the concept as a postdoc. "We hope to achieve conversion efficiencies towards 30% in the near future. With further development of individual perovskite materials, efficiencies towards 36% are within reach." That would already rival the performance of current silicon technology, yet at considerably lower cost. In the meantime, Datta is in the last year of his PhD research where he will focus on combining perovskites with a silicon cell in a hybrid tandem cell set-up – a collaboration between researchers from TU/e, Delft University of Technology, AMOLF, University of Amsterdam and industrial partners. The idea here is to complement the spectral absorption features of silicon-based devices using thin perovskite films and thereby improve performance. Datta: "Whether it will be all-perovskite or silicon-perovskite, the conclusion is clear: multi-junction cells will be the way to go in solar technology."

Junke Wang, Valerio Zardetto, Kunal Datta *et al.*, "16.8% Monolithic all-perovskite triple-junction solar cells via a universal two-step solution process," *Nat. Commun.* 11, 5254 (2020). DOI: 10.1038/s41467-020-19062-8

News, awards & grants

Three honorary doctorates in anniversary year

THE THREE LAUREATES ARE WORKING ON COMPUTATIONAL MATHEMATICS, CHEMICAL ENGINEERING AND REGENERATIVE MEDICINE.

In this thirteenth lustrum year as many as three professors will receive an honorary doctorate from TU/e. They all work at prestigious American universities: computational mathematician Margot Gerritsen (Stanford University), chemical engineer Klavs Jensen (MIT) and biomedical engineer David Mooney (Harvard University). If the corona pandemic allows, the laureates will receive their decorations on October 15th during MomenTUm.

"A wonderful, inspiring researcher," professor of Biomedical Materials & Chemistry Patricia Dankers says about David Mooney. "And an amiable, pleasant colleague," professor of Cell-Matrix Interactions in Cardiovascular Regeneration Carlijn Bouten stresses. "David is a leading scientist who is also very down to earth; a true role model in our field."

David Mooney (Harvard University)

Dankers and Bouten both act as honorary supervisors for Mooney, who studied chemical engineering in his hometown of Madison, Wisconsin, after which he obtained his PhD from MIT. He has been working as a professor at the Harvard School of Engineering and Applied Sciences since 2004. Mooney is also a founding core department member at the Wyss Institute for Biologically Inspired Engineering at that same university in Cambridge, Massachusetts.

How antifreeze proteins could help preserve donor organs for longer

Photo: Bart van Overbeeke

WITH SO-CALLED POLYAMIDES ILJA VOETS HOPES TO MIMIC THE MOST FAVORABLE PROPERTIES OF ANTIFREEZE PROTEINS THAT ENABLE THE PRESERVATION OF COMPLEX TISSUES.

Freezing often leads to damage. Antifreeze proteins can limit this damage. These miraculous proteins ensure that the blood of animals, such as arctic fish and snow fleas, does not freeze in the cold environment in which they live. Chemist Ilja Voets develops new materials inspired by these proteins that make it possible to preserve tissue or donor organs much longer.

Conductive polymers imitate the brain

In the Dutch chemical Magazine C2W, ICMS researcher Yoeri van de Burgt explains his research into neuromorphic computing. He deploys conductive polymers to create a new type of artificial memory, inspired by the ways neurons and synapses operate in our brain.

Yoeri van de Burgt

Major EU grants for groundbreaking research into scoliosis and transplant organ rejection

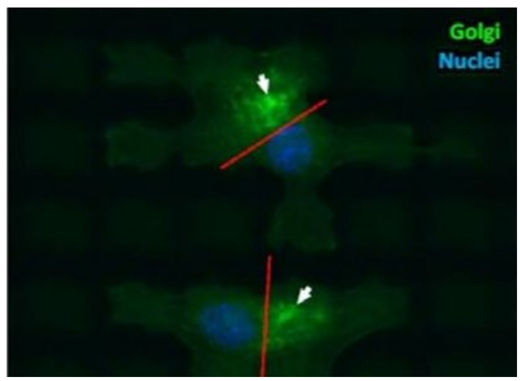
THE TWO PROJECTS ARE LED BY KEITA ITO AND WILLEM MULDER, PROMINENT RESEARCHERS IN THE FIELD OF BIOMEDICAL ENGINEERING.

Keita Ito and Willem Mulder

The European Union invests a total of 5.25 million euros in groundbreaking health-related research at the University of Technology Eindhoven (TU/e). Two ERC Advanced grants will fund research to better prevent and treat scoliosis and transplant organ rejection, conditions that affect millions of people across the world.

