Volume 3 - June 2014

nanotextnl

nanonextnl magazine

Selective mirrors

Head start in commercialisation

Light cleans water

Nanoscale metropolises

Midterm Review,

Magnets count proteins,

Graphene separates hydrogen,

and more

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innovating with micro and nanotechnology

NanoNextNL at a glance

NanoNextNL is composed of 28 programmes which are part of 10 main themes. For up-to-date information, please visit our website www.nanonextnl.nl

1. Risk Analysis and Technology Assessment (RATA)

1A Human health risks
Dr. ir. J.J.M. van de Sandt (TNO)
+31 (0)88 866 18 33 / han.vandesandt@tno.nl

1B Environmental risks
Prof. dr. A. van Wezel (KWR)
+31 (0)30 606 95 11 / annemarie.van.wezel@kwrwater.nl

1C Technology Assessment
Prof. dr. ir. H. van Lente (UU)
+31 (0)30 253 78 07 / h.vanlente@uu.nl

2. Energy

2A Efficient generation of sustainable energy
Prof. dr. W.C. Sinke (ECN)
+31 (0)224 56 40 58 / sinke@ecn.nl

2B Efficient energy utilization by secondary conversion of energy and seperation
Prof. dr. F. Kapteijn (TUD)
+31 (0)15 278 35 16 / f.kapteijn@tudelft.nl

3. Nanomedicine

3A Nanoscale biomolecular interactions in disease
Prof. dr. V. Subramaniam (AMOLF)
+31 (0)20 75 47 100 / v.subramaniam@amolf.nl

3B Nanofluidics for lab-on-a-chip
Prof. dr. ir. A. van den Berg (UT)
+31 (0)53 489 26 91 / a.vandenberg@utwente.nl

3C Molecular imaging
Prof. dr. K. Nicolay (TU/e)
+31 (0)40 247 57 89 / k.nicolay@tue.nl

3D Drug delivery
Prof. dr. G. Storm (UU)
+31 (0)30 253 73 88 / g.storm@uu.nl

3E Integrated microsystems for biosensing
Prof. dr. H. Zuilhof (WUR)
+31 (0)317 48 23 61 / han.zuilhof@wur.nl

4. Clean water

4A Nanotechnology in water applications
Prof. dr. ir. R.G.H. Lammertink (UT)
+31 (0)53 489 20 63 / r.g.h.lammertink@utwente.nl

5. Food

5A Food process monitoring and product quality assessment
Dr. ir. M.A. Jongsma (WUR-DLO)
+31 (0)317 48 09 32 / maarten.jongsma@wur.nl

5B Molecular structure of food
Dr. K.P. Velikov (Unilever)
+31 (0)10 460 50 68 / krassimir.velikov@unilever.com

5C Food products and processes
Prof. dr. ir. K. Schroën (WUR)
+31 (0)317 48 33 96 / karin.schroen@wur.nl

5D Microdevices for structuring and isolation
Prof. dr. ir. K. Schroën (WUR)
+31 (0)317 48 33 96 / karin.schroen@wur.nl

6. Beyond Moore

6A Advanced nanoelectronics devices
Prof. dr. B. Koopmans (TU/e)
+31 (0)40 247 48 55 / b.koopmans@tue.nl

6B Functional nanophotonics
Prof. dr. L. Kuipers (AMOLF)
+31 (0)20 754 71 94 / k.kuipers@amolf.nl

6C Nano-bio interfaces & devices
Prof. dr. S.G. Lemay (UT)
+31 (0)53 489 23 06 / s.j.g.lemay@utwente.nl

6D Active nanophotonic devices
Prof. dr. P.M. Koenraad (TU/e)
+31 (0)40 247 41 05 / p.m.koenraad@tue.nl

7. Nano materials

7A Supramolecular and bio-inspired materials
Prof. dr. A.E. Rowan (RU)
+31 (0)24 365 23 23 / a.rowan@science.ru.nl

7B Multilayered and artificial materials
Prof. dr. ing. A.J.H.M. Rijnders (UT)
+31 (0)53 489 26 18 / a.j.h.m.rijnders@utwente.nl

8. Bio-nano

8A Nanomolecular machines in cellular force-transduction
Prof. dr. A.M. Dogterom (TUD)
+31 (0)15 278 59 37 / m.dogterom@tudelft.nl

8B Bionano interactions for biosensing
Prof. dr. ir. G.J.L. Wuite (VU)
+31 (0)20 598 79 87 / g.j.l.wuite@vu.nl

9. Nano fabrication

9A Nano-inspection and characterization
Prof. dr. ir. A.J. Koster (UL)
+31 (0)71 526 92 92 / a.j.koster@lumc.nl

9B Nano patterning
Prof. dr. ir. P. Kruit (TUD)
+31 (0)15 278 14 97 / p.kruit@tudelft.nl

10. Sensors and actuators

10A Systems and packaging
Prof. dr. U. Staufer (TUD)
+31 (0)15 278 68 04 / u.staufer@tudelft.nl

10B Micro nozzles
Dr. ir. H. Wijshoff (Océ)
+31 (0)77 359 34 25 / herman.wijshoff@oce.com

10C Microdevices for chemical processing
Dr. ir. M.T. Blom (Micronit)
+31 (0)53 850 68 62 / marko.blom@micronit.com

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innovating with micro and nanotechnology

welcome

Meet the future

This years' NanotextNL magazine once again shows the great scope of micro and nanotechnology research in the Netherlands. This is also reflected in the conclusions of last year's 'Midterm Review' of NanoNextNL by an international committee. The committee members commended the high standard of the programme and were impressed by the attention given to the application of the knowledge in society. Of course some things can be improved, and the Executive Board, theme coordinators and programme directors have picked up the glove and are going full steam ahead, see page 4.

A main impulse to our community this year is the creation of a new event on nanotechnology: NanoCity2014 (page 32). It is the start of a three year-journey during which the Dutch nanotech community will get together and present itself. NanoCity is building up to an international event in 2016 when The Netherlands chairs the European Union. NanoCity brings together everyone interested in nano: scientists, industrial specialists, entrepreneurs and policymakers.

An excellent example of what collaboration may lead to can be found in the work of Erik Stroes (page 18) where science, physicians and a spin-off company tell a great story of a new, nano-targeted approach to treating atherosclerotic plaques.

We hope this magazine leaves you excited with the prospects for the future.
And of course we hope that you will come meet that future at NanoCity!

Dave Blank
Chair of the Executive Board

contents

Colophon

nanotextnl

Editor-in-chief Sonja Knols, Ingenieu∑e | **Editors** Dave Blank, Jeroen van Houwelingen, Albert Polman, Fred van Keulen, Karin Schroen, Urs Staufer, Erwin Woord | **Text correction** Dave Thomas, NST Science
Art direction Foton visuele communicatie, Tjerk de Vries | **Print** Foton visuele communicatie | **Cover images** Rob Lammertink, Intel, Gijs van Ouwerkerk, Kees Bennema | **Distributor** NanoNextNL programme office
Technology Foundation STW, P.O. Box 3021, 3502 GA Utrecht
info@nanonextnl.nl / +31 (0)30 6001 363 / +31 (0)30 6001 322
www.nanonextnl.nl

Text Mariette Huisjes / Photos NanoNextNL

“From successful science to successful business is a huge step”

NanoNextNL’s Midterm evaluation meant facing up to the facts and “being brutally honest”. What has gone well in the past three years and what can be done better? At the end of 2013 the Board of NanoNextNL prepared a self-evaluation, followed by two intensive days of interviews in December. These were held by the International Advisory Councel (IAC), composed of international specialists in the field of nanoscience and technology and chaired by Martin Schuurmans, former director of Philips Research Laboratories and founding chairman of the European Institute of Innovation and Technology. Both Schuurmans and NanoNextNL chairman Dave Blank speak of “a very stimulating process”.

What surprised you the most, reviewing NanoNextNL?

MS: "In its short period of existence, NanoNextNL has succeeded in strengthening the high-tech landscape in the Netherlands. And believe me, that is no trivial matter and it certainly cannot be said of all innovation initiatives. Furthermore, we were surprised to discover that much of the research is not just of an internationally high standard, but that the researchers also focus on the possible applications of their findings."

After the thorough self-evaluation, why did you need the personal interviews with the programme directors?

MS: "You can never judge an organisation purely on the basis of its paperwork. You have to look into people's eyes to see their enthusiasm, or the lack of it. And to evaluate the brilliant publication or the misstep that taught us something new."

DB: "The personal interviews were also useful for establishing a working relationship. Because we did not choose to fly in an international panel just for the review and then have them fly back again for good. The panel will remain involved with NanoNextNL as advisors, meeting at least twice a year, so they can see what has become of their suggestions."

Being brutally honest, you must have found some points for improvement.

MS: "We did find that the business orientation is only in the starting phase. The pitches to make business out of knowledge are sometimes… let's call it fragile. The choices made are not sufficiently based on sound arguments; it is unclear who will take on the entrepreneurship and what exactly will generate the profits; or the relevant risks, regulations or societal aspects of a new technology have not been properly considered."

So do you think scientists are basically naïve or unpractical?

MS: "Certainly not. But if you've been a scientist all your life, even a very good one, the step to being good at business is still huge. I think the science curricula in Dutch universities should pay much more attention to entrepreneurship. A lack of training is basically what we encounter in NanoNextNL. And don't forget the business case format is very strict and revealing. The least omission or weakness will become manifest immediately. In my days as a researcher, I was quite happy speaking to large audiences. But I found presenting a business case absolutely nerve-wrecking!"

Martin Schuurmans and Dave Blank

What can be done to raise business awareness?

DB: "We have set up training courses in entrepreneurship. Also we will try to allocate funds to create personal incentives for those who want to take the entrepreneurial risk, or to create a financial safety net."

Risk analysis and technology assessment is a specific point mentioned by the committee.

MS: "If you want to make business out of a new technology, systematic attention for these aspects is a must. The most exciting opportunities also involve societal aspects such as health or environmental risks and economic advantages or disadvantages. If you don't take these aspects extremely seriously right from the very start, you will end up running into dead alleys, or being waylaid by regulations that you could have anticipated if you had done your homework properly."

DB: "During the self-evaluation we had

Results

Midterm Review NanoNextNL

In its final report, the International Advisory Council concludes: "NanoNextNL has strengthened the high-tech environment in the Netherlands considerably: Stronger cooperation Public-Private and Academia-Academia, build-up of a corresponding interdisciplinary eco-system, broadened and deepened talent education, stronger goal focus of excellent people, science and engineering up to international benchmarks, enhanced application focus and first signs of societal value creation.

In short, NanoNextNL lives up to its mission midterm down the road and is on its way to economic, societal and science value creation.

Continuous improvements will further contribute to the success of NanoNextNL. In particular the IAC suggests positioning of Risk Analysis and Technology Assessment in a more business impact way, introduction of business coaching and incubation to enhance the chances for business and societal impact, strengthening (focus, ambition, research lead) of the few programmes not (yet) at par with international benchmarks, EU programme participation promotion by a high level NanoNextNL ambassador in Brussels, use of remaining funding for business creation and help to foster the contribution of SMEs even further, for example by goal oriented matchmaking amongst SMEs."

already come to the conclusion that risk analysis and technology assessment are underestimated within the NanoNextNL consortium. This is new to us: but risk analysis and technology assessment have become a crucial part of research. We have to get used to it and find ways to organise it. But researchers are not alone in this. As the Executive Board we encourage people in the consortium to help each other by sharing expertise or infrastructure."

Another point that can be improved is the orientation towards Europe.

