Universität Basel

Swiss Nanoscience Institute

SNI SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL

SNI update October 2016

10 years SNI

Dear colleagues,

Once again, a great deal has happened since we last reported on our activities in the last "SNI update". In September, we came together for a highly interesting annual meeting at Lenzerheide. I was pleased to hear about the progress being made by exciting research in a wide range of fields and to see how well our doctoral students presented themselves. I, too, was again able to learn a great deal.

The colloquium held to mark my 60th birthday was a very special occasion for me, of course. The organizers surprised me with an amazing program as well as with many old friends and colleagues from Switzerland and other countries. However, it was also a successful occasion from a scientific point of view. For that, I would like once again to extend my sincere thanks to everyone who helped organizing the colloqium and came along.

Michel Calame was one of organizers of this event. Now it is my turn to congratulate him! From October, Michel will be heading up a group at Empa in Dübendorf that is looking at nanoscale transport phenomena. Over the last few years here at the SNI, Michel has done tremendous work on setting up the PhD School and has led an outstanding scientific team. On behalf of the whole SNI, I would like to thank him for his commitment and support. We wish him all the best in his new role and hope to continue working together closely in the future.

On the scientific front, the last few weeks at the SNI have been marked by some remarkable results achieved using atomic force microscopes (AFMs). Christoph Gerber, Carl Quate and Gerd Binnig have just received the Kavli Prize for their invention of AFM. Right on cue, in the last few months we have seen several papers of SNI members accepted for publication where AFM played a key role. Thanks to many press releases we have issued on the subject, we have been able to secure coverage of these successes by a wide range of media.

I hope you enjoy this issue and look forward to the SNI's next big event – our 10th anniversary celebrations at the end of October.

Kind regards,

Christian Schönenberger

SNI Director, University of Basel

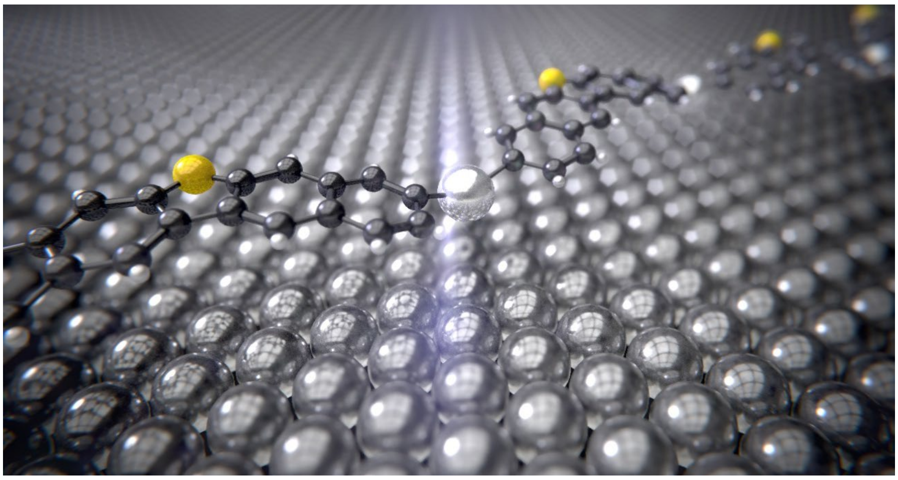
Cover story

Solving riddles with the AFM

On September 6 this year, Professor Christoph Gerber, Professor Carl Quate and Dr Gerd Binnig received the Kavli Prize in Nanoscience. The formal ceremony took place in Oslo, in the presence of Crown Prince Haakon of Norway, and recognized the prizewinners' invention and development of the atomic force microscope (AFM) 30 years ago. Since then, the AFM has become an important tool for nanoscience research, with a wide range of uses. This is reflected in some of the publications by SNI members that have appeared in recent weeks in prestigious scientific journals such as "Nature".