New grant to fund research on the inner workings of the cell

HFSP RESEARCH GRANT AWARDED TO JAN DE BOER AND INTERNATIONAL COLLEAGUES TO STUDY THE GOLGI COMPLEX.



Removing the Golgi system from the cell will force the cell nucleus to take immediate action to replace the Golgi system. Image courtesy of Urnaa Tuvshindorj.

Jan de Boer and collaborators based in the US and Italy have received a Human Frontier Science Program (HFSP) research grant worth more than one million euros to study the mechanisms that cells use to build the Golgi complex, a central hub in the cellular membrane that plays a key role in directing proteins and lipids towards their final destinations in cells. With this grant, the researchers are seeking to find a way to control the transcriptional program of the Golgi complex by bioengineering specific patterns and/or materials

Theses

NOVEMBER 2020 – MARCH 2021

Rational design of porous silica-based materials via multiscale colloidal assembly
ANDREAS FIJNEMAN
November 5, 2020
PhD advisors:
G. de With,
A.C.C. Esteves,
H. Friedrich

Bioinspired soft robots: shining light on liquid crystal polymers
MARINA PILZ DA CUNHA
November 13, 2020
PhD advisors:
A.P.H.J. Schenning,
D.J. Broer,
M.G. Debije

Rational design of small molecule 14-3-3 protein-protein interaction stabilizers
FRANCESCO BOSICA
November 13, 2020
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G. O'Mahony

Development of scalable processes for the manufacture of nanocarriers
JALEESA BRESSELEERS
November 18, 2020
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J.C.M. van Hest,
W.E. Hennink,
S.A. Meeuwissen

Unconventional chromophores for organic solar cells
BART SAES
November 20, 2020
PhD advisors:
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Interfacial, compositional and morphological engineering for single- and multi-junction perovskite solar cells
JUNKE WANG
December 10, 2020
PhD advisors:
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Correlative microscopic characterization of nanoscale assemblies at interfaces
MICHAEL BEUWER
December 15, 2020
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Structural elucidation of novel allosteric regulatory mechanisms in nuclear receptors
RENS DE VRIES
December 16, 2020
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Controlling the optoelectronic properties and structural organization of diketopyrrolopyrrole polymers via specialized design motifs
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January 15, 2021
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Relaxation pathways for soft materials
SIMONE CIARELLA
January 22, 2021
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Computational modeling of synthetic molecular scaffolds
JOB ROODHUIZEN
January 29, 2021
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Liquid crystal flow stimulated by light and electricity
YUANYUAN ZHAN
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D. Liu

Selective laser sintering of polymer particles studied by in-situ visualization
PRAKHYAT HEJMADY
February 4, 2021
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Applications of elastin-like polypeptides in nano-medicine
MONA ABDELGHANI
February 9, 2021
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Biochemical communication in synthetic protocell communities
ALEX JOESAAR
February 10, 2021
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Designed micro- and nano-compartmented factories for chembio cascade reactions in a one-flow process
CHENYUE ZHANG
February 25, 2021
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Self-assembly and silicification of macromolecules
PAULA VENA
February 25, 2021
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Molecular simulations of vesicles and dendrimers
SANDER SMEIJERS
March 9, 2021
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Fragment-based discovery of protein-protein interactions stabilizers
DARIO VALENTI
March 10, 2021
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Designing optimal behaviour in mechanical and robotic metamaterials
GIORGIO OLIVERI
March 19, 2021
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One-flow synthesis of cannabinoids and neuraminic acids
VICTOR BLOEMENDAL
March 26, 2021
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F.P.J.T. Rutjes

Production planning and control of poultry processing plants
KAY PEETERS
March 30, 2021
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POLYMER SCIENCE AND TECHNOLOGY

Measuring materials under extensional flow

Jessica Pepe is a PhD student in the Polymer Technology group of Patrick Anderson (Mechanical Engineering). Her work on a filament extension rheometer demonstrates that it is possible to determine how polymer chains rearrange in space when subjected to a uniaxial extensional flow. This novel in situ technique provides much-needed insights into extensional polymer processing.