MS: "Europe hurtles on! We strongly encourage NanoNextNL to participate in European research programmes. There are two good reasons for this: firstly to safeguard your position in the international honours league. Secondly to be sure of your financial security in the long run. The European administration can be intimidating, I know. But please do take this hurdle, as an investment in your future."

DB: "Indeed this is something we must do and we are already working on it. One of your suggestions was to appoint a NanoNextNL ambassador in Brussels. He or she would do lobby work but also navigate us through the administrative system. In April, I was at a European conference in Greece and I was already scanning the scene in the hope of finding our ideal ambassador!"

Looking back, how does the Executive Board feel about the evaluation?

DB: "The Midterm Review was a very valuable activity and provided us with excellent guidelines to further optimise the final outcome of NanoNextNL in 2016."

Key Performance Indicators
as reported in the Midterm Review (dec'13)

Reponse

The Executive Board of NanoNextNL responded: "The Executive Board is very grateful for the detailed and in-depth analysis the International Advisory Council (IAC) has made of the progress of NanoNextNL since it started in 2011. We are glad the IAC is 'happy with the great progress that NanoNextNL has made and the truly excellent science and application focus that we witnessed.'"

The IAC provided several suggestions for improvements. Based on the IACs findings and suggestions NanoNextNL has devised an action plan that will be carried out in the second half of the programme.

KPI Description	KPI status	target 2013	% of target 2013	target 2016	% of target 2016
Peer-reviewed papers and conference contributions					
Peer-reviewed papers and conference contributions	1052	300	351%	1200	88%
- with industrial and academic co-authorship	201	50	402%	200	101%
EU projects					
EU funded projects submitted and awarded	30	3	1000%	15	200%
Research positions					
PhD students and post-doctoral researchers	259	240	108%	300	86%
Patent filings					
Patent filings (first filings)	38	15	253%	115	33%
Licenses					
Licenses to parties not participating in NanoNextNL	2	3	67%	12	17%
Start-ups or spin-offs					
New start-up's or spin-off companies exploiting IPR created in this programme and predecessors	3	0		15	20%
RATA events					
Events on Risk Analysis and Technology Assessment *(including programme meetings)*	19	2	950%	5	380%
Activities for non-specialists					
Publications	99	17	582%	34	291%
Public events	42	5	840%	10	420%

Text Nienke Beintema / Photo Shutterstock

Screening for TB anywhere in the world

Imagine a handheld device that can detect tuberculosis (TB) in a person's lung slime. Imagine that it is user-friendly, quick, reliable and affordable. Such a device would be invaluable in health clinics around the world, notably in rural areas in developing countries.

"Such technology is definitely realistic. In fact, we're well on the way with its development," says Vincent Spiering, business development manager at Qmicro BV. Within the NanoNextNL programme, this small company has entered into a unique cooperation with the company ATAS GL and the University of Amsterdam.

"Our specialty is to develop innovative gas analysis technology," says Spiering. "Our products are designed to quickly identify the different components of gas mixtures, and to determine their relative concentrations. We use a chip with microscopic gas channels that direct the gas flow to a separation column and then towards a detector." This technology in itself is nothing new: gas chromatographs have been around for several decades. The innovation lies in the fact that Qmicro's products are considerably faster and smaller than conventional machines, which take at least 20 minutes to deliver their results and equal an average refrigerator in size. "Our devices are the size of a human hand and deliver their output in 20 seconds," states Spiering, "which brings a whole range of new applications within reach."

"Our devices are the size of a human hand and deliver their output in 20 seconds"

As an example he names medical diagnostics – for instance screening for *Mycobacterium tuberculosis*, the cause of TB. "The traditional approach is to study a person's sputum under a microscope," explains Spiering. "This is a time-consuming method that requires skilled professionals. In addition, it is impossible to distinguish between different types of mycobacteria, some of which are more contagious and dangerous than others. Our new technology solves all of these issues."

Qmicro's partner company ATAS GL is developing a method to convert sputum and feed its gaseous components into Qmicro's gas analysis compartment. A PhD student from the University of Amsterdam is working on a reliable way to use gas 'signatures' to accurately diagnose TB. "And our task," says Spiering, "is to make the detector more sensitive, to combine the different components and to make them even smaller."

Text Nienke Beintema / Image Wouter de Laat

Stay in the loop

It is not the linear, but rather the three-dimensional structure of chromosomes that determines which enhancer (shown in red) acts on which gene.

How can a complex animal arise from a single fertilised egg? This is one of the oldest and most fascinating questions in biology. Processes such as growth and specialisation are coded in the organism's DNA. But doesn't each body cell carry the exact same code? Why do certain cells end up as liver cells and others as neurons? "The bottom line is the fact that different sets of genes are switched on in different cell types and at different times," says Wouter de Laat, group leader at the Hubrecht Institute, Professor of Biochemical Genomics at the Utrecht University.

De Laat and his colleague Denis Duboule recently published a review article in *Nature* that describes one of the molecular mechanisms that can switch genes on and off. It was discovered recently, and its intricacies are now being unveiled thanks in part to new biochemical techniques developed at the Hubrecht Institute. "DNA is a very long molecule," De Laat explains. "Only 2 percent of it consists of genes that code for proteins. The rest has long been called 'junk DNA', but we now know that it does have a function. For one thing, it contains millions of sequences that control the activity of protein-coding genes – even at a distance." In order to switch a gene on and off, these distant, non-coding sequences, called enhancers, have to make physical contact with the target gene. This is possible when the DNA folds into a loop. It is this 3D folding process that De Laat and his colleagues at the Hubrecht Institute are studying within NanoNextNL theme 3.

The *Nature* article is a general overview that shows how this mechanism contributes to the complexity of animals, but in fact De Laat's research does have a concrete practical application. "In one of our research projects, we study the genetic makeup of tumours," he says. "One of the characteristics of tumour cells is the fact that their DNA contains certain rearrangements compared to healthy cells. Our technique shows us exactly how the DNA was rearranged." Blood of a cancer patient always contains some DNA fragments arising from this or her specific tumour. De Laat now has a tool to monitor how a tumour responds to cancer drugs. "There are other sequencing strategies to do that," says De Laat, "but our technique is expected to be robuster, more sensitive and cheaper."

Last year was a very fruitful one for NanoNextNL projectleader Jaime Gómez Rivas. He published a vast amount of articles in topjournals, researchers from his group won different prizes, and as icing on the cake, FOM awarded him a new industrial partnership programme. And all that was estahblished in a remarkable way of cooperation between academia and industry.

Publications *and* patents

Text Anouck Vrouwe / Photo FOM

Jaime Gómez Rivas is group leader at AMOLF and professor at Eindhoven University of Technology, but his office is at the High Tech Campus in Eindhoven. Since 2005, the AMOLF research group *Surface Photonics* had been embedded within Philips. Recently, AMOLF and Philips agreed to maintain the collaboration indefinitely.

Starting an AMOLF research group at the High Tech Campus was an experiment in itself. “Both AMOLF and Philips wanted a closer collaboration. From there the idea arose to start an embedded research group at Philips.” When Gómez Rivas started his job in Eindhoven, he had an empty laboratory at his disposal. “And only a vague plan what we were going to investigate,” he admits. “Philips was interested in semiconductor nanowires, so we started there.” Since cooperation between science and academia is in the core of NanoNextNL, his work fitted seamless into this research programme.

The experiment was a success. Nine years later, his group has taken root in Eindhoven. In January, the FOM Foundation and Philips renewed their joint research programme; they signed a so-called rolling Industrial Partnership Programme (IPP). The cooperation will continue indefinitely, with a minimum of four years. Just like before, the results are being shared: the scientists get their articles and Philips gets the intellectual property rights when the collaboration results in an invention. “That sometimes means Philips has to file a patent in an early stage, because we want to publish the results,” Gómez Rivas explains.

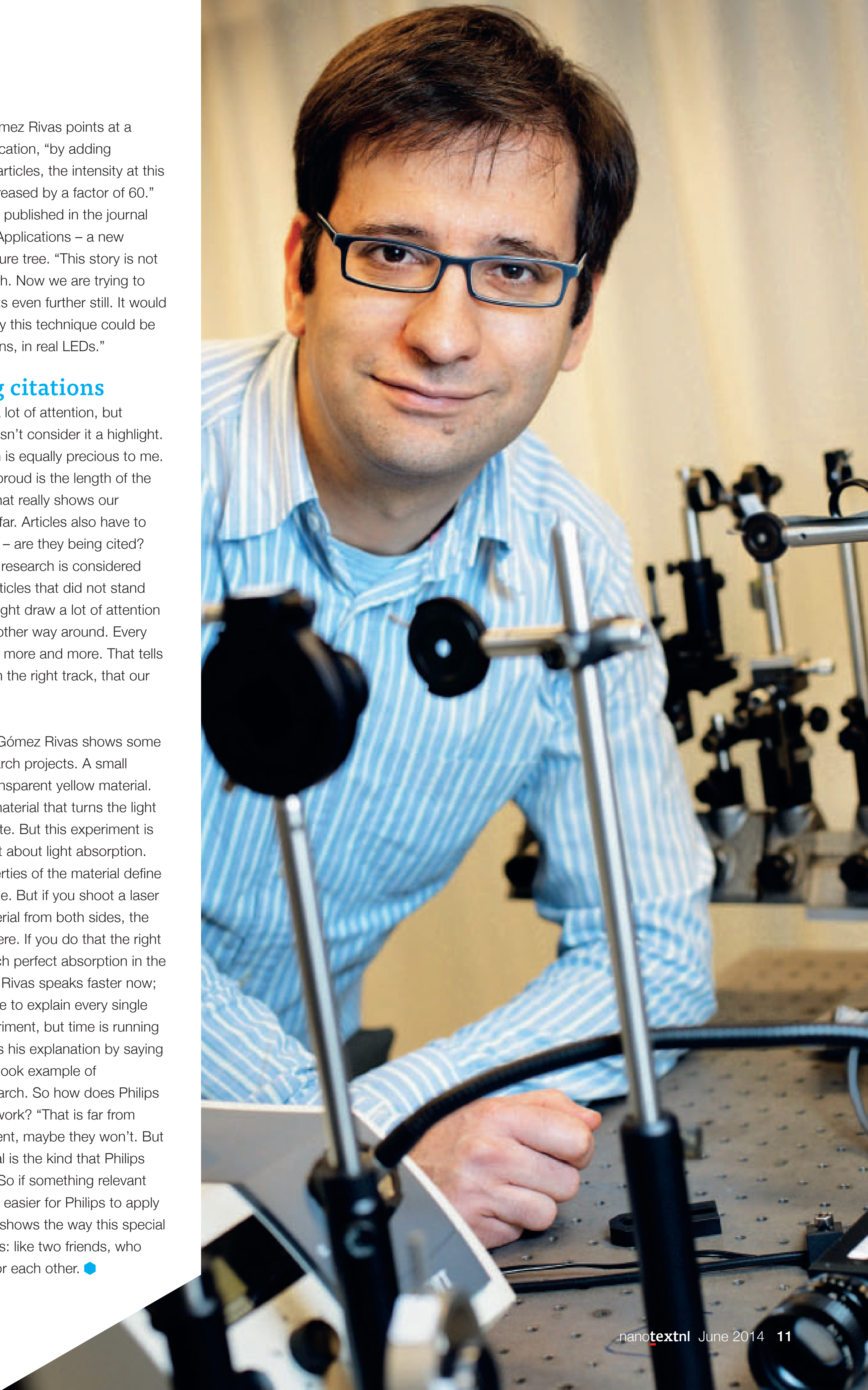
The once empty laboratory in Eindhoven is now packed with optical benches, loads of mirrors and lenses, lasers and microscopes. Here the scientists play with light and nanomaterials. One of the group's main breakthroughs was the enhancement of the fluorescent layer in

