

CINSaT

Center for
Interdisciplinary Nanostructure
Science and Technology

Newsletter No. 8 (June 2020)

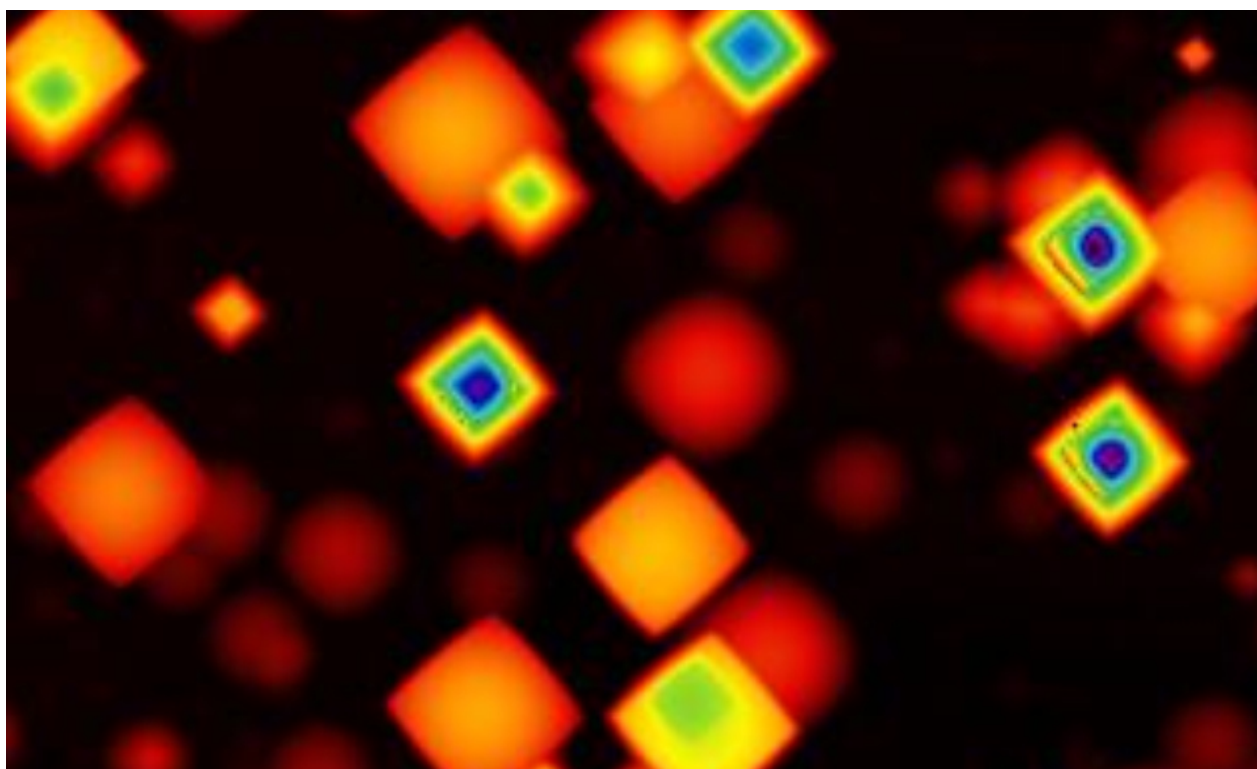


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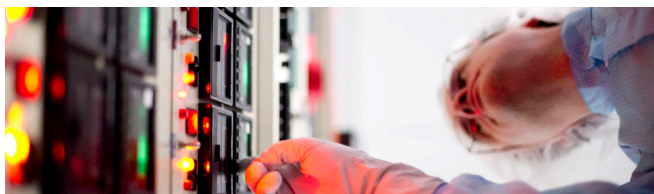
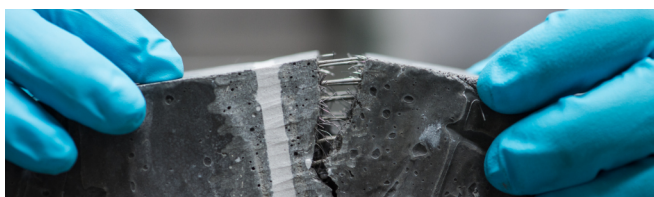
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Cover image

Julia Heupel (Techn. Physics)

White light interferometer measurement featuring flat and pyramidal monocrystalline diamond structures

Preface

Welcome to the first newsletter in 2020. Thanks again to all the article writers contributing to this issue with their stories about their exciting research results and presentations of new projects. I would like to take the opportunity to encourage all the CINSaT members to utilize this platform for the communication and visualization of their research for students, colleagues and the interested public.



This issue starts with some general information from the management. There is not much news, but there are important ones: The scientific advisory board meeting was a great success and after discussion with the presidium and the submission of the extension application we can now announce that the centre has been prolonged for another 5 years.

Since Corona has had and continues to have an influence on all areas of daily life, there is nothing new to report from the students this time. However, we are pleased to have four research highlights at once: a collaboration between Technion and University of Kassel developed and demonstrated a new approach for incorporation of dense nanometer-thin layers of NV centers in diamond for advanced quantum sensing. A cooperation project between Prof. Ehresmann and Institute of Molecular Physics of the Polish Academy of Sciences in Poznan shows that we must change our perspective on domains and domain walls when dealing with rare-earth-transition-metal ferrimagnets. The group of Prof. Schaffrath reports about the thrilling option that urmylation by Urm1 might rather be not-ubiquitin-like and functions as a sulfur transfer pathway. As a final contribution to this section, Priv.-Doz. Dr. Benyoucef reports on a special issue on Photonic Quantum technologies, for which he was leading guest editor.

In the next section, Prof. Hillmer reports about the successful completion of the BMBF project “Nanoscale” in which micromirror arrays helped with efficient energy and CO₂ savings, but could also find application in other technological fields. Additionally, The German Research Foundation (DFG) founded a three-year research grant to Prof. Dr. Monika Stengl (Neuroethology/Animal Physiology Group, University of Kassel) and Priv.-Doz. Dr. Susanne Neupert (Young Research group: Single cell analysis within neuronal networks, University of Kassel) for a new research project on “Circadian clock of the Madeira cockroach”.

CINSaT also welcomes a new member – Prof. Dr.-Ing. Hans-Peter Heim – who introduces his group and working area.

In addition, two PhD students from the Popov research group received poster prizes, for which CINSaT would like to congratulate them.

Finally, a report on the spring colloquium, which was a complete success despite Corona, is given. This year, new formats such as poster flash sessions and a kind of “science speed dating” were incorporated into the programme and were very well received by the participants. The interactions between different disciplines and groups was increased and we are really looking forward to the new ideas and projects that will result from this.

You should also take a look at the announcements and of course do not miss nano art.

Enjoy the reading of this issue and stay healthy!



General

Latest information from the CINSaT Management

Here we report briefly about major issues from the CINSaT committees any major discussion results in their meetings.