Jessica Pepe

The properties of processed polymer materials depend on both the chemical nature of the polymer and the processing conditions. It is well known that the combination of flows exerted to the melted polymer during processing, together with the thermal history, will determine the final morphology and, thus, properties of the material. However, to determine a priori which specific set of processing conditions will result in a certain material property is not yet possible. In industry, this still requires a costly and time consuming approach of trial-and-error. During processing, the system is too complex to be studied. There are multiple flows, consisting of both shear and extensional contributions. To gain more insight, researchers have broken down the problem. “With our filament extensional rheometers, we can reproduce polymer processing while focusing on just one type of flow,” Jessica Pepe explains. “We are able to observe in situ how the polymer material responds to uniaxial extensional flow, by measuring the polymer viscosity and using X-ray scattering and diffraction to follow morphology evolution.”

"WHATEVER YOU WOULD LIKE TO STUDY IS POSSIBLE"

MID-FILAMENT POINT

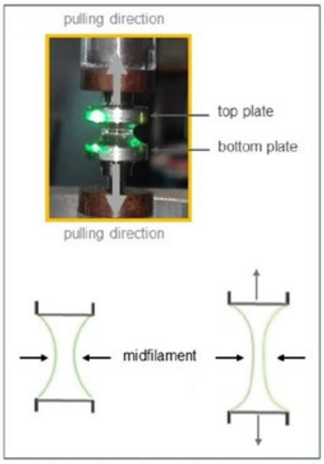
In this rheometer, equipped with an oven for temperature control and nitrogen flow to prevent polymer degradation, the polymer melt is positioned between two plates. As the plates move apart, the material in between starts to stretch. It loses the initial cylindrical shape and becomes narrower in the middle. Here, in this smallest dimension diameter of the material, the viscosity and morphology characterization measurements are performed.

This is the most remarkable rheometer of its kind. A great deal of engineering has been invested to ensure precise control of both the location and deformation of this mid-filament point. By simultaneously moving the two plates at the same velocity, the mid-filament point remains fixed in space as the material is being stretched. This middle point is thus always aligned with the different source beams and detectors, making the in situ measurements possible. Furthermore, by also regulating the velocity at which both plates move, the diameter of the mid-filament point follows an ideal exponential decrease in time. In turn, this guarantees an ideal uniaxial extensional deformation at this point. Pepe: "The mid-filament point is where the highest stresses concentrate, where the material can be assumed to be a cylinder and, given the controlled deformation, where the equations can be applied."

LDPE

Low-density polyethylene (LDPE) was selected to test whether the filament extensional rheometer could deliver on its promise. A sensible starting point for this type of study as LDPE easily orients without requiring extreme conditions like very low temperatures or very strong flows. From being entangled in the melt, LDPE polymer chains can rearrange into highly ordered, dense ("shish kebab") structures as the material is being deformed. Remarkably, under certain flows and temperatures, even some crystals can be detected. Characterization measurements are also carried out when the flow is no longer applied, to see how morphology further evolves. All oriented structures formed during stretching are also monitored. "Some of these structures might eventually relax and lose the shape, once the flow that constrains them disappears," Pepe observed. Comparison of the data obtained while stretching the material and at rest allows to understand how the applied flows influence the formation kinetics of these ordered structures. All the morphological information generated with this technique, by changing one parameter at a time (temperature, deformation rate, deformation time, etc.), is then combined to give a full understanding of how the polymer behaves under uniaxial extensional flows.

With her proof-of-concept work, Pepe has paved the way for new studies on other semi-crystalline polymers. She sees a world of opportunities for this powerful and versatile filament extension rheometer. "Whatever you would like to study is possible, in principle. You can always place the rheometer with another source and measure some other property, *in situ*."



Picture of the melted polymer stretched between top and bottom plates and schematic representation of how the mid-filament point becomes more narrow, but remains stationary in space as the plates move apart.

Surprise Solution

Bas Rosier and Jurgen Schill

Sometimes the most innovative solutions arise without the conscious act of seeking answers. A casual conversation over coffee between two PhD students, sharing the trials and tribulations of their research, led to the joining of dots and a fusion of ideas. Jurgen Schill and Bas Rosier, both TU/e Biomedical Engineering alumni, headed in different research directions as PhD students, but their paths would soon merge again. Here, they tell the behind-the-scenes story of their recent joint paper in Angewandte Chemie.