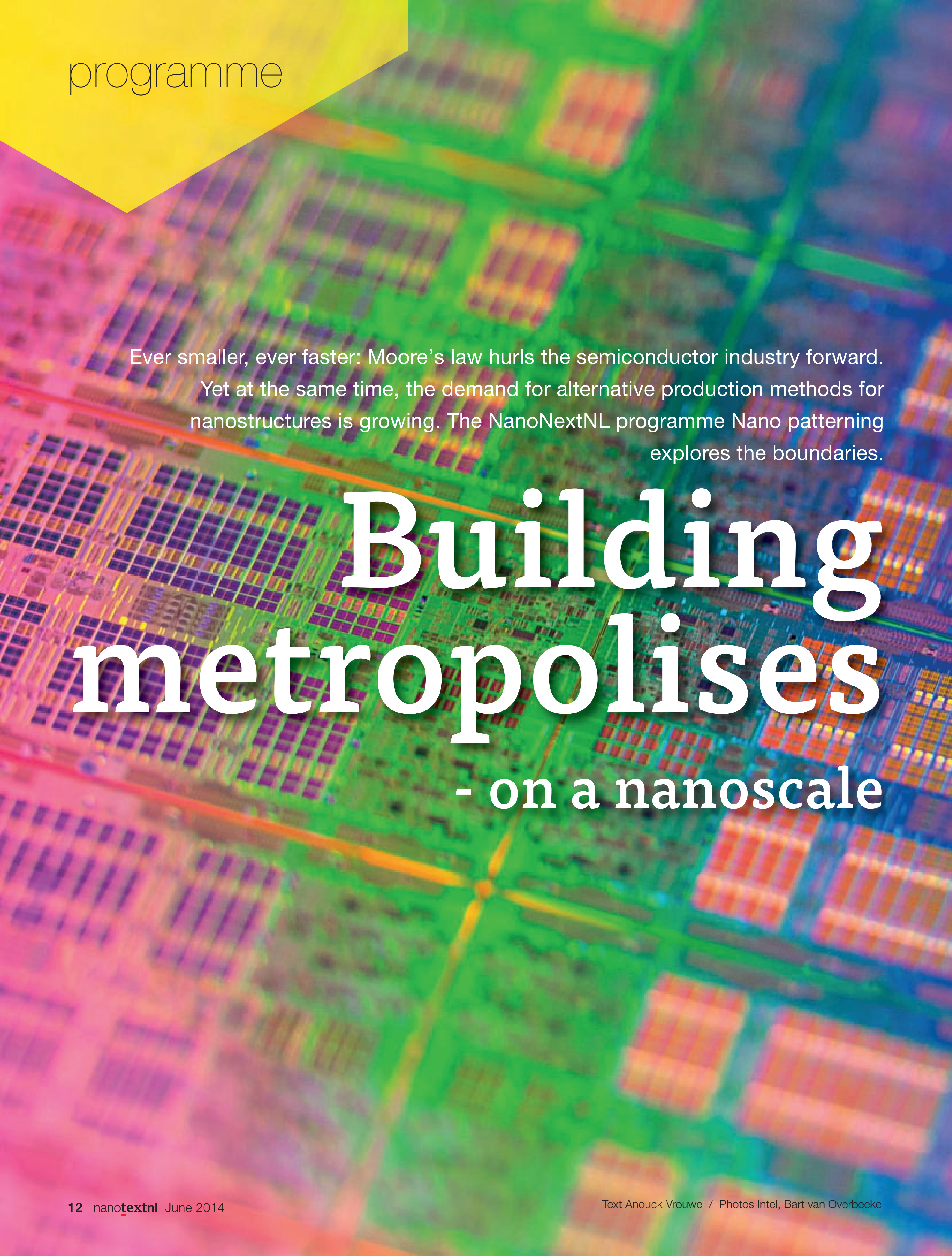
LEDs. “Here,” Gómez Rivas points at a graph in the publication, “by adding aluminium nanoparticles, the intensity at this wavelength is increased by a factor of 60.” The research was published in the journal Light: Science & Applications – a new branch of the Nature tree. “This story is not finished yet though. Now we are trying to improve the results even further still. It would be great if one day this technique could be used in applications, in real LEDs.”

Increasing citations

The article drew a lot of attention, but Gómez Rivas doesn’t consider it a highlight. “Every publication is equally precious to me. What makes me proud is the length of the publication list. That really shows our achievements so far. Articles also have to prove themselves – are they being cited? That shows if our research is considered relevant. Some articles that did not stand out at the start might draw a lot of attention later on, and the other way around. Every year, we get cited more and more. That tells me that we are on the right track, that our results last.”

In his laboratory, Gómez Rivas shows some of the latest research projects. A small clamp holds a transparent yellow material. “It is the kind of material that turns the light of a blue LED white. But this experiment is not about that but about light absorption. Usually, the properties of the material define the absorption rate. But if you shoot a laser beam at this material from both sides, the light beams interfere. If you do that the right way, you can reach perfect absorption in the material.” Gómez Rivas speaks faster now; he really would like to explain every single detail of the experiment, but time is running out. He concludes his explanation by saying that this is a textbook example of fundamental research. So how does Philips benefit from this work? “That is far from clear at the moment, maybe they won’t. But the yellow material is the kind that Philips uses in its LEDs. So if something relevant pops up, it will be easier for Philips to apply the results.” That shows the way this special cooperation works: like two friends, who always look out for each other.





Ever smaller, ever faster: Moore's law hurls the semiconductor industry forward. Yet at the same time, the demand for alternative production methods for nanostructures is growing. The NanoNextNL programme Nano patterning explores the boundaries.

Building metropolises - on a nanoscale

Text Anouck Vrouwe / Photos Intel, Bart van Overbeeke

“Have you ever seen a chip?” Pieter Kruit (Delft University of Technology) asks. “It's a world on its own. Just open up a mobile phone and put one of the chips under a microscope. You'll see tremendous detail. Myriads of tiny lines that form a miniature metropolis. And every 'paving stone' was designed and produced. The progress achieved in the past 30 years is quite simply astounding.”

Kruit is the head of NanoNextNL's Nano patterning programme, which was initiated to support the Dutch semiconductor industry with academic research. All three Dutch technology universities are participating, along with FOM institute Differ. From the commercial sector, companies like ASML, FEI and MAPPER are involved.

Impressive as Kruit finds these miniature metropolises, the ones found in phones are definitely not the end of the line for the chip industry. It's all hands on deck working on technology to make the lines even narrower still, the paving stones even tinier. Ever smaller, ever faster is the dominant law in the world of microchips. Moore's law observes how the number of transistors on a chip doubles roughly every two years; it has pushed the semiconductor industry for decennia. Kruit emphasises microchips didn't come out of thin air: “Over the last decennia an incredible amount of technology has been developed to get that chip into your mobile phone. To move forward from this point we'll have to work really hard to gain the necessary new knowledge.”

New directions

Moore's law has been stretched to its limits, but the miniaturisation of chips carries on regardless. In the Netherlands, ASML makes lithography machines for the production of computer chips. The company is working on the latest generation of machines that use extreme ultraviolet (EUV) light to create even smaller and more refined chips. Kruit: “The industry still needs to learn how to work with EUV. At present we still do not understand a lot of the physics underlying this process.”

Detecting and reducing pollutants in EUV lithography is the focus of one of the research clusters within Nano patterning. Kruit explains that dust particles can disrupt the process. On this scale a dust particle isn't an insignificant speck, but a large, destructive boulder. “That's why this research is focused on how to protect the machine against dust. By incinerating it or by placing essential parts in thin sleeves, for example.”

"Everyone has to deal with contamination of their machines"

Shouldn’t the company concerned be tackling this kind of problem? “Obviously it's a critical issue for ASML because they are developing EUV machines,” Kruit concedes. “But the problem is not relevant to them alone. Everyone working in nanotechnology has to deal with contamination of their machines, regardless of the kind of machines they happen to use. It's a relevant problem, the engineering is interesting, and so it's good to look at it from a broader perspective.” This applies to other subjects in the programme as well; one company's problem turns out to be relevant for other companies as well. “This kind of mutually beneficial research doesn't happen as a matter of course come about by itself, you have to organise it. That's what NanoNextNL does.”

Moore's law drives the chip industry, but there is more to the world of nanostructures. Research centre Holst, for example, is working on roll-to-roll imprint lithography. A kind of stamping method that might make the fast and cheap production of flexible electronics possible. It is well suited for the production of single-serving RFID (radio frequency identification) or OLEDs (organic light-emitting diode).

“Another trend is what we call More than Moore. Not only do we want more transistors on a chip but other types of nanotechnology as well,” Kruit explains. This refers to the addition of 'functional components' to a chip that are not necessarily made of silicon. Kruit: “Think of it as chips with a sensitive layer that can be used as sensors. Chips with actuators or chips with parts made of graphene. Anything is possible.” In the long run Kruit expects to see chips with various biological components such as proteins or antibodies. They could, for example, be used in medical diagnostics.

Jewel

In turn, More than Moore demands new technology. How do you produce new parts and then integrate these on a chip? Nano patterning is also exploring these issues. Physicist Erwin Kessels from Eindhoven University of Technology is working on better deposition techniques. One of his PhD's has recently come to a proof-of-principle for a new technique to build nanostructures, from scratch. Kruit considers this to be one of the jewels in the crown of the Nano patterning programme. “Kessels’ work is a textbook case of More than Moore.”

The physicist got the best of both worlds: straight, yet high quality lines

Within his department Kessels is working on alternative methods to construct nano-structures on a silicon base. “Chips are produced in a cumbersome way. You start by building up a layer of silicon, only to then etch away most of the material. Only the few lines you're after are left. Imagine you were to build a house that way. You build up the entire footprint of the house in bricks and then remove all of the bricks except those that form the walls.” So Kessels is working on bottom-up production methods where you build up the chip from the foundation, just like a house. “That's the direction we're heading in.”