(a) Steering Committee

Since the last newsletter we had two meetings, one on 29th of January and one virtual on 28th of May. Following issues can be reported:

- The Scientific Advisory Board Meeting took place on 18th of December 2019 and was a great success. The report from the scientific advisory board is quite positive. The meeting also provided some suggestions for the future.
- There was an informal meeting with the Presidium about the prolongation of the center on 4th of March
- Decision P/23 prolongs the Centre for a further five years. This includes some targets to be achieved and a commitment to a 50% secretariat for three years.
- In cooperation with the working group macromolecular chemistry and molecular materials, the CINSaT is acquiring a rheometer

(b) Research Coordination Committee

The Research Coordination Committee helped intensively in the preparation of the Scientific Advisory Board meeting and contributed to its success.

The committee also supported the management in preparing for the spring colloquium and implemented some ideas for a more interactive format.

(c) Member Meeting

Since the last issue of the newsletter, no member meeting had been held. The next member meeting is scheduled for 9th of July 2020. Nevertheless there is a little to report:

- The application of Prof. Dr.-Ing. Hans-Peter Heim was approved by the Presidium and he is now a full member
- Prof. Dr.-Ing. Stefan Böhm applied for a full CINSaT membership. A date for his introductory talk will be announced soon.

Research Highlights

Novel ultra localized and dense nitrogen delta-doping in diamond for advanced quantum sensing

A collaboration between Technion – Israel Institute of Technology and University of Kassel developed and demonstrated a new approach for incorporation of dense nanometer-thin layers of NV centers in diamond

The negatively charged nitrogen-vacancy (NV) color center in diamond is an important system for emergent quantum technologies and sensing at room temperature. The most routinely reported methods for creating large ensembles of NVs with controlled and localized depth are low-energy nitrogen implantation in diamond and nitrogen incorporation from a precursor gas (N_2) introduced for a short period of time during the chemical vapor deposition (CVD) of diamond. The low-energy implantation method suffers from damage to the diamond lattice in the NV vicinity which adversely hinders the NV spin coherence time and also from localization broadening due to straggling and channeling effects. On the other hand, the introduction of nitrogen during the CVD growth, which is commonly referred to as nitrogen delta-doping technique, usually results in relatively low nitrogen incorporation within the layer (ca. 10^{16} cm^{-3}) due to inefficient activation of the N_2 precursor and its low sticking probability. Furthermore, this technique suffers from low N to NV conversion efficiency as well as from growth instability and nitrogen contamination in the chamber after the nitrogen injection.

In our work recently published in **Nano Letters** we demonstrated a new approach for NV patterning in diamond achieving a deterministic, nanometer-thin, dense delta-doped layer of negatively charged NV centers in diamond. A pure nitridation stage using microwave plasma and a subsequent *in-situ* diamond overgrowth were employed for this purpose. The highest reported nitrogen concentration in a delta-doped layer ($1.8 \times 10^{20} \text{ cm}^{-3}$) was presented while maintaining the pristine diamond crystal quality. Applying a high-precision depth profiling using time-of-flight secondary ion mass spectroscopy (TOF-SIMS), energy dispersive X-ray spectroscopy (EDS) and transmission electron microscopy (TEM) a nanometer width of the nitrogen delta layer ($< 3 \text{ nm}$) was revealed. At the same time, the epitaxial quality of the overgrown diamond was demonstrated by high resolution TEM and scanning TEM. The conducted optical confocal depth scans for collecting the room-temperature photoluminescence (PL) showed a clear signature of the NV delta-doped layer separated from the diamond background PL signal by almost 2 orders of magnitude. The optically detected magnetic resonance (ODMR) spectra acquired without and with an external $<100>$ -oriented magnetic field exhibited a large ODMR contrast and ca. 2 MHz line width.

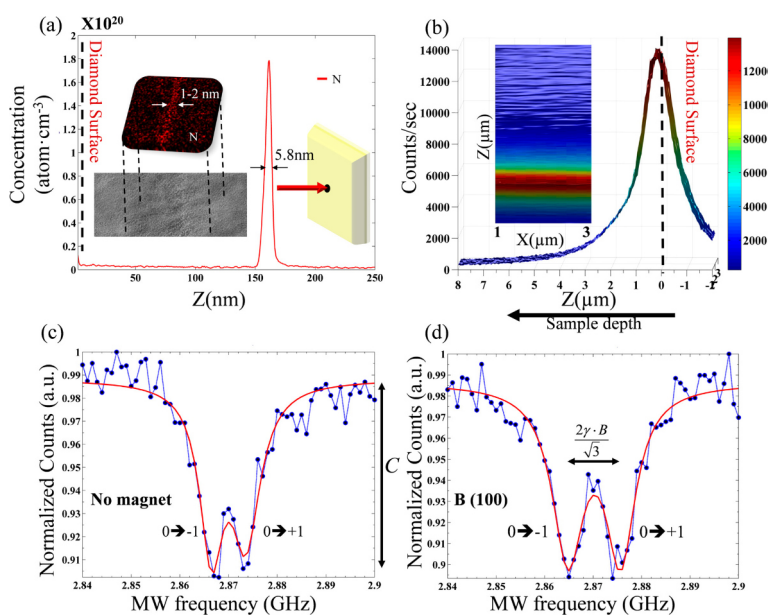


Figure 1: (a) SIMS profile of the nitrogen delta-doped layer in a single crystal diamond. Inset: TEM (gray) and EDS (red and black) measurements of the nitrogen delta-doped layer. (b) NV PL depth scan in confocal configuration, complementing the SIMS profile with a diffraction-limited NV delta layer signature centered at a precise depth. (c, d) CW ODMR spectra acquired without and with an external $<100>$ -oriented magnetic field.

The ability to generate multi-delta layers comprised of NVs with deterministic depth localization was also demonstrated by the fabrication of two delta-doped NV layers separated by 3 μm in the crystalline diamond. We further employed this delta-doping technique on high-quality diamond nanostructures fabricated by a combined top-down & bottom-up approach for realization of topographic NV patterning in order to enhance the sensing and

hyperpolarization capabilities of NV-based devices. This can increase substantially the interaction cross-section between the NV ensembles and molecules, spins or nanophotonic elements such as plasmonics in their vicinity, which can pave the way towards highly sensitive NV-based nano-magnetometers.

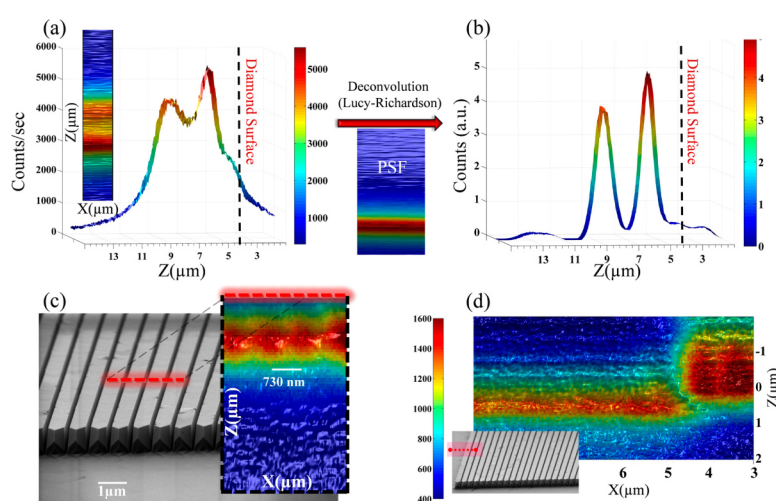


Figure 2: (a) PL depth scan acquired in confocal configuration of a double-delta layer of high-density NV concentration embedded in diamond. (b) The deconvolved PL spectrum as a function of the depth based on the PSF acquired from a single NV delta layer in diamond combined with a maximum likelihood algorithm (Lucy-Richardson). (c) SEM image of the high-quality diamond grating and the NV delta-doping PL confocal scan. Inset: Correlation between the PL modulation along the grating cross-section and the grating pitch of 730 nm. (d) PL confocal scan in the XZ plane of the topographic NV delta-doped layer along the grating edge interface.