Jurgen Schill was undertaking his PhD in the Chemical Biology research group of Luc Brunsveld, focusing on supramolecular polymers – monomers assembled and connected through non-covalent (transient) interactions into dynamic polymers. He wanted to find out whether such polymers can be designed to interact with biological matter. That way, they could be used to create micromaterials that enable safe administration and release of drugs into the body. “We wanted to mimic naturally occurring dynamic polymers using artificial supramolecular systems to create materials that interact with living cells in a biologically compatible way,” explains Schill.

EACH SINGLE MOLECULE

“Creating a supramolecular polymer that is able to deliver drugs and interact with cells, requires an intimate knowledge of the fundamental make-up and dynamics of that polymer,” says Schill. As each supramolecular polymer is made up of many monomers, it is important to understand the interactions of each single molecule that contributes to the supramolecular structure. “The more you want to mimic the characteristics of naturally occurring supramolecular polymers, the closer you need to look at the properties and dynamics of a single structure rather than the bulk solution. There are millions of structures, each with their own dynamic behavior.” It is a bit like studying the behavior of a herd of wildebeest, whilst having very limited understanding of the natural behavior of each individual animal. “For example, when observing a migration, the herd from afar seems to move as a whole. However, because we cannot clearly see each individual animal, we miss crucial interactions between animals. Each animal has to sense the environment and react appropriately

"YOU NEED TO LOOK AT THE PROPERTIES AND DYNAMICS OF A SINGLE STRUCTURE RATHER THAN THE BULK"

to move safely from one place to the next." Understanding these molecular-scale interactions and their effects on the overall supramolecular structure became a key goal.

DNA ORIGAMI

Joining Jurgen Schill for coffee one day was Bas Rosier, now a postdoctoral researcher in the Protein Engineering group of Maarten Merkx. Rosier gained his PhD in the Synthetic Biology group of Tom de Greef, working on DNA nanotechnology and specifically on DNA origami. "DNA origami is the process of taking one long strand of DNA and programming it by using short single stranded DNA 'staples' to fix it together to form nanometer size objects," Rosier explains.

DNA origami enables researchers to precisely manipulate and direct the motion of matter on the nanoscale. Rosier's PhD was focused on how to use these DNA origami structures to study proteins. "You can position and assemble proteins on a DNA origami structure and by doing that you can control the distance very carefully, down to the nanometer," Rosier points out. "A DNA origami object acts like a nanoscopic microscope module – allowing for precision positioning of proteins and covalent polymers, almost as if using very small tweezers. By fine tuning the distance and placement of proteins so precisely we can study how they behave and interact with each other."

A PROBLEM SHARED

Whilst casually meeting together over coffee to discuss the progress of their PhD projects, the penny dropped! DNA origami's unique selling point of precision placement could potentially be put to good use in Schill's project. If DNA origami had been used as a tool to study covalent polymers and proteins, why could it not be used to study non-covalent supramolecular polymers? Boosted by the literature, Schill and Rosier set up their first joint experiment to test the space.

As previously explained, Schill wanted to study the dynamic characteristics and properties of supramolecular polymers. Rosier was able to use his expertise to create nanoscopic DNA origami structures upon which to place these non-covalent polymers and image them whilst keeping them dynamic. "A huge benefit of this system is that you can study the dynamics, kinetics and behavior of these polymers in real-time," explains Rosier. "Using established fluorescence microscopy techniques for studying these dynamics is comparable to taking five pictures to capture an event versus using DNA origami, which is the equivalent of recording a five-minute high-definition video."

THREE STEPS

The paper that followed their joint research provided proof-of-concept that DNA origami can be used as a template to allow the dynamic study of supramolecular polymers at the nanoscopic scale. For Schill and Rosier, this is just the first step on a three-step journey, with the baton now being handed to the wider scientific community. Step two will be for this method to become an established way for scientists to gain fundamental knowledge about the intrinsic properties of supramolecular polymers. Step three involves the creation and design of novel non-covalent structures with properties and characteristics suitable for biocompatible materials that could advance discoveries in both fundamental research and applied medicine.

DEMYSTIFYING DNA ORIGAMI

An additional benefit, which Schill and Rosier are keen to highlight, is how this paper advocates DNA origami as an accessible method for studying matter at the nanoscopic level. According to Rosier, DNA nanotechnology is a promising technique to precisely control the position and assembly of molecules and they both hope that this paper provides the groundwork for widespread use. Rosier: "Adding DNA origami to the toolbox of cell and structural biologists can enrich scientific discoveries at the fundamental level."