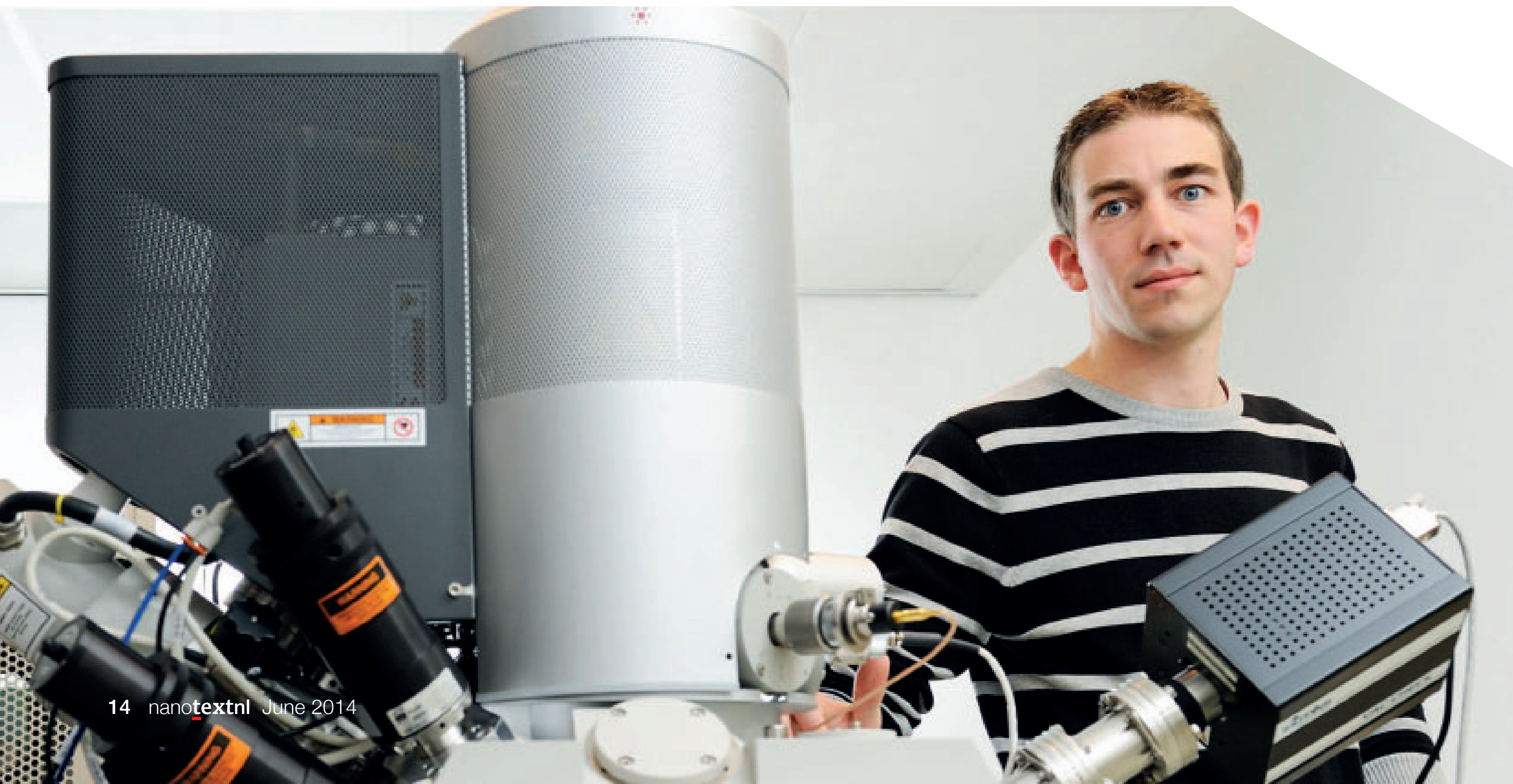
One method to construct a pattern bottom-up is by 'scribing' a pattern with an ion or an electron beam. In beam-induced deposition the beam is directed at a gas. Deposition of the molecules onto the substrate only occurs in the path of the beam. Kessels: “It works. You can produce very fine nanostructures this way. However, the quality leaves a lot to be desired. This method builds the walls, but it leaves a lot of rubbish along the way.” This limits the possibilities for this production method in the semiconductor industry.

Atomic layer deposition is another bottom-up construction method that is often applied in Kessels' lab. In this case, self-regulation plays an important role: the structure 'grows' atomic layer by atomic layer. However, this method lacks accuracy: the walls of the house are not of a constant thickness.

“Each method has its strengths and weaknesses,” Kessels says. Adrie Mackus, one of Kessels' PhD students, therefore researched the possibility of combining two deposition techniques: atomic layer deposition and electron-beam-induced deposition. This research was done in collaboration with FEI, which produces electron microscopes. FEI holds the patent the project led to.

Mackus built structures from platinum. Using an electron beam, he deposited the first layer of platinum bricks with high precision. Then he used a form of atomic layer deposition to build up the walls on that foundation. The physicist got the best of both worlds: straight, yet high quality lines. Because of this innovation he gained his PhD with distinction. Kessels: “This technique allows you to place platinum contacts on chips, but it is also suited for building other nanostructures. The moment you want to put components of new nanomaterials like graphene on a chip, bottom-up deposition techniques are, in principle, better suited than lithography. I'm not saying that Adrie's method is the be all and end all of future production methods for this kind of nanostructure. Nevertheless, an approach like this that combines the best qualities of both methods will go a long way. Remember that current production methods in the chip industry once started just like this.” ⬢

Adrie Mackus graduated with distinction on deposition techniques.



Text Nienke Beintema / Photo Rob Lammertink

Using light to clean water

Tap water is a treacherous thing: in many countries, tap water still contains residues of drugs and hormones, even after wastewater treatment.

These residues can be harmful to living organisms even in low concentrations. “Drug and hormone residues are notoriously difficult to remove from wastewater,” says Rob Lammertink, Professor of Soft Matter, Fluidics and Interfaces at the University of Twente and programme leader within NanoNextNL theme 4. “They can be chemically removed, for instance with peroxide or ozone, but this involves some aggressive chemistry that you don’t really want to use in drinking water production. Some of the breakdown products may in fact be more harmful than the original compounds.”

A promising alternative is the use of photocatalysis for wastewater treatment. This chemical process requires no additives – only a catalyst, which is not converted during the reaction, and light. “There have been many attempts at using photocatalysis in this context,” says Lammertink, “but so far the reactions have been too slow. We try to speed up the process by improving the reactor design.”

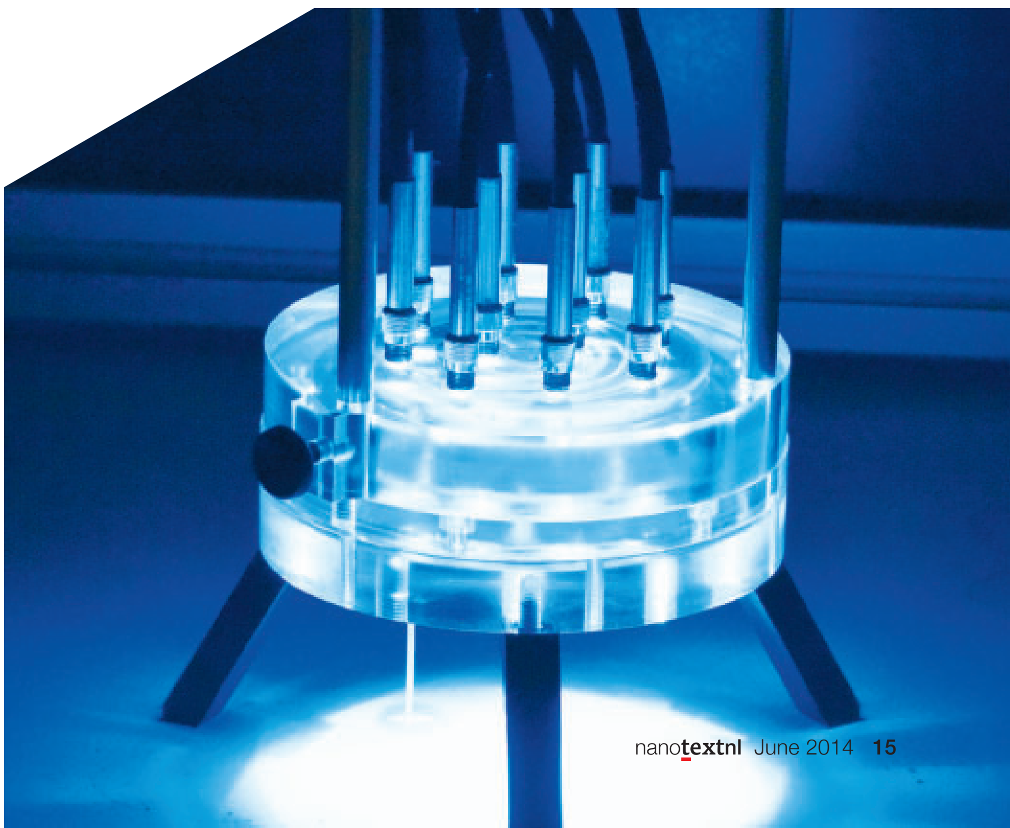
Lammertink and his colleagues use titanium dioxide as a catalyst. One strategy to improve its efficiency is by increasing its surface: the area exposed to the wastewater. The scientists therefore use nanosized grains of titanium dioxide, which are spread out and immobilised as a thin, porous layer on a substrate. The wastewater flows alongside this porous layer while it is exposed to light.

“The paradox is that you want light to be able to penetrate all the way into the layer,” explains Lammertink, “so it should not be too thick. At the same time you don’t want it to be too thin, because that would reduce the total surface area of titanium dioxide. In practice, we use layers that are around one micrometre thin.”

> "We are currently working on household scale"

During the reaction, only a very thin water layer is flowing along the porous catalyst layer. Consequently, it is very difficult to scale up this process. “We are currently working on household scale,” says Lammertink, “aimed to effectively clean a few litres of water per hour.” A remaining challenge is to understand the chemical details of the cleaning process better, for instance the nature and quantities of breakdown products. The scientists are also exploring alternative materials to use as a catalyst and as a carrier for the catalyst layer.

Lammertink is unsure when catalytic reactors will enter the market for wastewater treatment. “It may be several more years,” he says. “However, various companies have shown an active interest in our research. I have no doubt about its considerable potential for new applications.”



Photocatalytic reactor.

Text and illustrations: Eric Verdult

Extreme strain is first step towards novel graphene applications

Strained graphene separates hydrogen

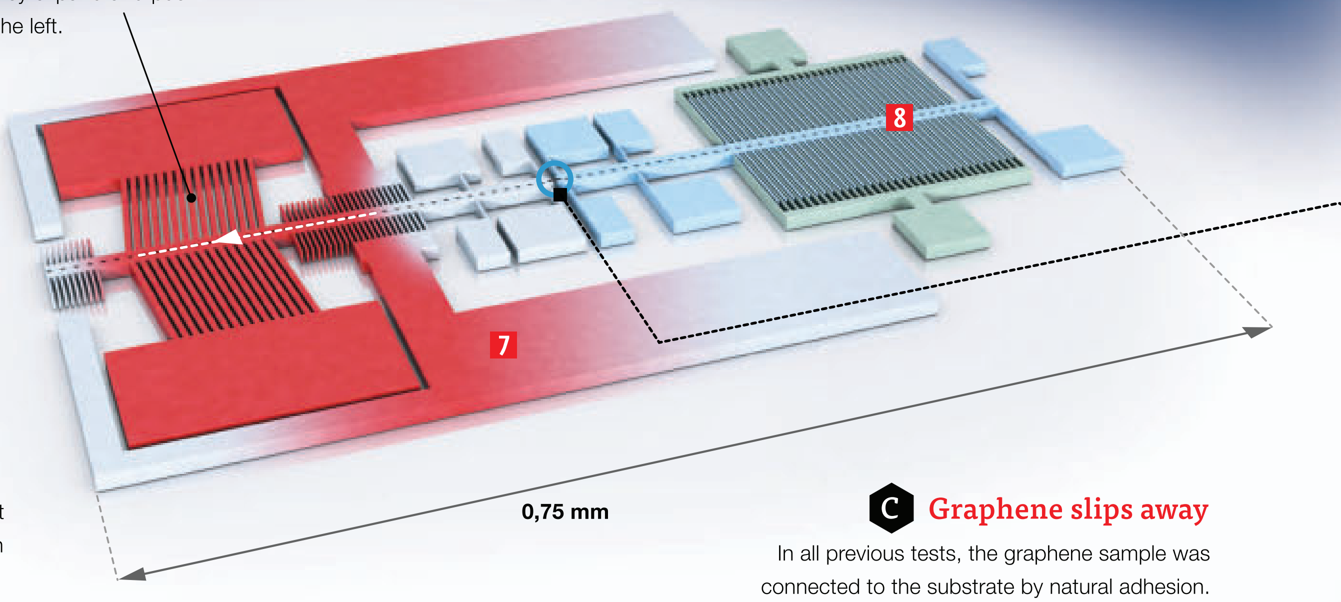
Many groups have carried out strain tests on graphene. So far the highest strain achieved was 1.3 %. Researchers at the Delft University of Technology have developed nanotools with the aim of stretching graphene up to 10 % and testing its performance in hydrogen separation and storage.