Observing chemical reactions

In the last few weeks and months, scientists working with Professor Ernst Meyer and Dr Shigeki Kawai have published papers describing their use of a high-resolution atomic force microscope with a carbon monoxide tip to track and understand chemical reactions. They have been able, for example, to watch a silver catalyst at work for the first time. During the so-called Ullmann reaction, silver atoms catalyze the bond between two carbon atoms. The researchers' observations allowed them not only to work out how the reaction takes place, but also to calculate the energy turnover involved. This may make it possible to find ways of optimizing this long-established and often implemented reaction.

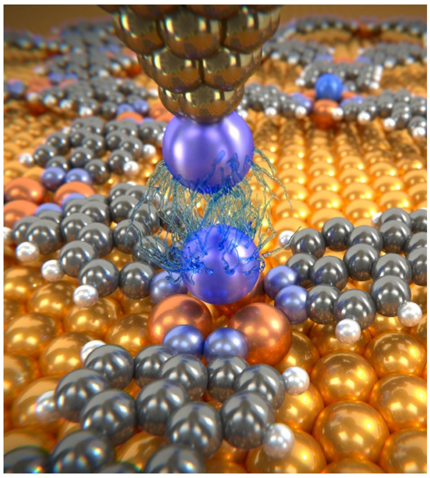


The intermediate product of the Ullmann reaction with the silver catalyst (silver) between the carbon rings (black) and sulfur atoms (yellow) curves like a bridge over the silver surface.

In another study, copper rather than silver functioned as the catalyst. Starting with a molecule in which three benzene rings were bound together by triple bonds, chemical reactions took place on a copper surface, leading via several steps to the production of new aromatic hydrocarbon compounds that had never previously been synthesized in solution. Comparative computer calculations yielded the precise molecular structure of the compounds, which perfectly matched the microscopic images.

Measuring the tiniest forces

Using atomic force microscopy, scientists from Ernst Meyer's and Professor Thomas Jung's group have succeeded for the first time in measuring the very weak Van der Waals forces between individual atoms. To do this, they fixed noble gas atoms in a molecular network and evaluated the interactions with a single xenon atom placed on the tip of a cantilever in the atomic force microscope. As expected, the forces were dependent on the distance between the two atoms, but sometimes they were significantly greater than theoretical calculations had suggested.



Rare gas atoms deposited on a molecular network are investigated with a probing tip, which is decorated with a xenon atom. The measurements give information about the weak van der Waals forces between these individual atoms.

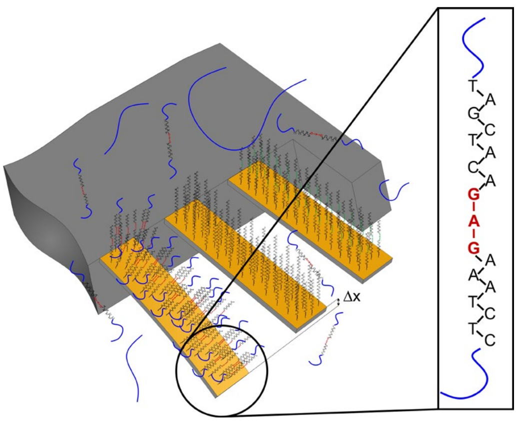
Evidence of exotic particles

Scientists from the SNI and the Department of Physics at Basel are using atomic force microscopy not only to study and understand chemical processes: With the different microscopes available, which can be used in a variety of ways, it is also possible to observe physical phenomena in the most precise detail. Professor Ernst Meyer's group and the theoretical physicists grouped with Professor Jelena Klinovaja and Professor Daniel Loss are working together using AFM to find experimental proof of the existence of so-called Majorana fermions, which are also their own anti-particles. These exotic particles were first described around 75 years ago by the physicist Ettore Majorana. Interest in them has grown hugely since then, as they may have a role to play in producing a quantum computer. The Majoranas are already well described in theoretical terms. However, studying them and finding experimental proof of their existence has proved difficult, as they always occur in pairs, but usually combine to form a normal electron. Very ingenious combinations and arrangements of different materials are therefore needed to produce two Majoranas and keep them apart.