Further Information

Tzach Jaffe, Mohammed Attrash, Mohan Kumar Kuntumalla, Roza Akhvlediani, Shaul Michaelson, Lior Gal, Nina Felgen, Miri Fischer, Johann Peter Reithmaier, Cyril Popov, Alon Hoffman, and Meir Orenstein, *Nano Letters* (2020)

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Dr. Tzach Jaffe

phone: +972 - 54 - 2883530

e-mail: tzahifa@gmail.com



Dr. Nina Felgen

phone: +49 561 804 - 4384

e-mail: felgen@cinsat.uni-kassel.de



apl. Prof. Dr. Cyril Popov

phone: +49 561 804 - 4205

fax: +49 561 804 - 4136

e-mail: popov@ina.uni-kassel.de

Artificial Magnetic Domains Without Domain Walls

Since the discovery of magnetic domains as regions within a magnetic material in which the magnetization shows a uniform direction, physicists have treated the transition between these domains as domain walls, where magnetic moments have to reorient causing an additional exchange energy contribution. Recent results from a cooperation project between the University of Kassel and the Institute of Molecular Physics of the Polish Academy of Sciences in Poznan show that we must change our perspective on domains and domain walls when dealing with rare-earth–transition-metal ferrimagnets.

For more than a decade, the two groups have collaborated in the field of magnetic thin films and the effects of light ion bombardment on their magnetic characteristics. Throughout the recent collaborative work, it was found that thin films consisting of rare-earth and transition metals known to exhibit ferrimagnetic characteristics, can be magnetically modified via the bombardment with keV He⁺ ions. Due to the layering of the materials, the two magnetic subsystems with opposing sign create a ferrimagnetic system in which one of the both materials dominates over the other so that a net magnetization remains.

When treating the layers with a perpendicular magnetic anisotropy in which originally the rare-earth (RE, here Tb) subsystem dominated in magnetization with increasing ion doses, the Tb contribution to the magnetization was observed to decrease such that above a certain ion dose the transition metal (TM, here Co) starts to dominate over the rare-earth. The reduced Tb contribution is related to its preferential oxidation compared to Co when treated with ions as observed in secondary ion mass spectroscopy (SIMS) measurements. By the different influence of the ion bombardment on the element's relative contribution to the properties of the ferrimagnet it is possible to pattern the ferrimagnetic film into domains with rare-earth dominance right

next to domains with transition metal dominance by ion bombardment through photoresist masks.

Thus, a two-dimensional lattice of Co dominated (TM⁺) areas with a smaller switching field than the protected RE⁺ matrix was fabricated. In the presence of a saturating field this system shows an effective mono-domain state, with a domain wall on the border between the TM⁺ and RE⁺ areas (Fig. 1a). During the magnetization reversal, first the Co⁺ areas are reverted in their effective magnetization causing an effective multi-domain state (Fig. 1b). Although in state a change of the direction of the effective magnetization is present, this alone is not a valid criterion for the presence or absence of a domain wall. Here, the right criterion shall be whether there is a rotation of the magnetic moments for each sublattice and as this is not the case, the multi-domain state appears without a domain wall on the Co⁺/Tb⁺ borders. The reorientation of the magnetic configuration corresponds to the transition between states 1-2 indicated on the hysteresis loop measured using the magneto-optical Kerr effect (Fig. 2). Note, that the signal enhancement during this transition does not describe an increased net magnetization since the technique is only sensitive to the Co sublattice.

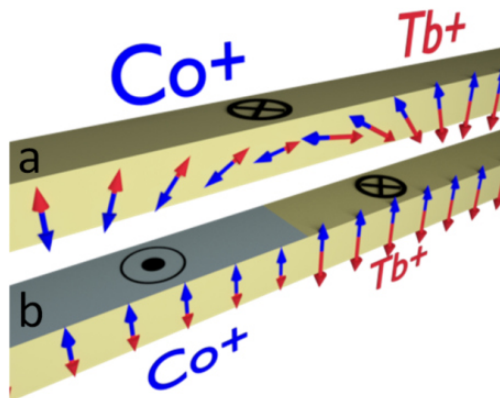


Fig.1 Magnetic configurations: effective magnetization of TM sublattice (blue arrows, Co) and RE sublattice (red arrows, Tb) in the saturated mono-domain state (a) and the remanent multi-domain (b) state.

The reverse transition from state 2 to 1 is shown in the minor loop (red dots), where a much higher magnetic field is necessary than for the transition from state 1 to 2 (minor loop in Fig. 2). This indicates that the multi-domain state without a domain wall (state 2) is energetically more stable than the mono-domain state with a domain wall (state 1). The reason for this is a deep minimum in the energy of the system due to flux closure and a corresponding magnetostatic energy reduction without an increase in energy by exchange and anisotropy terms across the walls. Consequently, the remanent state of the layered system strongly depends on the

history of the applied field, where a mono-domain state is achieved in remanence after fully saturating the sample. However, subsequent to the application of a magnetic field sufficient to transfer the sample from state 1 to 2 without saturating it reversely (state 3) the prepared ferrimagnetic arrays display a particularly stable multi-domain configuration in remanence.

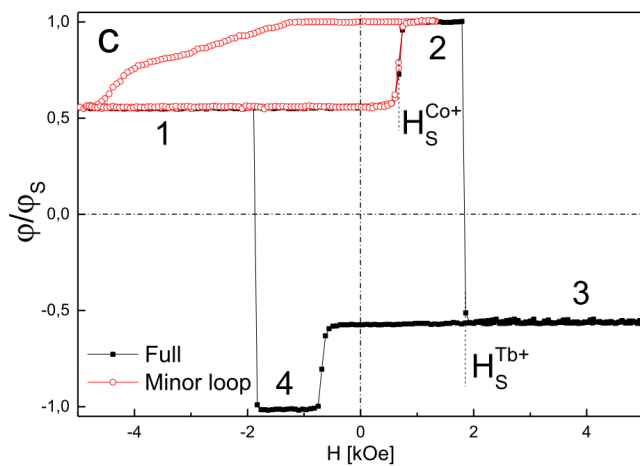


Fig. 2: Full and minor hysteresis loops of the structured ferrimagnet measured with magneto-optical Kerr effect.

References: Frąckowiak et al. (2020). Phys. Rev. Lett. 124, 047203, DOI: 10.1103/PhysRevLett.124.047203

Further information: The cooperation project is financially supported by the polish ministry of science and higher education and the DAAD.