B Stretching graphene

Theoretical studies predict that if graphene can be stretched to more than 10 %, the strong bonds between carbon atoms will weaken. These weak bonds might allow hydrogen to pass through 5 or might result in the hydrogen binding 6 to the cabon. The Delft project is exploring conditions that lead to reversible interaction with hydrogen and thus its separation from a gas mixture.

MEMS thermal actuator

Applying a voltage heats the beams up (900 °C), they expand and push the shuttle to the left.



Heat 7

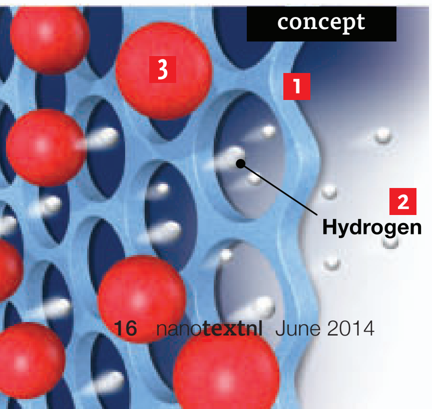
Excessive heat is dissipated in heat sinks.

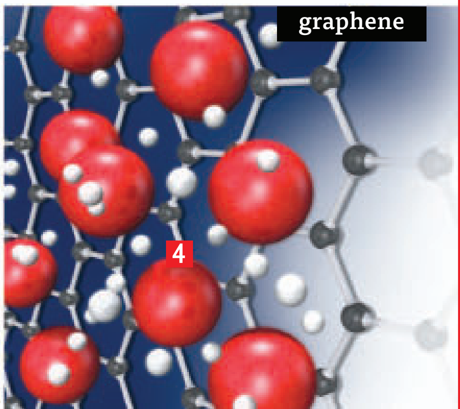
C Graphene slips away

In all previous tests, the graphene sample was connected to the substrate by natural adhesion. Initial tests in Delft show that at 0.6 % strain the graphene slips away. The stretching forces exceed the van der Waals' forces and further stretching is impossible.

A Graphene: the ultimate membrane

Graphene is an ideal membrane because it consists of a one-atom thick layer of graphite. Graphene has a hexagonal structure with a diameter that would allow hydrogen to pass through. However, the strong bond between the carbon atoms and a high-density electron cloud blocks the passage 4 of any molecule. Hydrogen does not bind and does not pass through. Graphene is impermeable.





Energy carrier of the future

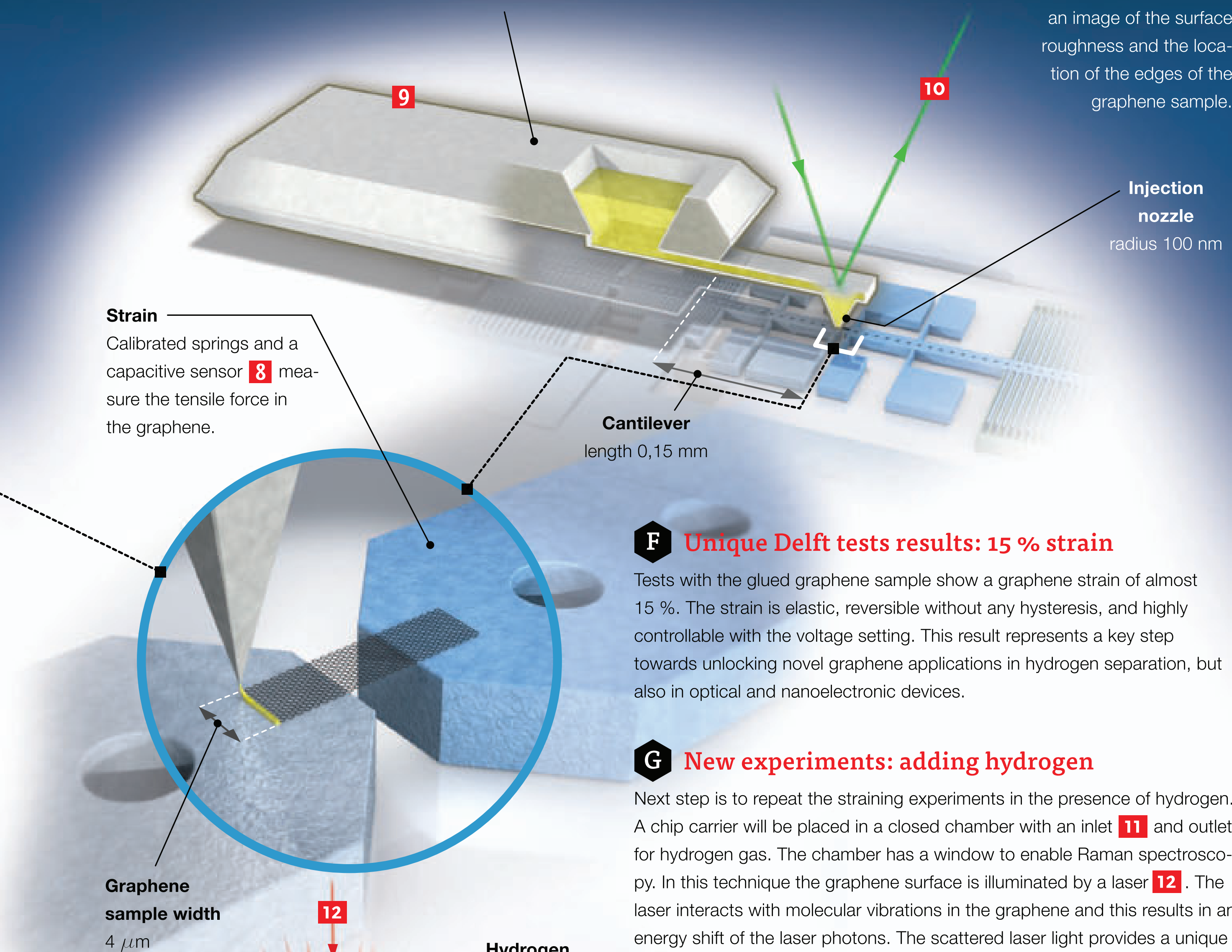
Hydrogen is a potential carrier of energy in the future. However, hydrogen atoms are always connected to other molecules. Industry now uses porous membranes 1 to separate hydrogen. First, methane gas is mixed with steam to split off hydrogen. Then hydrogen is separated from the gas by diffusion: small hydrogen molecules 2 pass through the pores in the membrane while bigger atoms 3 stay behind. In practice some big atoms slip through and pollute the hydrogen. A major finding is that the thinner the membrane, the more efficient diffusion is.

D Gluing with a femtopipette

To prevent the graphene from slipping, the sample is glued onto the substrate. A special injection device was developed to dispense a minute volume of glue along the edges of the graphene, This femtopipette 9 (femto refers to the injected volume: 10^{-15} liter) has a glue reservoir and a fluid channel towards the nozzle at the tip of a cantilever. The pipette is mounted on the arm of a remotely controlled robot to dispense the glue accurately (resolution 0.5 nm).

E Scanning the surface

Before gluing, the cantilever is used to scan the surface. A continuous laser beam is reflected 10 by the reflective tip of the cantilever and is detected by a photodiode (atomic force microscopy). By bringing the sharp tip in contact with the surface and moving the tip around, reflection provides an image of the surface roughness and the location of the edges of the graphene sample.

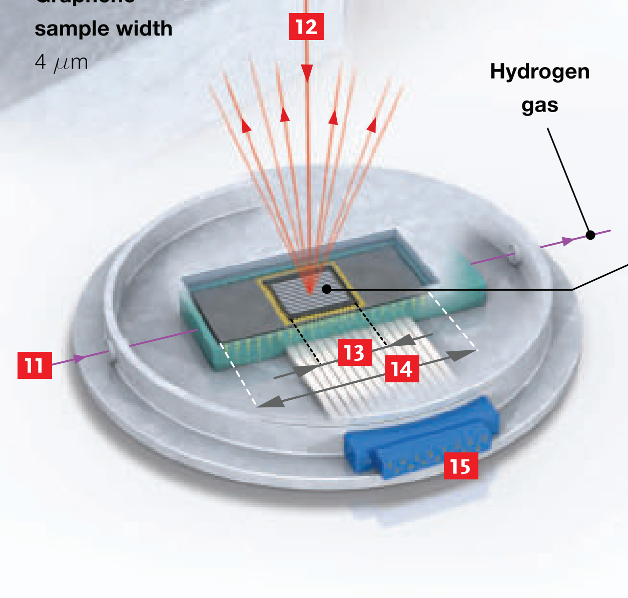


F Unique Delft tests results: 15 % strain

Tests with the glued graphene sample show a graphene strain of almost 15 %. The strain is elastic, reversible without any hysteresis, and highly controllable with the voltage setting. This result represents a key step towards unlocking novel graphene applications in hydrogen separation, but also in optical and nanoelectronic devices.