Cancer diagnosis

AFM employs cantilevers equipped with a sharp tip to scan samples. The inventor of AFM Christoph Gerber is now using these cantilevers for diagnostic purposes. Gerber's team coats the cantilevers with different molecules, depending on what is needed. In a study published recently in "Nano Letters", he presents the use of cantilevers in initial clinical trials to help treat malignant melanoma.

To do this, Gerber's team coats the cantilevers with a recognition sequence for a gene mutation exhibited by 50 percent of all patients with malignant melanoma. RNA is then isolated from patients' tissue samples and applied to the cantilevers. If the genetic change is present, the RNA binds to the recognition sequence on the cantilever. The resulting surface stress causes



The cantilever on the left bears the recognition sequence for the target mutation. If this is present in the sample being tested, the corresponding segment of RNA binds to the cantilever, causing the latter to bend. This can be measured, providing clear evidence that the genetic change is present.

this to bend, providing the scientists with a clear signal that indicates the presence of the mutation. As a potential treatment is available for patients who exhibit this genetic change, a quick and inexpensive test of this kind is highly valuable.

Development brings new applications

Christoph Gerber and his colleagues laid the foundations for this and many other research studies 30 years ago. Since then, there has been ongoing development of AFM, and today it can be used in a huge variety of ways. For example, Professor Patrick Maletinsky is placing diamonds with nitrogen-vacancy centers in atomic force microscopes as quantum sensors, enabling him to generate images of magnetic fields in superconductors at a resolution not yet seen. In a recent issue of "Nature Nanotechnology", Maletinsky's team describe their success in using this new kind of AFM for the first time in cryogenic conditions, at temperatures of around 4 Kelvin (-269,15 °C). With it, they were able to image magnetic stray fields of vortices in a high-temperature superconductor with unprecedented precision.

Argovia Professor Martino Poggio is also working to develop a new type of AFM, as he describes in "Nature Nanotechnology". To do so, Poggio's team are using nanowires as tiny sensors, which allows them – unlike with traditional devices – to measure both the magnitude and the direction of forces. Here the researchers are able to exploit the special mechanical properties of the nanowires, which vibrate at roughly the same frequency along two axes at right angles to each other. Using AFM, the scientists measure the changes in vibration that are triggered by different forces. They therefore use the nanowires as tiny mechanical compass needles indicating both the direction and the magnitude of the surrounding forces.

These are just some examples of research results involving AFM that have been published by SNI members in recent months. “Since AFM was invented, around 350,000 publications have appeared about it,” Christoph Gerber notes. “And it will be fascinating to see how the technology continues to evolve.”

In September, Crown Prince Haakon of Norway awarded Carl Quate, Christoph Gerber, and Gerd Binnig with the Kavli Prize for the invention and development of the AFM (image: Thomas Brun/NTB Scanpix).

Night shifts as routine

Jan Nowakowski becomes the first graduate from the SNI’s PhD school

In 2013, the first doctoral students at the SNI’s newly established PhD school started work on their research projects. Jan Nowakowski was one of them. Now he has become the first to complete his doctorate.

Understanding nature

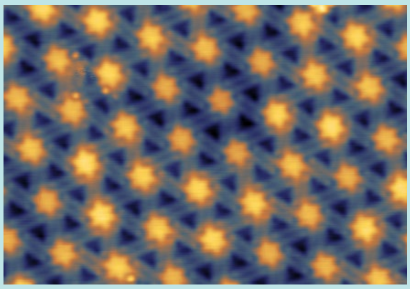
Jan Nowakowski was born and grew up in Bydgoszcz, Poland. He became interested in science early on. In lower secondary school, he chose biology, in order to achieve a better understanding of nature. Later he turned his focus to physics and mathematics, with the same goal in mind. Inspired by his physics teacher, after finishing school he decided to study technical physics in Poznań – and has never regretted it. “Whereas at school there were some subjects I didn’t really like, at university everything was exciting and interesting. I enjoyed those five years a lot,” Jan Nowakowski recollects. Even while still working on his degree, he was looking beyond the boundaries both of physics and of his home country. He completed an internship in Germany and was keen to write his master’s thesis there. His university