M.Sc. Meike Reginka

phone: +49 561 804-4063

e-mail: reginka@physik.uni-kassel.de



Prof. Dr. Arno Ehresmann

phone: +49 561 804-4060

fax: +49 561 804-4150

e-mail: ehresmann@physik.uni-kassel.de

Urm1 – the (not so) ubiquitin related modifier?

The bifunctional ubiquitin-like protein Urm1 acts as a sulfur donor for tRNA thiolation and as a protein modifier in a lysine-directed conjugation also known as urmylation. This functional duality is well conserved from prokaryotes to eukaryotes.

Based on sequence similarities, eukaryotic Urm1 (ubiquitin related modifier 1) belongs to the ubiquitin-fold protein superfamily. Like certain prokaryotic members, e.g. small archaeal modifier proteins (SAMPs), it acts as a sulfur carrier protein for tRNA thiolation and is also engaged in ubiquitin-like modification of substrate proteins. Remarkably, both functions are coupled to the initial transfer of sulfur onto the C-terminus of Urm1, yielding an activated thiocarboxylate, a step different compared to the modification process by ubiquitin.

Using baker's yeast *Saccharomyces cerevisiae* as a model organism, we elucidated the covalent conjugation of Urm1 to the peroxiredoxin Ahp1 (*Redox Biol.* 2020; 30: 101438). The latter is an antioxidant protein that reduces peroxides with thiol groups of two redox-active cysteine residues and thus is critical for the protection of cells against oxidative stress. Ahp1 assembles into a homodimer by a hydrophobic dimerization interface. During peroxide reduction, the highly conserved peroxidatic cysteine becomes oxidized and undergoes a conformational change towards the resolving cysteine of the opposite subunit to form intersubunit disulfides. These bonds are subsequently reduced by the thioredoxin system restoring the peroxidatic cysteine for another catalytic cycle (Fig. 1). Interestingly, urmylation coincides with oxidative stress, but it is unclear how this modification happens on a molecular level.

We found that mutants lacking the peroxidatic cysteine and thus are unable to reduce peroxides fail to be urmylated. Intriguingly, Ahp1 urmylation can be prevented in yeast cells exposed to high organic peroxide concentrations that are assumed to cause irreversible hyperoxidation of the peroxidatic cysteine. Hence, it seems likely that oxidation, but not hyperoxidation, of the peroxidatic cysteine and the resultant conformational change are critical to prime Ahp1 for Urm1 conjugation.

Previous studies suggested that the urmylation of Ahp1 exclusively occurs at a lysine residue next to the redox-active resolving cysteine. When mutating this lysine, we found that Urm1 conjugation indeed dropped to significant low levels but, surprisingly, was not entirely abolished. Further investigation led to the identification of another lysine residue close to the redox-active cysteines functioning as an additional Urm1 acceptor site. Consequently, we consider that the lysine directed Urm1 conjugation to Ahp1 may be promiscuous and less specific than originally anticipated.

From this it is likely that the primary Urm1 transfer onto Ahp1 may involve a non-lysine site, i.e. the peroxidatic cysteine, followed by subsequent and probably random conjugation to an adjacent lysine residue.

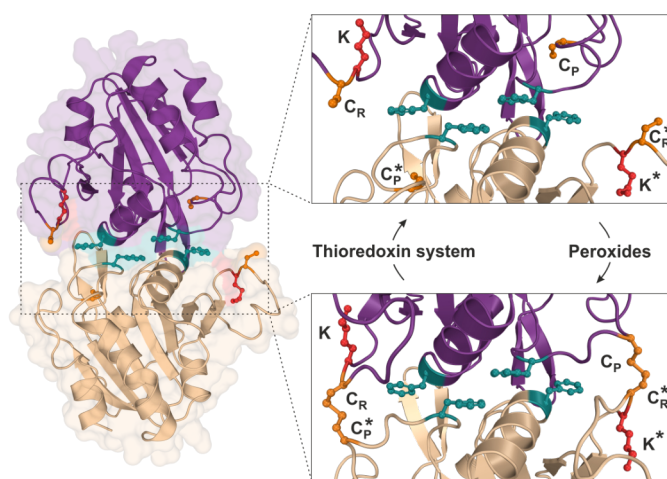


Figure 1: Ahp1 structure and catalytic cycle.

Ribbon diagram of the Ahp1 homodimer in reduced form (PDB: 4DSR) composed of two subunits (magenta & wheat). Residues critical for peroxidase activity (orange), dimerization (teal) and urmylation (red) are highlighted. The enlargement focusses on the homodimer interface. In its reduced form (top panel), the peroxidatic cysteine (C_p) is buried inside the active center. Upon oxidation by peroxides, the C_p approaches the resolving cysteine of the opposite subunit (C_R^*) leading to the formation of intersubunit disulfides (bottom panel, PDB: 4DSQ). These are subsequently reduced by the thioredoxin system. Note, next to the C_R is a lysine residue (K) located, reported to function as acceptor site for post-translational modification of Ahp1 by Urm1.

Most likely, the thiocarboxylated Urm1 will condense with the oxidized and thus accessible peroxidatic cysteine to form an acyl disulfide between Ahp1 and Urm1. Hereon, the nucleophilic attack by a nearby lysine residue will generate an isopeptide bond with Urm1 and leave the peroxidatic cysteine persulfidated (Fig. 2). Due to steric hindrance, the conjugation to Urm1 may

protect the persulfide on Ahp1 from destruction by the resolving cysteine and enables the enzyme to relay the sulfur to other proteins (transpersulfidation). This raises the thrilling option that urmylation might rather be not-ubiquitin-like and functions as a sulfur transfer pathway.

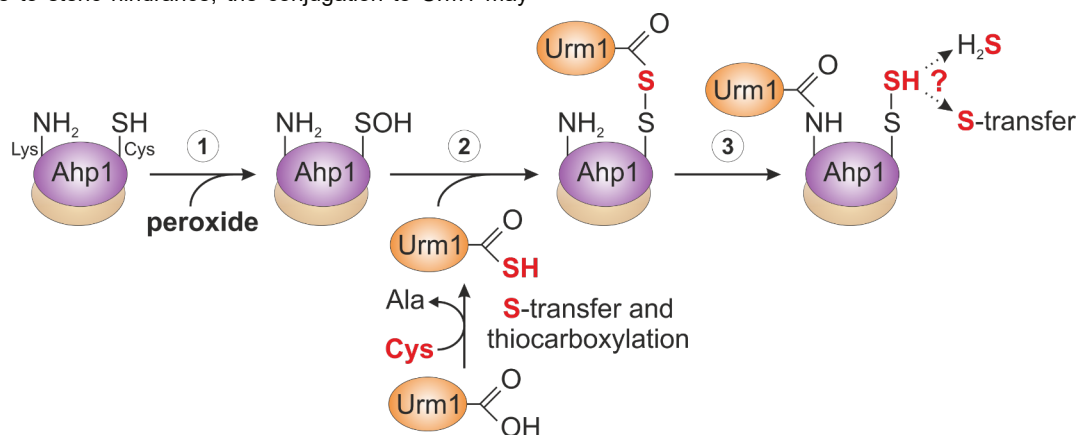


Figure 2: Proposed three-step working model for urmylation of the yeast peroxiredoxin Ahp1.