The complexity of deep transitions


Geert Verbong

In a series of lectures organized by ICMS and Studium Generale TU/e, the grand themes of complexity are discussed. In March 2021, major transitions were on the agenda. Johan Schot (Utrecht University) and Geert Verbong (TU/e) shared their views on the nature of these transitions and how they can be realized.

The current energy transition is comparable to the industrial revolution, says Johan Schot, professor of Global History and Sustainable Transitions at Utrecht University. He held a Studium Generale lecture on what he calls "deep transitions." Up to now, we have experienced only one of these all-encompassing transitions, Schot told his audience. The First Deep Transition was the industrial revolution, which not only led to industrialization, but also brought migration to cities, faster transport and totally new ways to communicate. This transition was more than just the introduction of a new technology; it changed the whole fabric of society. Tapping into fossil energy resources enabled our present way of life.

Now that we must exchange fossils fuels for renewable energy sources, it will again cause a major rupture in society. We are facing the Second Deep Transition, says Schot. "It will not only affect climate. All of society will feel the change. An energy transition will also have an impact on the water crisis, the crisis of inequality, and the ecological crisis. The current crises are all connected. It therefore doesn't make sense to only tackle only one crisis."

Johan Schot and Geert Verbong are the second duo in a series of lectures organized by the ICMS Focus Area "Grip on Complexity," together with Studium Generale. Geneticist George Church (Harvard University/MIT) and one of the founders of synthetic biology, is the next speaker in this series. His lecture will be on 14 June, followed by a Complex Friday-seminar by Jan van Hest, scientific director of ICMS.

LED FROM ABOVE

What policy can lead us through this Second Deep Transition? Geert Verbong discussed these themes on a Complex Friday seminar, following Johan Schot's lecture. Verbong, professor of Systems Innovations and Sustainability Transitions at TU/e, thoroughly studied the Dutch switch to natural gas in the 1960s, which is worldwide regarded as a textbook example of a smooth and fast energy transition. "At the time, the simplest option would have been to feed the newly discovered gas directly to industry. Yet the main actors – Esso, Shell and the Dutch government – wanted to use it to bring comfort and cleaner indoor air to households. Prioritizing households was a radical idea at the time. The government set a price for natural gas, far above costs, which enabled a fine-mazed distribution system. Five years after the start of this transition, eighty percent of Dutch households were connected to the gas network."

It was a transition led from above, Verbong explains. Political guts and public-private partnerships were vital to its success. The disadvantaged parties, such as the state mines, were either enrolled or bought out. According to Verbong, households accepted the change because there was a convincing narrative that focused on the improvements natural gas could provide – the change was not about costs, but about comfort and health.

LEARNING FROM THE PAST

We cannot simply repeat this process, says Verbong. "Current energy systems are far more complex. The variability of wind and sun is an extra hurdle. Techniques are also much more intertwined; often heat and power are generated simultaneously. Liberalization of energy markets has made the stage more complex and society has become more difficult to direct. People will have to adapt their behavior amidst all kind of influences. In the 1960s, the traditional societal structures and institutions still were influential. Now, the government has less control over the energy supply and society as a whole."

Johan Schot doubts whether present governments can cope with this complexity. "Deep Transitions start with a coalition of the willing, bringing together a range of people from governments, business, civil society and scientific institutions. Those who are willing, can act by their visions and expectations. They can connect with others to support new initiatives and to learn new ways of living. We need to build and nurture niches, replicate and expand them, and bring them to the mainstream." The current energy policy only takes a technological perspective and continues along the path taken with the industrial revolution, says Schot. "That reinforces global mass production, where cycles cannot be closed. The current policy aligns with the First Deep Transition, instead of paving the way for the Second. We have to move towards sharing, circularity and local production."

MODELING FOR POLICY

Verbong sees more room to maneuver. According to him, computer models are a good way to deal with the complexity of the energy transition. "Computer models needn't tell politicians what to do. Agent-based models can show them the consequences of their decisions. Modeling is not about predicting the future, but about exploring options. This is what Naud Loomans and Auke Hoekstra at NEON and TU/e have done for the province of Brabant. A politician considers doubling the capacity of wind energy? The model shows how this doubling and the site selection affect the electricity grid. The challenge is now to include social changes in these models. Then you get closer to an integrated approach to deep transitions."

THE GOVERNMENT HAS LESS CONTROL OVER THE ENERGY SUPPLY AND SOCIETY AS A WHOLE

Johan Schot


"SERVING YOUR
INNOVATION NEEDS"