Nano Image Award 2016

This year`s submissions for the Nano Image Award have again shown how beautiful the nanoworld can be. The winners are:

Marietta Batzer, Dominik Rohner, University of Basel: Winter landscape. Diamond surface after etching with a plasma (rectangular paddles can be broken out and used as samples)

Gulibusitan Abulizi, University of Basel: Oxidized polycrystalline copper foil after chemical vapor deposition growth of a monolayer hexagonal boron nitride on its surface



Rémy Pawlak, University of Basel: Star carpet: Self-assembly of HCB molecules on Au(111)

Congratulations to the winners and many thanks for all the beautiful contributions!

Sounds and Discussions

Art of Molecule

On Sunday 23 October at 5 pm, the first joint event of the NCCR MSE and the argovia philharmonic will take place. You will experience a concert, talks and round table discussions in Königsfelden Abbey.

Are you curious? Please find more information at:
www.nccr-mse.ch/de/ethics/art-of-molecule/

Basar Molecular

On 27 October 2016, 7.20 pm, the fourth "Basar Molecular" will take place at Sud in Basel at 7.20pm.

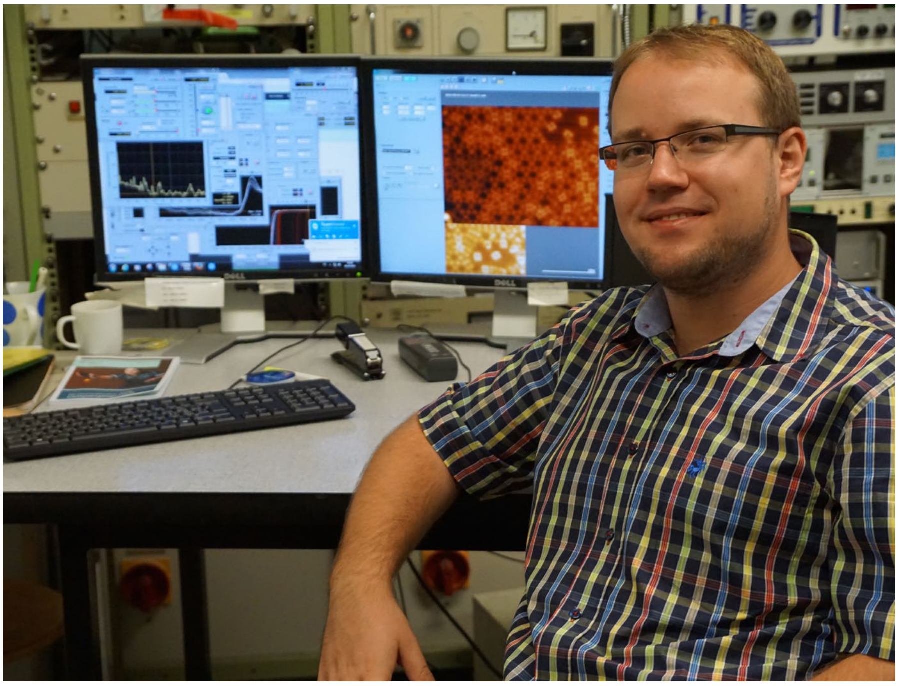
Leading members of the NCCR Molecular Systems Engineering team discuss (non-) scientific issues with opinion leaders, public figures and personalities from the arts, sports, the private sector, politics, and with the live-audience.