Step 1: The thiol of the peroxidatic cysteine (Ahp1-SH) is oxidized by the reaction with a peroxide to form the sulfenic acid (Ahp1-SOH) that becomes surface exposed and accessible for the reaction with Urm1. Step 2: Sulfur transfer from cysteine to Urm1 yields the activated Urm1 thiocarboxylate (Urm1-COSH). This condenses with the sulfenic acid to form an acyl disulfide (Ahp1-S-S-CO-Urm1). Step 3: The ε-amino group of a nearby lysine residue in Ahp1 (Ahp1-NH₂) can now mount a nucleophilic attack on the Urm1 carbonyl group, generating an isopeptide bond with Urm1 (Ahp1-NH-CO-Urm1) and a persulfide on the peroxidatic cysteine (Ahp1-S-SH). Possibly, Ahp1 may transfer the persulfide to other proteins or the resolving cysteine could attack the persulfide leading to intersubunit disulfide formation and hydrogen sulfide (H₂S) release. The lysine-directed urmylation might support the S-transfer by sterically preventing the latter option. For simplicity, the proposed model only involves one subunit of the Ahp1 homodimer.

Further Information

Brachmann C*, Kaduhr L*, Jüdes A*, Keerthiraju ER, West JD, Glatt S, Schaffrath R (2020) Redox requirements for ubiquitin-like urmylation of Ahp1, a 2-Cys peroxiredoxin from yeast. *Redox Biol* **30**: 101438. doi:10.1016/j.redox.2020.101438

* these authors contributed equally



M.Sc. Lars Kaduhr

phone: +49 561 804-4241
fax: +49 561 804-4337
e-mail: kaduhr@uni-kassel.de



Prof. Dr. Raffael Schaffrath

phone: +49 561 804-4175
fax: +49 561 804-4337
e-mail: schaffrath@uni-kassel.de

Research Professor Schaffrath

https://www.researchgate.net/profile/Raffael_Schaffrath

Microbiology Division Professor Schaffrath (home page)

<http://www.uni-kassel.de/fb10/de/institute/biologie/fachgebiete/mikrobiologie>

Special Issue on Photonic Quantum Technologies: Highlight

Photons are very promising resource for realizations of quantum communication and quantum computation. Bulk optics are currently not suitable for the realization of complex quantum optical schemes due to several drawbacks. The availability of sophisticated nanofabrication processes has led to an ongoing miniaturization of photonic structures. Such novel nanostructures have provided huge opportunities for physical research of novel phenomena in nanophotonic systems and quantum information applications.

To bring together experts in the field of quantum technologies, Mohamed Benyoucef (Lead Guest Editor) and other colleagues (Anthony Bennett, Stephan Götzinger, Chao-Yang Lu) have launched a **Special Issue** entitled **Photonic Quantum Technologies**, which was published in *Advanced Quantum Technologies* (2020). This Special Issue presents selective papers on photonic quantum systems from leading groups in the world. The articles represent a flavor of the cutting-edge research that is going on in this area.



The studied material systems range from molecules to semiconductor quantum emitters. A major challenge is the design of telecom photon emitters with high efficiency, good yield, spectral purity, stability and the possibility of mass manufacture.

Among the collection of articles, we have works more oriented to quantum technologies, including hybrid integration of single-photon emitters, cavity quantum electrodynamics (cavity QED) and light-matter interactions at nanoscale, on chip integration of entangled photon sources, and incorporating color centers into nanophotonic structures. Furthermore, fabrication of single-photon emission at the telecom wavelength, molecule based single-photon sources, quantum emitter-plasmonic cavity coupling, vertically coupled quantum dot (QD) systems and optomechanical coupling are also discussed.

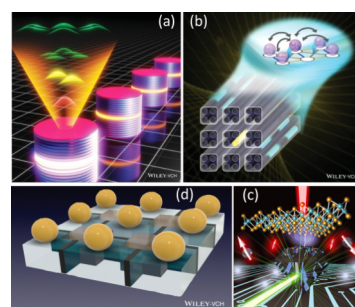


Figure: (a) **Front Cover**: a planar microcavity formed from two dielectric mirrors placed on either side of a fluorescent conjugated-polymer. (b) **Inside Front Cover**: A photonic lattice to simulate a strongly-correlated topological insulator. (c) **Inside Back Cover**: Schematic of a lattice of nonequilibrium condensates for spin interactions. (d) **Back Cover**: Diamond and two-dimensional materials.

This Special Issue provides an overview of recent exciting developments in the field of photonic quantum technologies, serving to keep researchers up-to-date with the latest progress and spurring on new concepts in this field. More detail about the selection of papers can be found in *Adv. Quantum Technol.* 2, 2000007 (2020).

Further information

Website <https://www.uni-kassel.de/forschung/ina/technische-physik/forschung/nano-optics/>

Special Issue Website:

<https://onlinelibrary.wiley.com/toc/25119044/2020/3/2>



Priv.-Doz. Dr. Mohamed Benyoucef

phone: +49 561 804 - 4553

fax: +49 561 804 - 4136

e-mail: m.benyoucef@physik.uni-kassel.de

New Projects

3D Micro- and Nanostructurization: Optical MEMS arrays for Smart Glass

Today, 3D Micro- and Nanostructures are integrated in many technical systems and have gained noticeable importance in different fields of science, economy and society. The size, shape and material compositions play a crucial role for the performance, reliability, sensitivity and functionality of the systems. The applications are already widely spread in medical technologies, sensorics, environmental technologies, analytics, energy technologies as well as data and telecommunication. The department of Technological Electronics at INA is active on this field since many years using 3D micro- and nanostructures, among others in sensorics via nanospectrometers and in energy technologies via optical MEMS¹.

NANOSCALE

The sustainable design of 'smart green buildings' has become increasingly important for limiting global warming and carbon dioxide emission reduction via efficient energy saving. The implementation of efficient daylighting strategies can considerably reduce electricity consumption in buildings, since artificial light, cooling, and heating constitute today about 40 % of the global total energy consumption in buildings and cause a third of the global total CO₂ emission. In addition, daylight instead of artificial light is of major importance for the human biorhythm, health, learning success and minimization of error susceptibility. In winter, daylight directs favorable thermal energy into the buildings. However, daylight is also accompanied by uncomfortable solar glare and reflections on display screens, both of which interfere with optimum vision. Until now, no smart glass technology can actively adapt to all requirements without significant disadvantages.

3D micro- and nano-structured mirror arrays for daylight guiding [1-3] comprise millions of electrostatically actuatable micromirrors that can guide and control light dynamically (Fig. 1). The micromirror structure is implemented by a hybrid metal multilayer system with individual thicknesses between 10 nm and 100 nm in vertical direction and mirror sizes of typically 150 × 400 μm² in lateral direction. The micromirrors are miniaturized so that the naked eye cannot identify them from a distance more than 20 cm from the array; thus, an impression of a variable-tone pane is obtained. The main advantages are (i) long lifetimes due to miniaturization, despite using mechanically mobile parts; (ii) lower power consumption than any other smart glass technologies (LCD, electrochromic); (iii) light is reflected and not absorbed as in electrochromic or LCD systems; (iv) spectrum of the sunlight is unchanged – our smart glass is color neutral; (v) feasible operation at low temperatures (unlike electrochromic systems); and (vi) invulnerable to wind, window cleaning, or any weather conditions, since the mirror array is located in the space between the window panes filled with noble gas such as Argon or Krypton.