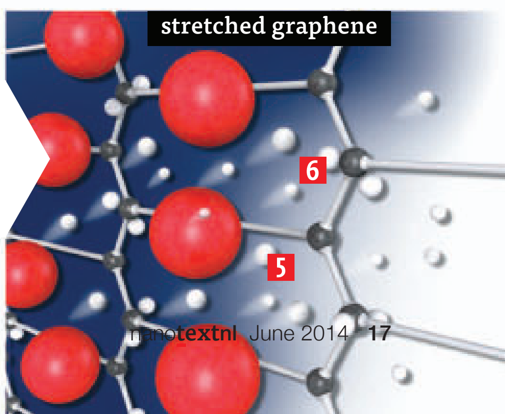
G New experiments: adding hydrogen

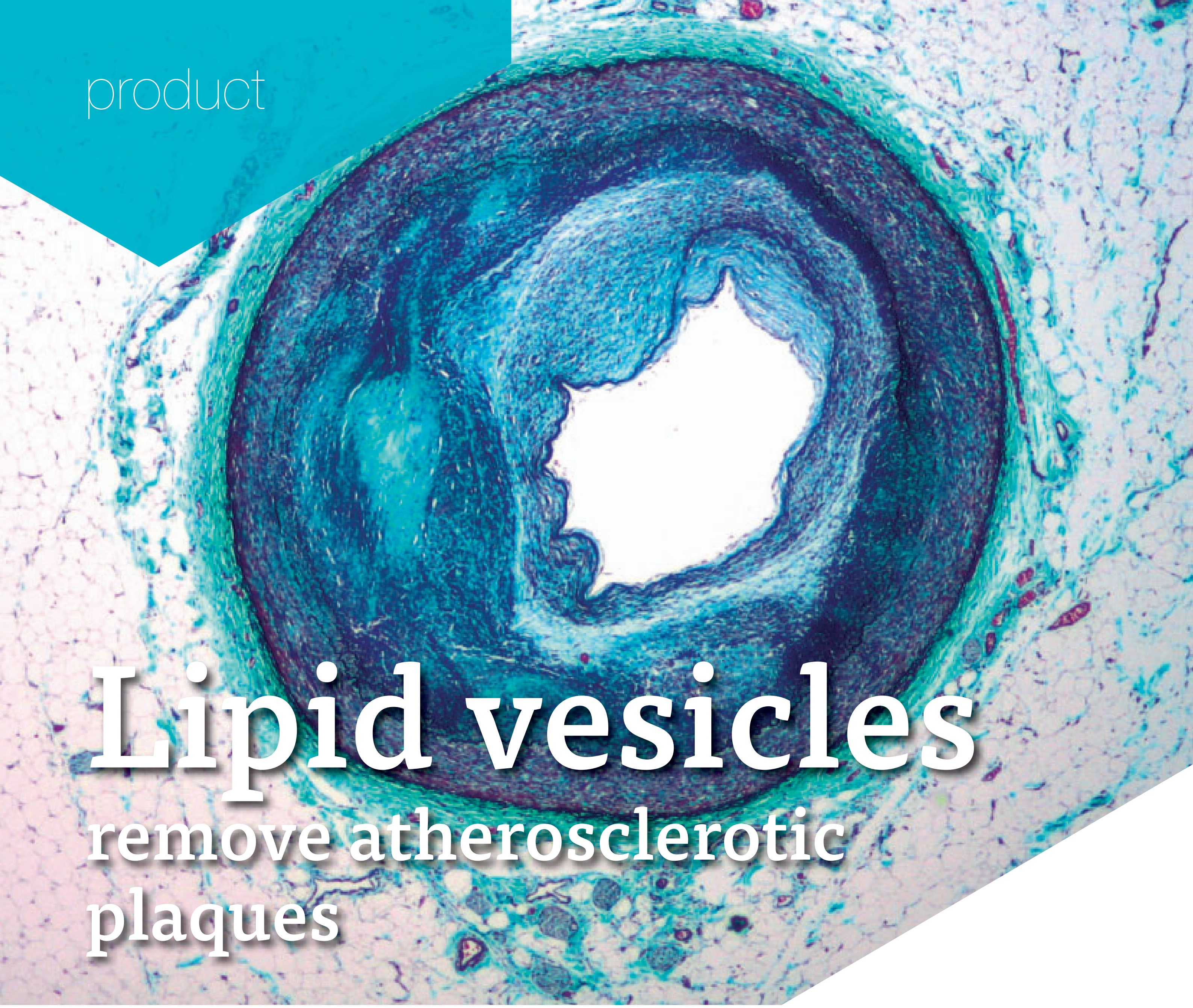
Next step is to repeat the straining experiments in the presence of hydrogen. A chip carrier will be placed in a closed chamber with an inlet 11 and outlet for hydrogen gas. The chamber has a window to enable Raman spectroscopy. In this technique the graphene surface is illuminated by a laser 12. The laser interacts with molecular vibrations in the graphene and this results in an energy shift of the laser photons. The scattered laser light provides a unique energy signature of graphene. If the strained graphene absorbs hydrogen 5 this will result in a different spectroscopy pattern. If the strained graphene works as a molecular sieve 6, another measuring technique will be applied.



Chip

A chip (10 x 10 mm 13) contains up to 40 tensile devices. This chip is placed in a chip carrier (length 14 30 mm) with electrical contacts 15 to apply the voltage.





Lipid vesicles
remove atherosclerotic plaques

Text Nienke Beintema / Image Wikimedia

The idea came from science, doctors are running the clinical trials, and a spin-off company is turning the finding into a product. In brief, that's the story of a new, nanotargeted approach to treating atherosclerotic plaques.

Cardiovascular disease is currently the number one cause of death in developed countries. A key contributing factor to this disease is atherosclerosis: local thickening of artery walls due to an accumulation of fatty materials, such as cholesterol, and calcium. These local ‘bottlenecks’, called plaques, are harmful as they reduce the blood flow. More importantly, if they rupture, they may clog small arteries. That can lead to myocardial infarction or stroke.

Scientists worldwide are working on strategies to address the dangers of atherosclerotic plaques. One approach is aimed at reducing their risk of rupturing. “Plaques are in fact local sites of inflammation,” says Gert Storm, Professor of Targeted Nanomedicine at Utrecht University. He is also programme director of the NanoNextNL programme Drug Delivery. “White blood cells accumulate in the plaques, where they transform into macrophages: immune cells that ingest harmful elements, in this case cholesterol. This immune reaction is of course intended to be beneficial. But at the same time it makes the plaques unstable and more likely to rupture. Our approach is therefore targeted at reducing the inflammation locally.”

Hit the target

This is done, as Storm continues to explain, by sending anti-inflammatory drugs towards the plaques. “The idea of nanotargeting,” he says, “is that the drugs are delivered precisely at the spot where their action is required. We achieve this by packaging the drug in tiny lipid vesicles, about 100 nanometer in size, called liposomes. These liposomes travel through the body unharmed, until they are ingested by the macrophages inside the plaques. Upon ingestion, they disintegrate and release their anti-inflammatory drug content.”

liposomes filled with anti-inflammatory drugs in the context of rheumatoid arthritis.” That research was carried out by Bart Metselaar who at that time was a PhD student in Gert Storm's group. Metselaar decided to start an academic spin-off company, called Enceladus, to further develop liposomal anti-inflammatory drugs and bring them to the market. “It was our common ambition to adapt this approach to cardiovascular disease.”

“I really think the approach is very promising,” says Metselaar, now CEO at Enceladus. “But some crucial pieces of the puzzle are still missing. We still don’t really understand all of the inflammatory pathways inside the plaques, how exactly they accumulate fatty materials, and why they rupture.” As a result, the researchers are still looking for the perfect pharmaceutical compound to target this particular inflammation. Metselaar: “Thanks to clinical trials carried out at the Academic Medical Center in Amsterdam, we do know that we can get our liposomes into the plaques and that they can successfully deliver their content – but we are still working on what that content should be.”

> "The great thing about NanoNextNL is that it bridges fundamental research and clinical practice"

Aren’t the liposomes ingested by macrophages elsewhere in the body? After all, macrophages are common immune cells and they play important roles in various immune responses. Storm: “Liposomes do end up in other macrophages, but one should realise that macrophages are different throughout the body, depending on their function. We have clear indications that our liposomes are ingested by the macrophages inside atherosclerotic plaques, which are adapted for ingesting nanoparticulate components. So far we haven’t found any serious detrimental effect elsewhere in the body.”

Here Storm interrupts his story to explain the historic context of the project. “For many years, our group has been working in cooperation with Mount Sinai University in New York,” he says. “Initially we studied

Animal and clinical studies will be needed to identify and develop the right pharmaceutical. Research in the context of rheumatoid arthritis, however, has developed far further. Several clinical trials have been successfully completed. Storm predicts that the first liposomal anti-inflammatory product will possibly reach the market within 3 to 4 years.

“The great thing about this NanoNextNL programme is that it bridges fundamental research and clinical practice,” Storm concludes, “which is a huge personal drive for all of us. There is a great deal of literature on nanotargeted medicine, but in this programme we really have an opportunity to finally bring all this academic knowledge to clinical practice. And in the end, this is something that society as a whole will benefit from.”

Timeline

1987
Gert Storm obtains a PhD degree at Utrecht University, focusing on anti-cancerliposomes. He spends a sabbatical at Liposome Technology Inc. (CA, USA), a company that in those days developed Doxil, the first US FDA-approved liposomal product on the market

1998-2002
Bart Metselaar works on anti-inflammatory liposomes as a PhD student with Gert Storm

2005
Based on successful preclinical animal data, Bart Metselaar establishes Enceladus, a spin-off of Utrecht University, to bring this class of targeted nanomedicines to the market

2008
First clinical trials with anti-inflammatory liposomes as a treatment against rheumatoid arthritis

2008
First animal studies with anti-inflammatory liposomes as a treatment against atherosclerotic plaques

2010
First clinical studies with anti-inflammatory liposomes as a treatment against atherosclerotic plaques

2018
Envisioned market launch of first anti-inflammatory liposomes against rheumatoid arthritis

Within NanoNextNL programme 6A, Johan Klootwijk from Philips Research is involved in the development of a formaldehyde sensor.

Text Anouck Vrouwe / Photo Shutterstock

Nanowires to sell air purifiers

What interest has Philips in a formaldehyde sensor?

“Formaldehyde is a toxic chemical. Chipboard, MDF and plywood contain formaldehyde-emitting glue, and it is also used in textiles. Until recently there were no proper tests on the market for low but carcinogenic levels of formaldehyde. If people can measure air quality, they are more willing to invest in the air purifiers Philips sells.”

Why use a nanowire-based sensor?

“Mainly because of the sensitivity of nanowire-based sensors. Another advantage is the production method; most of it is ordinary chip-making technology. So cheap, large-scale production is within reach.”

Is your sensor on the market yet?

“We have built some test sensors, but for Philips, the development of a formaldehyde sensor is no longer a priority. A chemical sensor is now available that is accurate enough. But Philips still closely follows nanowire-based sensors for other applications, and so we continue to be involved in the NanoNextNL-project. For now, the follow up research is being done at Delft University of Technology.”

What is the biggest issue that needs to be resolved?

“The selectivity of the detection layer is key. The nickel oxide receptor we used reacts with other gases as well. A solution might be to put multiple detection chemicals on one sensor. All those receptors react to a different set of gases, so the read out of the sensor would be a fingerprint of the chemicals in the air. A lot of researchers in this field are working on that now, but it will take several years for real products to emerge.”

Can nanowire based sensors do more than measure gas alone?

“Marleen Mescher, a PhD student in this project, is working on a water sensor. She uses the same layout we did. She has mounted little tubes on top that conduct the flow of water over the nanowires. That is the great thing about nanowire-based sensors; you play with the receptors, but the underlying chip stays the same.”

Multilayer

A nanowire sensor is like a sandwich cake. The recipe: start with a bottom of silicon and add a dielectric layer of silicon oxide. The third layer is silicon again. All of this is simple, traditional semiconductor technology. By etching, the third layer is turned into a bunch of small rods – nanowires, to which electrodes are added. The crucial final step is the icing on the cake: a receptor spread on the

In the NanoNextNL food theme, Lies Bouwman from Leiden University, in a smooth cooperation with Wageningen University and the companies Nanosens and EMS, develops an ethylene sensor.

Text Anouck Vrouwe / Photo Freeimages.com

Sensible fruit ripening

cake

nanowires. You can choose any receptor you like. Take, for example, a metal oxide that interacts with certain chemicals or an antibody receptor that binds the proteins of a virus. Now your layered sensor cake is ready. When a molecule or virus interacts with the receptor, the resistance of the small nanowire changes immediately. That makes the sensor extremely sensitive.

Are you heading in the right direction?

“We are testing and refining a first prototype. We let nature inspire us. Plants have an ethylene receptor, in which a copper ion binds to the hormone ethylene. So we started by working with copper in our laboratory, too. We developed several copper complexes that can bind to ethylene. We tried one of them in a chip by adding it to the nanowires. A chip measures the change in resistance of the nanowire when the ethylene binds. This complex seems to perform well and so we have the first proof of principle.”

What could the sensor be used for?

“Ethylene stimulates fruit ripening. Retailers would like a low cost sensor to help condition their fruit storage facilities. Growers would also like to measure the quantity of ethylene in their greenhouses. And if you could make the sensor extremely cheap and small, supermarkets might even add sensors to fruit wrapping; it could tell customers if their mango is ripe yet.”

What is your role in the cooperation with NanoNextNL?

“In a nutshell: we develop the copper complex that binds the ethylene, Nanosens puts it on a chip, Wageningen University does the testing and EMS develops the actual sensor. This work should first of all lead to a patent; we will publish the results after that.”