More information at:
www.nccr-mse.ch/de/public-events/basar-molekular-public-talk/

agreed to this, but his prospective supervisor in Germany fell ill and the plans came to nothing. Together with his wife Sylwia Nowakowska – whom we introduced in our April 2015 issue – he searched online for alternatives. A job advert posted by Professor Thomas Jung caught the couple's eye. After a few e-mails and phone calls, it was clear what their next step should be.

Special conditions in ultra-high vacuum

As Thomas Jung supervises one working group at the Paul Scherrer Institute (PSI) and another at the Department of Physics at Basel University, he was able to offer both young physicists a master's thesis project. "Here in Switzerland, I was responsible for an ultra-high vacuum system for the first time," Jan Nowakowski explains. "I have learnt a lot since then. When you are working at ultra-high vacuum, any mistake can cost you between one and several days, so it makes sense to learn from your mistakes," he adds with a grin. He loved the work and the atmosphere in the group, so the establishment of the SNI's PhD school in 2012 came at the perfect time for him. He was happy to choose as his doctoral thesis an SNI project submitted by Thomas Jung, and subsequently approved, on paramagnetic molecules on ferromagnetic substrates.



Jan Nowakowski becomes the first graduate from the SNI PhD school.

A range of possible applications

Since joining PSI, Jan has spent almost 180 nights using the PSI's synchrotron to measure and study how molecules containing metallic ions behave on different substrates. Thus, for example, he analyzed the magnetic properties of porphyrins on magnetic surfaces. These organic pigments, which are present in the protein hemoglobin and whose functions include transporting oxygen in the blood, change both their configuration and their magnetism depending on their binding with gases. This means that it may one day be possible to use porphyrins as gas sensors or for data storage.

Testing with the synchrotron

Analyzing these samples involves significant work, as it has to be undertaken in ultra-high vacuum conditions. The best way of examining their magnetic properties is by using the synchrotron light source at the PSI, as this extremely intense X-ray light allows you to distinguish between differently magnetized areas. As a large number of research groups run tests with the synchrotron, users are allocated specific slots, which cannot generally be moved around. Thomas Jung's group – and hence Jan Nowakowski – prefers the night shifts for these measurement phases, as it leaves time for sample preparation during the day and the fresh samples can be measured at night. "During my Master and PhD studies, I have spent about six months using the synchrotron to take measurements at night," Jan Nowakowski recalls. "That is why, unfortunately, I never managed to take part in the SNI PhD school's winter school – the dates always clashed."

However, he was always keen to attend the other events on offer to PhD students within the SNI. The rhetoric and communication workshop was a particular highlight. "By meeting the SNI's other PhD students on a regular basis, I made friends outside my own laboratory. I also enjoyed the interchange across different disciplines," he notes.

Sights set on industry

Jan Nowakowski is now preparing for the next step in his career. Although research still appeals to him, he would now like to take up a position in industry. As his wife Sylwia has already secured her first job, following completion of her PhD, and the position is in Switzerland, naturally Jan would also like to stay here. "What's more, I can no longer imagine living in a place where everything is flat," he adds with a laugh, as skiing and spending time hiking in the mountains in summer, have become his great passion.

Jan Nowakowski learnt a huge amount while working on his dissertation. Although he experienced some setbacks with his experiments, he never threw in the towel. In the end, he was able to complete his doctorate in good time and with top grades. As he leaves the SNI – hopefully, soon to find a job in industry in a nanoscience-related area – his advice to young PhD students would therefore be, "Never give up."

New Argovia projects

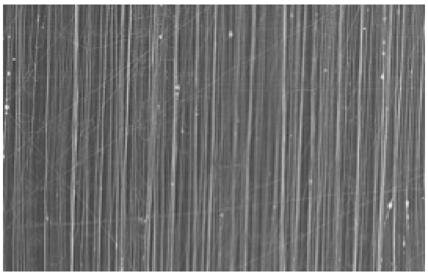
In the April edition of "SNI update", we introduced the first three Argovia projects launched in 2016. Here is an overview of two further applied projects that are in progress.