Figure 2 displays a schematic cross section of four application scenarios: (left) displays different sun positions in the sky, (middle) the white space between the two blue glass panes is filled with insulating gases Ar or Kr and includes also the micromirror arrays visualized by strongly magnified bars, (right) a room inside a building. The four different scenarios for summer or winter as well as users present or absent are described in the figure caption. Figure 3a shows a schematic of a single mirror actuator, consisting of the flat mirror plan, the bent hinge, and a supporting post attached to the glass pane. Fig. 3b depicts a SEM including a blow-up to reveal the nanoscale layered multi-metal-system. During micromachined fabrication, the sacrificial layer is removed in wet chemical process. Due to layer stress, the uncompensated hinge region strongly bends and lifts the mirror to a vertical position.

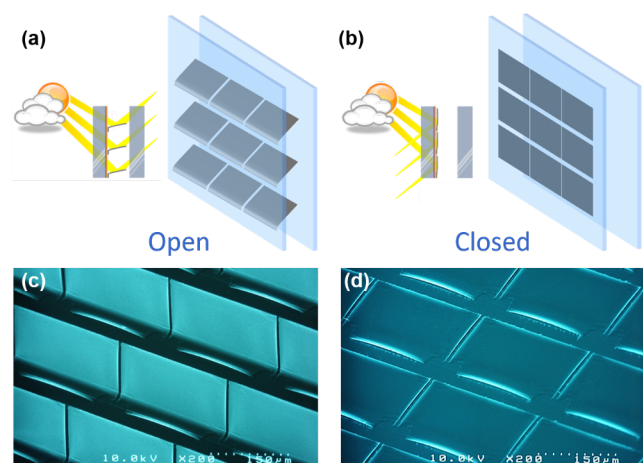


Fig. 1 Micromirrors in open and closed scenario, shown in schematics (a, b) and SEM micrographs (c, d), respectively. The smart glass pane is integrated into a double insulation glazing in Ar atmosphere and sealed by butyl.

¹Abbreviation of micro-electro-mechanical system

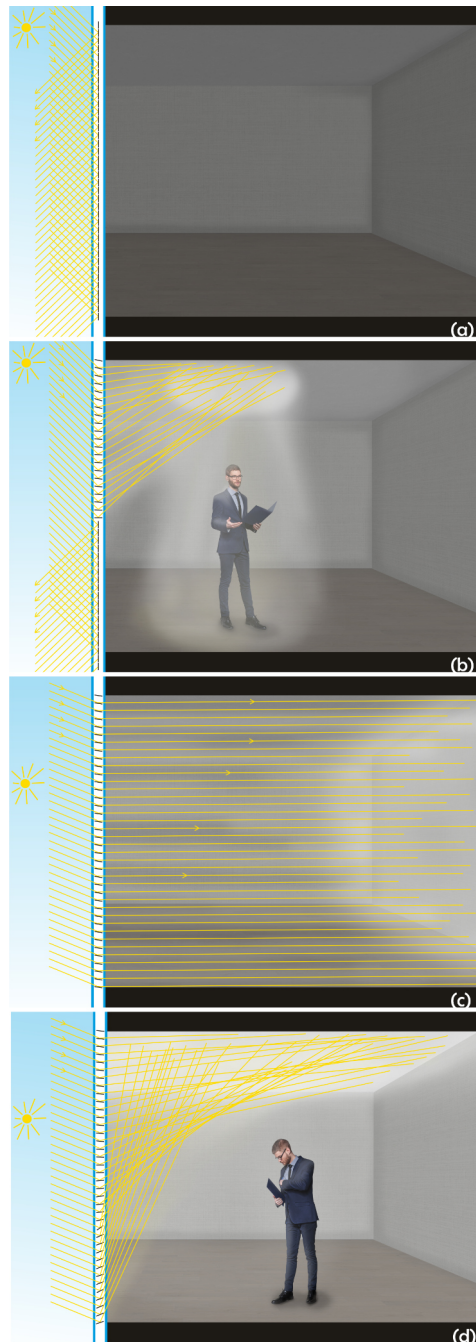


Fig. 2 Scenarios of a room with / without persons present. Schematic sun ray tracing is depicted for 4 different scenarios: (a) *Summer, absent user*: sun radiation is reflected back and the room is not heated, (b) *Summer, user present*: Since only a part of the light is reflected to the ceiling, the heating of the room is limited, (c) *Winter, absent user*: the solar infrared is completely used and heats a wall, (d) *Winter, user present*: All the visible and infrared radiation is reflected to the ceiling.

The mirror area is stress compensated, resulting in flat mirror areas. The electrostatic actuation voltage is applied between the metal mirror (dark gray in Fig. 3a) and a transparent electrode (light purple in Fig. 3a) on the pane. The transparent conductive layer is implemented either by indium tin oxide ITO, fluorine doped tin oxide FTO, or a 5 nm-thick Ag layer included in low-emissivity (low-e) coatings. The two electrodes are separated by a SiO_2 insulation layer (yellow). By changing the actuation voltage, an equilibrium in the moments of force between electrostatic attraction and elastic repulsion leads to different angles.

The 3D micro- and nanofabrication process involves optical or nanoimprint lithography, followed by deposition of dielectric materials and metals, perpendicular etching, and finally lateral under-etching to remove sacrificial resist layers [1]. The smart glazing is color neutral in comparison to other smart glass like electrochromic technologies. It is also much more robust against harsh temperatures and numerous open-closed cycles, in contrast to electrochromic technologies. The pane modules show no failure during multiple temperature cycles ($0 \rightarrow +80 \rightarrow 0 \rightarrow +80$ °C and so on) and under extreme temperature conditions between -80 °C and $+120$ °C. Typical actuation voltages of 40 V (best case 12 V) have been measured. The lowest power consumption of 0.2 mW/m^2 to keep the mirrors permanently in position is by a factor of 100 or 1000 lower compared to electrochromic or LCD technologies, respectively. Amplitude modulation response studies provided a resonance frequency of 3 kHz and a -3dB frequency of 6 kHz. Long-time reliability tests yield a preliminary lifetime estimate