What is the most difficult problem?

“The main issue is the selectivity, to develop a metal complex that only binds ethylene and not other gases like carbon monoxide, ethanol and water vapour. We do a lot of measurements to see which material performs best. Another challenge is upscaling the technique: does our copper complex stay stable enough and can it be produced on a large scale for the right price? We are focusing our research on this right now.”

When will your sensor hit the market?

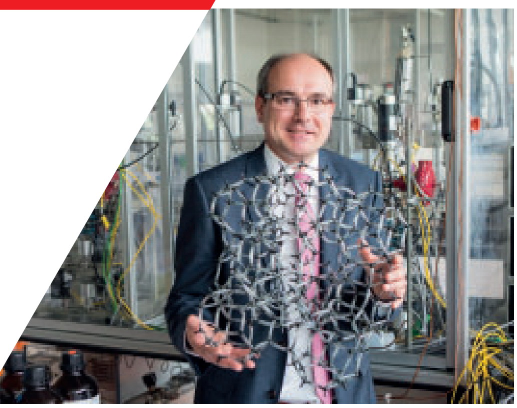
“I do not know for sure, but the results look promising. I hope we can develop a sensor that can be used in fruit packaging.”

events, seminars, courses, people

Meeting on future of NanoNextNL

On 13 March 2014, NanoNextNL programme directors and theme coordinators came together in Villa Jongerius in Utrecht to talk about the next two years of NanoNextNL. Chair Dave Blank opened the meeting with a presentation about the conclusions of the Midterm Review. Subsequently, the different themes worked in smaller groups on a plan to implement these conclusions for their own specific theme. After the lunch the participants attended presentations about the importance of Risk Analysis and Technology Assessment and the Golden Egg Check, a tool to score business cases.

Spinoza Prize for Bert Weckhuysen



Bert Weckhuysen, photo NWO/Ivar Pel

NanoNextNL project leader and chemist Bert Weckhuysen has received the highest award in Dutch science: the NWO Spinoza Prize. The Prize consists of 2.5 million euros to devote to scientific research. Bert Weckhuysen is Professor of Inorganic Chemistry and Catalysis at Utrecht University. His research focuses on the understanding and development of new or improved catalysts for the conversion of fossil and sustainable raw materials into transportation fuels, chemicals, plastics and building blocks for medicines.

ERC Grants for NanoNextNL researchers

The European Research Council has awarded ERC grants to NanoNextNL researchers Kobus Kuipers, Pouyan Boukany, Jorge Gascon and Gijsje Koenderink.
Kobus Kuipers (AMOLF) received an ERC Advanced Grant (€ 2.5 million) for his proposal 'Control of the Structure of Light at the Nanoscale (CONSTANS)'. ERC Advanced Grants allow exceptional and established research leaders of any nationality and any age to pursue groundbreaking, high-risk projects that open new directions in their respective research fields or other domains. The ERC Advanced Grant funding targets researchers who have already established themselves as independent research leaders in their own right.
The other three researchers received an ERC Starting Grant (€ 1.5 million). The ERC Starting Grant aims to support up-and-coming research leaders who are about to establish a proper research team and start conducting independent research in Europe. The scheme targets promising researchers who have the proven potential of becoming independent research leaders.

Physica prize 2014 for Albert Polman

NanoNextNL board member Albert Polman has been honoured with the prestigious Physica prize of the Netherlands Physical Society (NNV). The NNV granted the prize to Albert Polman for his outstanding contributions, both in the Netherlands and internationally, to the physics of light. The Physica prize is awarded each year to an eminent physicist working in the Netherlands. Albert Polman received the prize on 1 April 2014 at the FYSICA 2014 conference in Leiden. Afterwards he gave the Physica lecture.

Albert Polman, photo FOM

MicroNanoConference'13

Photo: Ad Utens

On 11 and 12 December 2013 over 400 researchers, entrepreneurs and others interested in micro and nanotechnology gathered in Ede at the Reehorst for the 2013 edition of the MicroNanoConference. The programme was filled with inspiring lectures and sessions about the latest developments in various areas of micro and nanotechnology research and products. Researchers from NanoNextNL made a major contribution to the programme with 35 presentations and 34 posters.
A short video impression can be found at the website of the MicroNanoConference'13: www.micronanoconference.nl

Sensors for water and food applications

On 19 November 2013, NanoNextNL's Technology Assessment programme organised interactive workshops on demand-driven innovation strategies for sensor applications in the food & beverages and drinking water industries. These industries face important challenges in managing and assuring quality and safety of their products.
Some 35 participants from knowledge institutes, water companies, food companies, and representatives of government agencies, discussed customers' requirements and needs. The meeting was prepared by members of the Technology Assessment programme via in-depth research. The RATA researchers sketched different routes along which sensor applications could be explored and developed, anticipating developments in technologies, requirements of potential users, and their interactions with stakeholders such as customers, consumers and regulatory authorities.
During the discussions promising areas for sensor applications were identified. The modification or development of standards was considered to be especially relevant. Government agencies could play a stimulating role by developing regulations that would open up opportunities for the use of novel monitoring technologies and by facilitating collaborations between sensor researchers, technology developers and future users of sensor applications. Finally, workshop participants pointed out that public debates about acceptable risks in terms of quality and safety of drinking water, food & beverages, were also important for the overall innovation process.

Cooperation with Japan

During the past year, NanoNextNL has intensified its international relations. In December 2013, chairman Dave Blank signed a Memorandum of Understanding (MOU) with professor Ushioda of the National Institute for Materials Science of Japan (NIMS) to pursue collaboration in fields of mutual activity in the area of nanotechnology. NIMS's mission is to carry out fundamental and generic/infrastructural technology oriented research and development in the field of materials science so as to improve the national level of materials science and technology. A comparison of the NIMS and NanoNextNL research programmes has revealed the 'hot spots' in the available matching activities and interest. The MoU was prepared following the further development of contacts established during several visits and meetings in recent years, and has been followed up by a visit from a NanoNextNL delegation, chaired by Fred van Keulen (vice-chair of the Executive Board at NanoNextNL) to Japan in January 2014. This meeting extended the existing contacts between NIMS and NanoNextNL and the possibilities for further collaboration were presented and discussed.

Imagine: you're a researcher, and you have developed a technology that has the potential to be a game changer within a field. How can you commercialise that technology? What choices should you make, and when? Who should you talk to before starting a business? NanoNextNL researcher Verena Stimberg of the University of Twente asked herself exactly these questions while working on a microfluidic platform system to test the effect of substances on artificial cell membranes and proteins. She decided to organise a Risk Analysis and Technology Assessment workshop to explore the possibilities for commercialising her research results.

A few weeks later on a morning in January some twenty people have gathered for a brainstorm on the risks and possibilities of the lipid bilayer platform. The attendees come from very different backgrounds: among them are scientists working on similar techniques, owners of start-up companies in the life sciences, an Intellectual Property Manager of the University of Twente and representatives from the Rathenau Institute and from the National Institute for Public Health and the Environment (RIVM).

Tools for PhDs

Douglas Robinson, former PhD student within the NanoNed programme and currently part-time postdoc within the RATA programme of NanoNextNL, leads the workshop. "Within the RATA theme of NanoNextNL, we want to create tools for PhDs to address societal aspects of their research. For us as Technology Assessment researchers, today is an experiment to see if these kinds of workshops can deliver useful keys to what aspects should be addressed, and which people should be involved to give the researchers a head start in commercialising their results."

> "We want to create tools for PhDs to address societal aspects"

Stimberg starts by explaining the characteristics of the microfluidic device she developed under supervision of Séverine Le Gac within the BIOS - Lab on a chip group at the University of Twente. "Our topic today is a model platform for the cell membrane. The model system is incorporated in a microfluidic device, which includes both optical and electrical measurement options. This makes it possible to characterise the effect of synthetic molecules on the cell membrane and on proteins."

Text Sonja Knols / Photography Gijs van Ouwerkerk

Exploring routes towards commercialisation

Risk Analysis and Technology Assessment (RATA) is an important part of the NanoNextNL programme. Verena Stimberg, PhD researcher at MESA+, organised a RATA workshop to explore risks and opportunities associated with commercialisation of the lipid bilayer platform she is developing within the Nanomedicine theme.

Stimberg and Le Gac have thought about potential applications themselves. They see two distinct opportunities: either develop a platform solely for research purposes or try and produce a marketable version of their platform. In the latter case, the market they are thinking of is either toxicity screening of nanoparticles or drug screening on membrane proteins.

Workshop leader Douglas Robinson summarises: "There is a platform for bilayer experiments. The main application seems to be high throughput drug screening on membrane proteins. In this room we have experienced start-ups such as Medimate, business providers like Lionix and people who are experts in risk analysis. There seem to be four possible roads we could take: drug screening, research tool, nanotoxicity and combinations of the three. What do you consider possible?"

After a first round of questions on the ins and outs of the platform system, an energetic discussion follows. On the possibilities and impossibilities of developing a product for drug screening. On the main competitors already on the market. On regulations standing in the way of selling the platform as a medical aid. And on what business model to choose to ensure a start-up company will survive financially until the first actual product is sold.

Tips and tricks

Stimberg gets heaps of practical tips and tricks, most of them suited for anyone thinking of starting a business: Talk to your potential customers: what demand can your technology meet? Address communities of end users, and go to trade shows to demonstrate your finding to potential investors. And beware of the risks involved when your envisioned product is meant for medical purposes: it will take a long, and expensive road of testing and certifying before you can even think of sales.

These are all great tips, but for the PhD student the question still remains: Where to start? Douglas Robinson advises developing a roadmap, which interrelates the technology with possible products and possible markets. The participants start brainstorming about these three elements. By structuring their thoughts into the three aforementioned subjects, they immediately find new possibilities. “What about cosmetics? Within the EU animal testing is a no go for the cosmetics industry. If your platform can help them to find out in an early stage of development which ingredients might be harmful then that could save them a lot of time and money.”

Stimberg thanks all those present for their input and ideas. “This was a very stimulating meeting. At the moment there are no plans for actual commercialisation yet, but I will certainly include the outcome of this workshop in the RATA chapter of my thesis, which is required for all PhD projects carried out within the NanoNextNL programme.”

Photo Kees Bennema

Nanometre precision for EUV mirrors

Within NanoNextNL programme 7B, the research team of Fred Bijkerk from the MESA+ Institute for Nanotechnology at Twente works on mirrors for the reflection of extreme ultraviolet light (EUV). With a wavelength of only 13.5 nanometres, this light enables a high resolution imaging process for the fabrication of integrated circuits. Carl Zeiss and ASML are developing advanced equipment for this process.
Currently available sources of EUV radiation also produce undesired radiation of longer wavelengths. Within NanoNextNL, Bijkerk's team works on the design, fabrication and testing of advanced optics which still reflects EUV light but stops the undesired radiation components.

Text Sonja Knols / Image PhD thesis Andrea Ranzoni (TU/e, 2012)

Rotating magnetic clusters detect proteins

Detecting proteins in unbelievably small quantities, in a couple of minutes, in a drop of blood. That's in short the aim of Leo van IJzendoorn's research within programme 8B of NanoNextNL. To achieve this, Van IJzendoorn and his colleagues at Eindhoven University of Technology study rotating magnetic particles.

Current healthcare depends heavily on the use of centralised in-vitro diagnostic laboratories, resulting in time delays and in multiple patient interactions over several days. The benefit of decentralised point-of-care testing (POCT) systems close to the patient consists of on-the-spot decision making in a single patient interaction. This is particularly important in patients whose condition may deteriorate quickly, for example due to cardiovascular problems.