Vacuum-free method of producing optical coatings

In the Argovia project NF-Optics, scientists are working on a brand-new method of producing optical coatings without the need for a vacuum. The research team consists of the project head, Dr Martin Stalder, and Dr R. Ferrini's team from CSEM SA, as well as groups led by Professor Uwe Pieles (FHNW) and Dr Andreas Hafner (BASF Schweiz AG, Basel).

In optical devices, thin coatings are used to produce different optical effects. For example, they can act as an interference filter or an anti-reflective coating, or they can be used to split a light beam. The production of these coatings, which are only a few nanometers thick, usually takes place in cleanrooms with vacuum systems, so it is very resource-intensive. If there were a method for doing this under normal pressure conditions, it would bring down production costs, save energy and allow a greater range of materials to be used.

The team involved in Argovia project NF-Optics is now looking at whether electrospinning is suited to producing precisely oriented nanofibers that can be applied to glass or thin films and then used as optical coatings. The coatings produced in this way will be compared with traditional optical components to determine their quality. The electrospinning method is best known for the production of non-woven textiles, which are used in filters or to dress wounds, for example.



Electron microscopic image of a nanofiber coating produced in this way; the average diameter of fibers is about 100 nm.

As the illustration shows, the scientists have already managed to produce nanofiber coatings with the high degree of orientation required for the optical components they are planning.

Combining positive characteristics

In the Argovia project NanoSilkTex, Professor Oliver Germershaus and Professor Uwe Pieles (both of the FHNW School of Life Sciences) are working with Dr Monica Schönenberger (Nano Imaging Lab, SNI) and Dr Murray Height (HeiQ Materials, Bad Zurzach) to combine the positive characteristics of silk with those of synthetic textiles.

The cocoon of the Silk moth is made of a thread of raw silk up to 900 m long (image: Shutterstock).

For thousands of years, people have been using the silk threads of the silkworm (Bombyx mori) to produce fabrics. Silk's fine sheen, its immense strength, the superb insulation it provides against heat and cold along with its good water absorbency are among the qualities that have made it so popular. However, silk production is very laborious and expensive. Silk also lacks the functional versatility exhibited by modern synthetic fabrics. For this reason, the SNI researchers involved in the Argovia project NanoSilkTex are looking to improve synthetic fibers by adding silk proteins. To do so, they will extract the main constituent of the silk cocoon (silk fibroin), produce a protein solution from it and use that to coat synthetic fibers.

Previous results demonstrate that it is necessary to add a "glue" to bind the fibroin permanently to the synthetic fibers. When the fibroin coating is applied at a particular thickness, it imparts some of the positive characteristics of silk, such as increased water absorbency, resistance to UV rays and an improved feel, to the synthetic material. Now the process is being optimized further, in terms of the nanostructure of the layer that is applied. Novel approaches to the functionalization of the coating are also being tested.

The research team for the NanoSilkTex project consists of experts from a variety of fields. Specialists from HeiQ Materials are contributing their expertise in finishing textiles. Oliver Germershaus's laboratory has the know-how required for production and characterization of silk fibroin. Uwe Pieles and his team are experts in the field of materials testing and Monica Schönenberger can provide analyses of the surface at the nanoscale.

Events

A birthday party packed with science

On September 9, about 80 associates of the SNI's director, Christian Schönenberger, met for a colloquium to celebrate his 60th birthday. They talked about the early days of the Schönenberger group more than 20 years ago and the trips the team made into the Swiss Alps. However, the main focus was on the research that Christian Schönenberger's current and former colleagues are currently engaged in.

Audience members who are now working in other fields of research or who have left research completely had some difficulties following eveything; however, Christian Schönenberger was completely in his element. He entered into animated discussions about quantum dots, spins, entanglement, nanowires and Kondo systems with the eight speakers and the other guests who had made the trip from all over Switzerland, Holland, France and Germany. During breaks and at the evening barbecue, there was still plenty of time left for everyone to reminisce about old times and make new plans.