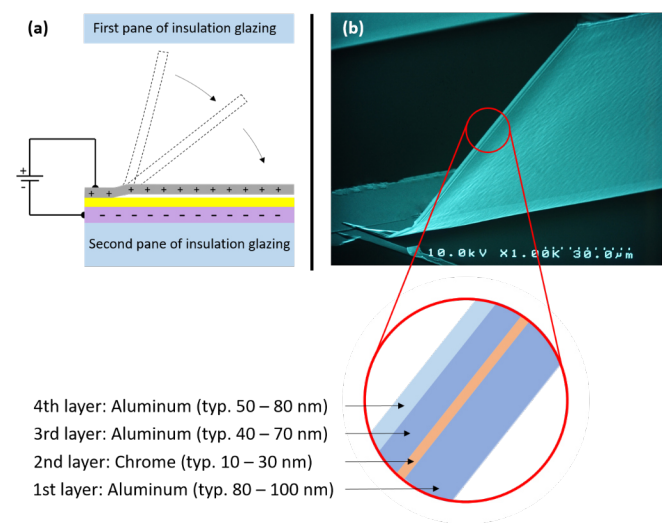


Fig. 3 (a) schematic of the electrostatic actuation of a single mirror; (b) SEM micrograph of a flat, free-standing micromirror

of beyond 50 years. Thermal measurements of a miniaturized room equipped with our smart window were performed. Five sides of the miniature room have been thermally insulated, while the smart window was located on the sixth side (micromirror arrays in Ar atmosphere inside the double isolation glazing). Thus, energy mainly leaves the room through the window via heat conduction, convection, and thermal radiation, where the latter is partly blocked by the low-e coating. A thermal white-light source (representing the sun) with adjustable position to allow different season scenarios was used. The 4 scenarios shown in Fig. 2 have been studied, demonstrating the energy saving and functionality of the smart glass. The energy required for cooling (air conditioning) in summer can be saved by thermal shielding, whereas the energy required for heating in winter can be saved by solar energy harvesting.

Additionally, a lab demonstrator of our smart window in a dollhouse is depicted in Fig. 4, consisting of four micromirror array modules (400 cm²). The micromirror arrays were installed in a modern quadruple insulation glazing filled with Ar using an industrial window module fabrication process.

Recent work on implementation of subfield addressing in the micromirror arrays enables further tailored control by segmentation of a single module into 16 addressable subfields via 4 × 4 passive matrix arrangement. These subfield modules (4 modules) were housed in a double pane insulated glazing – also using a standard industrial window module fabrication process with assistance of Energy Glas GmbH – resulting in a total of 64 addressable subfields in an active area of about 400 cm² (Fig. 5b). The illumination pattern on the ceiling and floor of a dollhouse in Fig. 5b is an example of light guiding variation and tailored ambience lighting in a room via selective actuation of subfields. The

subfield actuation is executed by applying potential difference between the 4 top and 4 bottom electrodes, as shown in the schematic diagram in Fig. 5a. With the closing and opening voltage (V_{close} , V_{open}) values known from measurement and characterization, a specific subfield can be in state of actuated (closed) or non-actuated (open), depending on the potential difference between the top and bottom electrode. Selection of different subfield combinations can be achieved for example by applying a different set of potential differences across different rows and columns, or by time multiplexing. Currently the actuation voltage is in the range of 80 V and is expected to be further reduced to 25 V with our currently ongoing design optimization.



Fig. 4 Demonstrator of a micromirror smart glazing in a dollhouse, visualizing the tailored light guiding and ambience control in a room.

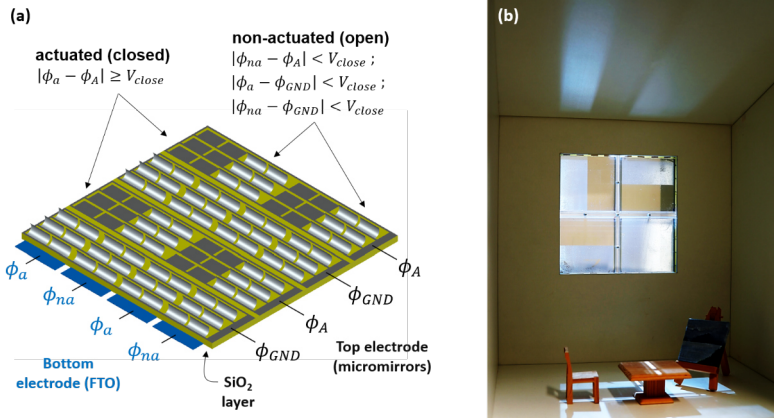


Fig. 5 (a) Schematic of 4 × 4 passive matrix arrangement of a micromirror array module, resulting in 16 addressable subfields.(b) Function demonstrator consisting of 4 subfield modules, built in a dollhouse to visualize different light guiding capability and ambience control in a room.

The passive matrix arrangement was adapted from the common addressing schemes used in visual display technology, namely the direct, passive matrix (PM), and active matrix (AM) addressing. The PM addressing scheme was selected due to its suitability with our envisioned application, as well as its advantage of having lesser connection line against direct addressing and much simpler fabrication complexity against AM addressing. Both PM and AM scheme have the same matrix arrangement of electrodes, however, AM scheme incorporates nonlinear switching elements – typically TFT – for each subfield. This has the advantage of higher contrast ratio and resolution, but at the expense of higher fabrication complexity and cost. Since the subfield requirement of our smart window application is envisioned towards large grouping of micromirror for tailored light guiding, a high resolution in the range of flat panel displays is not necessary, thus, the complex fabrication process can be spared. PM scheme is known to be more susceptible to ghosting and crosstalk phenomena, since all of the subfields in the same electrode will be partially selected during actuation. Considering the schematic shown in Fig. 5(a) as an example,

the whole electrode rows (bottom electrode) and columns (top electrode) of the selected subfields will be supplied with voltage potential, resulting in all of the subfields of these rows and column to be partially selected in the process. Nevertheless, this is more prominent in higher numbers of subfields, as indicated by Alt & Pleshko [4, 5]. Therefore, PM scheme is suited to low resolution application up to 320×240 pixels – still a far greater number as a limit for our subfield application in smart window.

The subfield addressing can be seen using the following links. In this video, the subfields are actuated one after another in increased actuation speed.

<https://hessenbox.uni-kassel.de/getlink/fi32MoYh9uUVrvi1HnLCMHxd/SF-actuation.mp4>