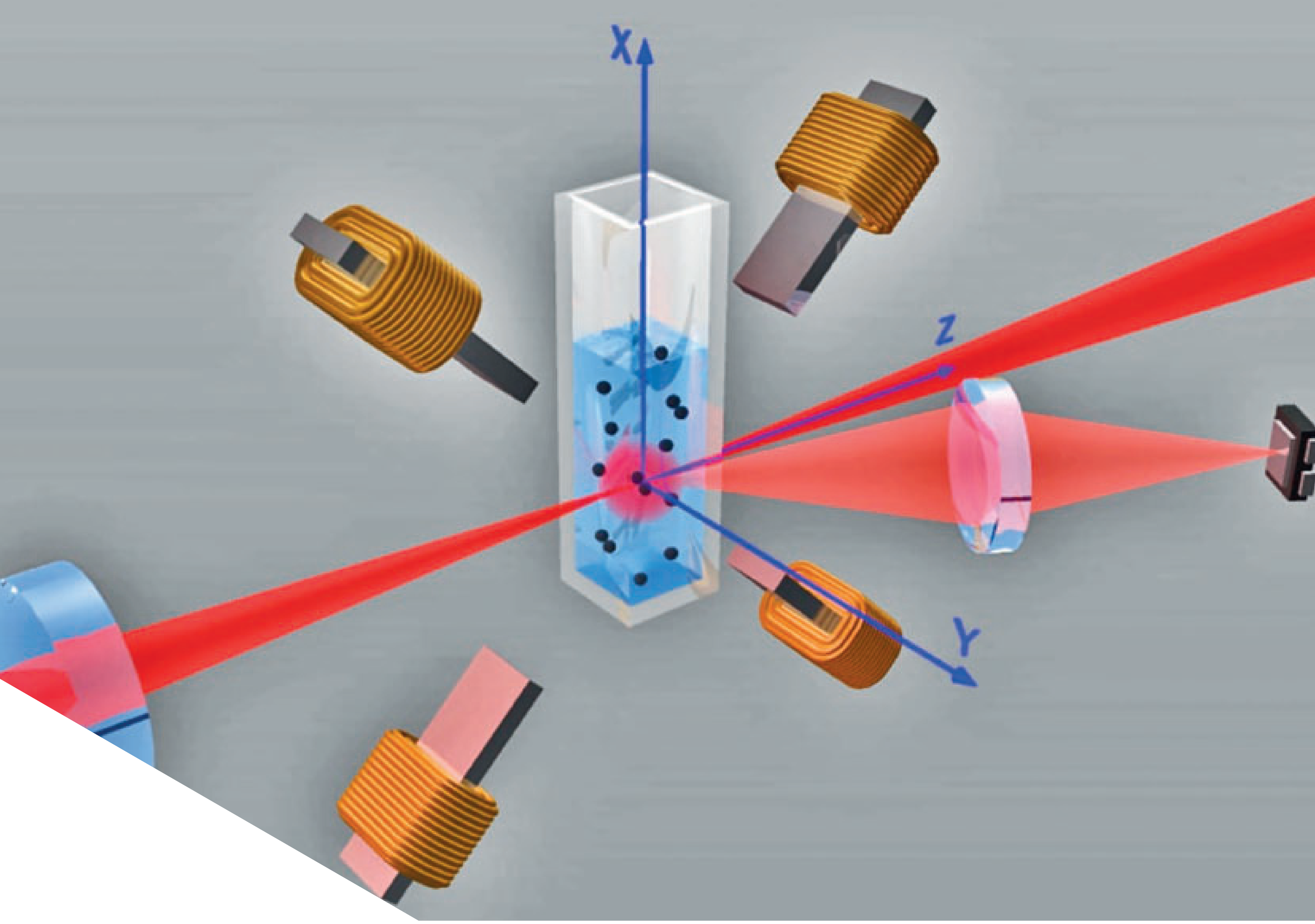
NanoNextNL-researchers at Eindhoven University are working on a technology that can detect proteins in very small quantities, in blood plasma, within minutes. To detect only the protein of interest, the Eindhoven researchers use one of nature's most specific locators: antibodies. "There is a wide range of antibodies on the market, which bind very specifically to known target molecules. By selecting the right antibody, you can bind to just one type of protein," explains physicist Leo van IJzendoorn.

Magnets speed things up

The researchers couple the antibodies to particles with sizes of approximately 500 nanometres. One protein can bind to two different particles, thus creating a dumbbell, a cluster of two particles. To speed up the binding process, the researchers use magnetic fields. "We work with so-called superparamagnetic particles," Van IJzendoorn explains. "These are polystyrene particles, filled with magnetic nanoparticles." As soon as a magnetic field is applied, the particles turn into little magnets that can be moved around in the sample to capture the proteins. The little magnets also attract each other and thus form strings of particles. When the magnetic field is turned off, the chains disassemble but the dumbbells remain.

But why would you want to form these dumbbells? Van IJzendoorn: "We use light scattering to detect the dumbbells in the sample and thereby reveal the number of proteins in the blood. In the case of protein biomarkers, we want to be able to detect concentrations of less than one picomol per liter. That concentration is very low, a factor of 10^9 lower than the concentration of glucose in blood. By binding the biomarker proteins to the particles, and by clustering the particles into dumbbells, we construct something that is detectable by light scattering." With this technique, subpicomolar sensitivity is within reach.

Van IJzendoorn shows the experimental set-up. It consists of lasers, several optical elements, and four electromagnets positioned around a small fluid chamber. "We apply a rotating magnetic field using the electromagnets. This causes the dumbbells to rotate. The resulting light signal oscillates and varies with the orientation of the dumbbells with respect to the incoming laser beam. The intensity of



the oscillating light is a measure for the number of dumbbells, and therefore of the bound proteins in the fluid." Former PhD student Andrea Ranzoni performed the first experiments at Philips Research. In the NanoNextNL-project, his successors found that the optical scattering signals contain an intriguing fine structure. "We are now looking into the origin of this fine structure and we have ideas how to use it for biosensing purposes." Simulations and a mathematical operation called Fourier transformation have already revealed that the fine structure should contain information on the distance between the particles. "There it gets interesting." glimmers Van IJzendoorn. "What if we can indeed use this analysis technique to accurately measure the distance between the particles? It implies that we could measure the size of the protein that binds the particles together! We could obtain direct insight into the nature of the bond between the particles and could, for example, discriminate between particles that are bound together by a protein and particles that are only bound accidently. With this, a significant improvement in the detection limit may be reachable.

"What if we can use this analysis technique to measure the distance between the particles?"

One of the most advanced technologies for point-of-care testing is currently the Minicare system that is under development at Philips. "This technology also employs magnetic particles for protein capture and it is based on the detection of particles bound to a surface." The rotating cluster technology investigated within the NanoNextNL programme is a solution-based assay without surface binding, which is explored for novel assay formats and novel applications in the field of affordable, fast and sensitive detection.

Point-of-care testing technologies are set to improve the accessibility and the quality of healthcare. So that the patient in the practitioner's office may be diagnosed from a single drop of blood, allowing the doctor to decide within minutes and with confidence if further medical action needs to be taken or if the patient can simply go home.

Text Nienke Beintema / Photos Ivar Pel

Systems & packaging

Sensors are omnipresent in our modern society. They measure physical parameters such as light, motion, temperature, or the presence of certain molecules. Thermostats, cars, medical equipment, industrial reactors, satellites: they all use sensors in one way or another. Because of the great socio-economic impact of sensor technology, and its potential to make our society more efficient and sustainable, experts agree that research is needed to improve the performance, robustness and error tolerance of sensors. That is exactly the focus of NanoNextNL programme 10A, from which two totally different start-ups emerged. They illustrate the broader applications of sensors: from smartphones to aerospace technology.

Elpasys

Arash Noroozi

"There are many exciting developments in fields such as software engineering, electronics, signal processing, mobile platforms and communication systems," says Arash Noroozi, "but these fields usually work quite separately. My ambition is to bridge the gap between these technologies. This would make the developments more efficient and give rise to entirely new applications." In 2012, Noroozi and his colleague Prem Sundaramoorthy founded the company Elpasys, a spin-off of Delft University of Technology. Elpasys develops innovative smartphone applications and electronic systems.

"Almost everyone owns a smartphone these days," says Noroozi. "They have great potential, but hardly any of it is currently being used." Imagine if smartphones contained sensors that collect air pollution data, he indicates. Combined with GPS tracking and time registration, this would give an unprecedented overview of air quality in different places at any given time. Moreover, this set-up could serve as an early warning system to bring to light sudden pollution events, or to warn people with respiratory or heart problems.

First product

"That is just one example," says Noroozi, "but there are countless other exciting possibilities." Monitoring the state of bicycle lanes, for example. "We recently launched our first product, a game that uses movement sensors in a smartphone. Now we are developing other applications in the area of education entertainment, where we combine new hardware and software elements."

Although Noroozi comes from a highly technical background, he enjoys the business side of this work. "Writing business plans, thinking along marketing lines, focusing on sales and procurements… I am learning along the way," he says cheerfully. "I am a researcher and an engineer, with a passion for innovation, but I always knew that I wanted to start my own company one day."

In ten years' time, Noroozi hopes that his company will be known – and operating – worldwide. "The field of smartphones applications is highly competitive," he says, "and it is not easy to survive. But on the other hand there is still much potential that hasn't been explored." A lot of hardware is already in place in current smartphones, he emphasises, which could also be combined with external hardware. "Our advantage is our interdisciplinary approach," says the engineer. "Combining different technologies is not something that many companies do. I am confident that we have found an interesting niche."

Hyperion Technologies

Steven Engelen, Cor in 't Veld and Bert Monna

In the olden days, sailors used to look at the starry sky to determine their position at sea. Today, satellites do roughly the same. They are equipped with star trackers: sensors that determine the satellite's so-called 'attitude' (3D-orientation relative to the celestial sphere) based on the detection of stars. In 2013, Steven Engelen, Cor in 't Veld and Bert Monna founded Hyperion Technologies, a spin-off of Delft University of Technology, to develop a new generation of star trackers.

"They are high-tech electronic devices," says Engelen, who started his work on star trackers during a PhD project in Delft. "They contain a camera that registers its own orientation and the relative position of stars, as well as software that calculates attitude based on this input. Our ambition is to make star trackers that can be used in the latest and smallest generation of satellites." These star trackers need to be extremely small – the size of an average coin – as well as light, yet robust and low-power.

Best yet smallest

Monna: "Traditional star trackers are built for satellites with masses of 100 to over 1000 kilograms. Ours can be built into satellites of only 1 to 3 kilograms. Of course these size restrictions result in technological limitations. But I can safely say that we are developing the best instrument that still fits into the smallest satellites."

Although Hyperion's work is ongoing, the company launched its first product at the end of 2013: supporting electronics for one of the high-resolution cameras on the International Space Station (ISS). "Our product is up there and it functions well," says Monna. "It helps to point the camera in exactly the right direction. The intention is that the ISS will also use our star trackers in the near future." Engelen adds: "This is exciting. The aerospace engineering world is traditionally quite conservative, and the ISS has some of the highest quality standards in the field. This work paves the way for use of our technology in other satellites as well."

And the market for this kind of technology, as they emphasise, is booming. Satellites are becoming smaller and more diverse in shape and function, and they are increasingly used in combined systems of satellites. Monna: "Eventually we aim to produce a plug-and-play system that would make it easier for satellite builders to incorporate our technology. We are confident that the demand for these small systems will only increase."