Colleagues from different research institutions in Europe came to Basel for the birthday colloquium of Christian Schönenberger.

Festival of Molecules

Amid glorious summer weather, the Festival of Molecules was held in the University of Basel's Kollegienhaus at the end of August. According to a press release from the University of Basel, over the two days of the festival around 80 school classes and more than 4,000 visitors attended this interactive exhibition on the fascinating world of chemistry. The SNI was represented, along with the Department of Physics, by a stand focusing on the topic of color. Children, young people and adults had the chance to split white light into the colors of the spectrum using a spectrometer they had built themselves, and then to produce white light again from the three primary colors – green, red and blue – using a gyroscope. Also very popular were the laser chess and polarizing films. By sticking pieces of tape all over these films at random, you can generate some quite amazing color effects.

Many visitors showed their interest at the SNI booth.

SNI Annual Event

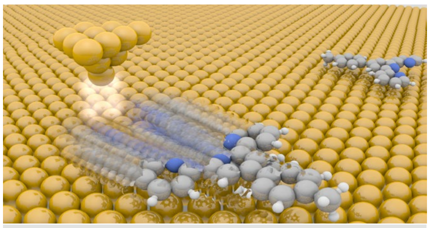
In September 2016, SNI members met for their third annual conference in Lenzerheide, where the 80 or so participants were treated to a diverse mixture of lectures and posters to encourage scientific exchange. Once again, the speakers succeeded in giving the audience an insight into their very different research topics, no matter whether these were related to questions in physics, chemistry or biology. “Presenting very specialized scientific topics to an interdisciplinary audience is always a major challenge,” the SNI’s director, Christian Schönenberger, writes in his foreword.

This year, Arne Barfuss, an SNI doctoral student in Professor Patrick Maletinsky’s group, coped with the challenge particularly well, winning the prize for the best lecture. Jan Oberbeck, an SNI doctoral student from Michel Calame’s group, won over the audience with his poster, for which he picked up a prize. Tomaz Einfalt, a doctoral student in Professor Cornelia Palivan’s group, also received an award for his hard work in support of the SNI’s outreach activities. This is the first year in which this outreach award has been presented. It is bestowed on those undergraduates or doctoral students who make a particular effort to get involved in fairs, exhibitions or laboratory tours.

Arne Barfuss won the Best Talk Award. Jan Overbeck won over the audience with his poster.

SNI on YouTube

At top speed around the bend



Currently, the Swiss Nano-Dragster holds the speed record.

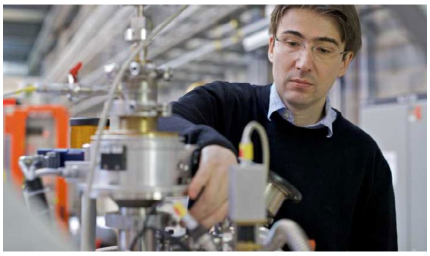
Some of Professor Ernst Meyer’s colleagues are taking part in the world’s first international nanocar race. It involves steering individual molecules along a tiny race track only 100 nanometers long. The two drivers on the Meyer team, Dr Rémy Pawlak and Tobias Meier, are currently the course record-holders, at 20 nanometers an hour. The SNI recently produced a short video clip describing the project.
https://www.youtube.com/watch?v=2YlKcl1QbAQ

Nanocontainers to treat arteriosclerosis

Professor Bert Müller (SNI member, University of Basel), Dr Till Saxer (Geneva University Hospitals) and Professor Andreas Zumbühl (University of Fribourg) are developing tiny capsules for targeted delivery of drugs to precisely where they are needed in the heart. The background is explained in a YouTube video from the Swiss National Science Foundation (www.youtube.com/watch?v=jM02xdUFv24).

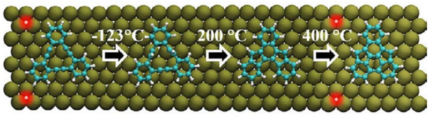
Media releases and uni news from SNI members

Paul Scherrer Institute, 04.10.2016. Physicists at the PSI's large-scale research facilities are thinking beyond the Nobel Prize theories



This year's Nobel Prize for Physics goes to David Thouless, Duncan Haldane, and Michael Kosterlitz for their investigations of topological phases and phase transitions in matter. This could have practical relevance one day for novel materials, for data storage, and for quantum computers. The Academy also cited, in its background report, experiments carried out by Michel Kenzelmann, who today is a laboratory head at the PSI. He and other researchers at the PSI continue to do experiments based on the theories that now have been honoured with the Nobel Prize.

University of Basel, 13.09.2016. On-Surface Chemistry Leads to Novel Products



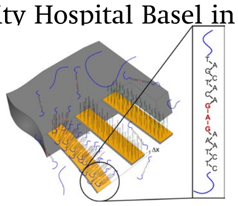
On-surface chemical reactions can lead to novel chemical compounds not yet synthesized by solution chemistry. The first-step, second-step, and third-step products can be analyzed in detail using a high-resolution atomic force microscope, as demonstrated in Nature Communications by scientists from the Swiss Nanoscience Institute and the Department of Physics at Basel University and their colleagues from Japan and Finland.

University of Basel, 06.09.2016. Christoph Gerber received the Kavli Prize

This week, Christoph Gerber of the Swiss Nanoscience Institute and the Department of Physics at the University of Basel received the Kavli Prize in Nanoscience. He was honoured together with Gerd Binnig and Calvin Quate for the development of the first atomic force microscope 30 years ago.

University of Basel, 06.09.2016. Nanotechnology Supports Treatment of Malignant Melanoma

Changes in the genetic make-up of tissue samples can be detected quickly and easily using a new method based on nanotechnology. This report researchers from the Swiss Nanoscience Institute, the University of Basel and the University Hospital Basel in first clinical tests with genetic mutations in patients with malignant melanoma. The journal Nano Letters has published the study.



University of Basel, 29.08.2016. Bringing artificial enzymes closer to nature

Scientists at the University of Basel, ETH Zurich in Basel, and NCCR Molecular Systems Engineering have developed an artificial metalloenzyme that catalyses a reaction inside of cells without equivalent in nature. This could be a prime example for creating new non-natural metabolic pathways inside living cells, as reported today in Nature.

University of Basel, 17.08.2016. Researchers Watch Catalysts at Work

Physicists at the University of Basel have succeeded in watching a silver catalyst at work for the first time with the aid of an atomic force microscope. The observations made during an Ullmann reaction have allowed the researchers to calculate the energy turnover and, potentially, to optimize the catalysis. The study, which was performed with experts from Japan and Iran, has been published in the scientific journal «Small».

University of Basel, 03.08.2016. Better Contrast Agents Based on Nanoparticles

Scientists at the University of Basel have developed nanoparticles which can serve as efficient contrast agents for magnetic resonance imaging. This new type of nanoparticles produce around ten times more contrast than the actual contrast agents and are responsive to specific environments. The journal Chemical Communications has published these results.

University of Basel, 26.07.2016. A new Type of Quantum Bit
In a quantum computer, quantum states form the smallest information units and replace the binary code used by today's computers. Until now, these so-called qubits were typically created in a semiconductor using individual electrons, but these were vulnerable to dephasing. Now, an international team of researchers led by physicists from the University of Basel has succeeded in using a missing electron to create a qubit. The team reported its findings in the journal Nature Materials.

You can find full texts of the media releases at: www.nanoscience.ch/nccr/media/recent_press_releases.
Media coverage based on the releases can be found at www.nanoscience.ch/nccr/media/in_the_media.

Your feedback is important

Please send information for SNI update and feedback to: c.moeller@unibas.ch.