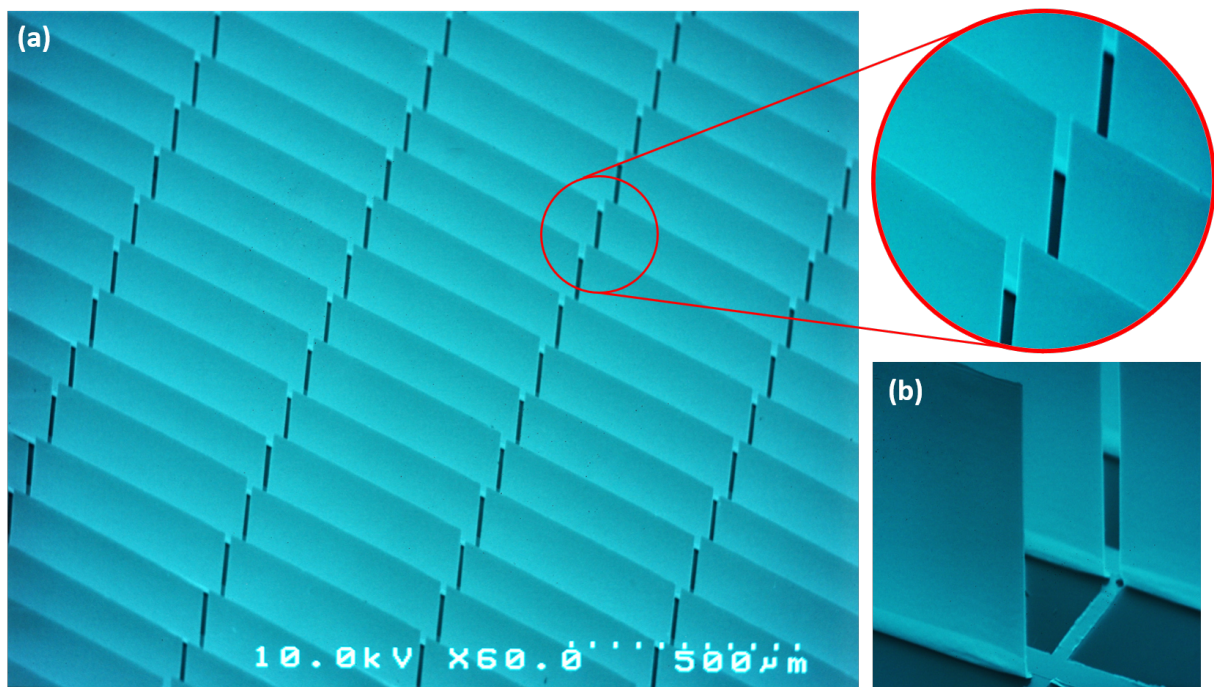


Fig. 6 (a) SEM micrograph of vertically standing, flat micromirror array with an inset of magnified area, (b) SEM micrograph of the hinge area at different angle to distinguish the vertical opening state of the micromirror.

Summary: The presented micromirror arrays (Fig. 6) for active smart windows have the following advantages: (i) much higher actuation speed and much larger operating temperature range than electrochromic systems, (ii) insensitivity to wind in contrast to external active sun blinds, (iii) low power consumption in comparison with systems based on all other concepts, (iv) no heating of the window in contrast to thermochromic, chemo-chromic, and electrochromic systems, which are based on absorption, (v) color neutrality in contrast to electrochromic technologies and (vi) the most important advantage a huge CO₂ saving potential up to 30% and an energy saving potential up to 35%, if applied in smart buildings. The energy saving results from savings in artificial lighting, air conditioning and heating caused by the novel smart glazing based on 3D micro- and nanostructures mirror arrays. The electrostatic actuation only requires a minimum in electrical energy: the low power consumption of as low as 0.2 mW/m² and the actuation voltages of as low as 12 V.

The technology has high application potential also in other fields such as: laser safety goggles, autonomous driving, endoscopy, micro-interferometry, THz point to point communication, filtering against electro-smog and STED microscopy.

The BMBF Project Nanoscale has been completed successfully end of January 2020.

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M.Sc. Mustaqim Iskhandar

phone: +49 561 804-4240

e-mail: iskhandar@student.uni-kassel.de



M.Sc. Md Kamrul Hasan

phone: +49 561 804-4396

e-mail: kamrul.hasan@student.uni-kassel.de



Dipl. NanoSc. Carsten Woidt

phone: +49 561 804-4240

e-mail: woidt@ina.uni-kassel.de



Prof. Dr. Hartmut Hillmer

phone: +49 561 804-4485

e-mail: hillmer@ina.uni-kassel.de

DFG Project: The circadian clock of the Madeira cockroach

The German Research Foundation (DFG) funded a three-year research grant to Prof. Dr. Monika Stengl (Neuroethology/Animal Physiology Group, University of Kassel) and Priv.-Doz. Dr. Susanne Neupert (Young Research group: Single cell analysis within neuronal networks, University of Kassel) for a new research project on “Circadian clock of the Madeira cockroach”.

Neural circuits use a combination of classical fast neurotransmitters and modulatory neuropeptides to communicate. Neuropeptide signaling is still far from being understood. The clock circuit uses an abundant amount of neuropeptides to regulate the circadian timing of physiology and behavior. In this project we focus on the physiological analysis of neuropeptide-dependent control of sleep wake rhythms at the circadian clock’s cellular level in an insect.

The nocturnal Madeira cockroach is an established model in chronobiology, especially suited to analysis on the cellular level. Its main circadian clock is the accessory medulla (AME) that shares core properties in structure and function with the mammalian circadian pacemaker center, the nucleus suprachiasmaticus (SCN). Both clocks release specific neuroactive compounds such as neuropeptides at specific times of the day to time rhythms in physiology and behavior. However, in contrast to the SCN, the cockroach clock lies easily accessible at the surface of the brain consisting of around 240 neurons (Fig. 1A), as opposed to ~20,000 clock neurons in the mouse SCN. Furthermore, it contains larger, individually identifiable neurons which allows for reproducible electrophysiological, and neurochemical analysis. Additionally, single identified cockroach clock neurons can be physiologically characterized using single

cell MALDI-TOF mass spectrometry, transcriptomic, and RNAi analysis. Therefore, we choose the ideally suited cockroach clock to study neuropeptide function in the control of sleep-wake rhythms at the neuronal network level as well as at the level of single cells.

Our preliminary studies suggested that peaks of neuropeptide release occur every 6 h at dusk and dawn, at the middle of day and night, activating neuropeptide-dependent neuronal networks, one promoting sleep, the other promoting activity. However, it is still unknown which neuropeptides are released at what time over the course of the 24 h daily cycle (Fig 1B). In our new project, we focus our analysis on the clock’s control of rest-activity cycles via its neuropeptide pigment-dispersing factor (PDF).

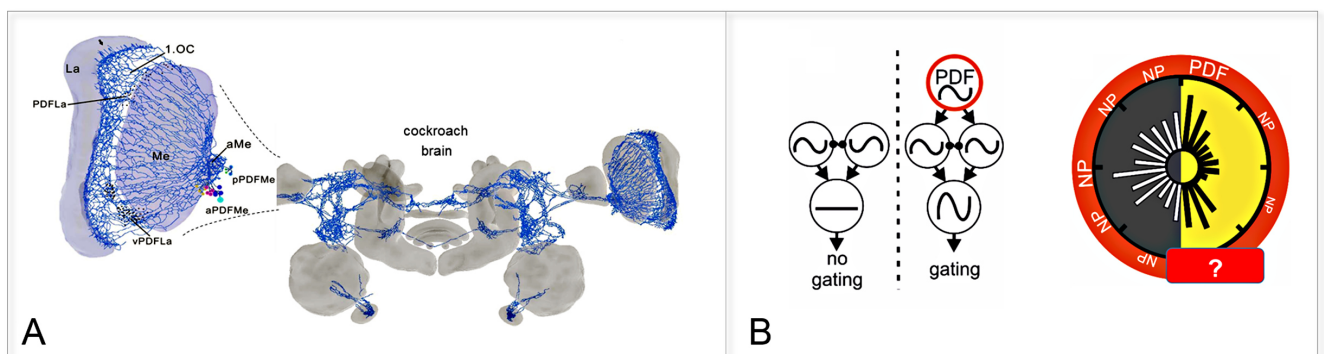


Fig. 1. Distribution and functional relevance of neuropeptide signaling in the cockroach circadian clock with focus on PDF clock neurons that control sleep-wake cycles. (A) Skeleton graph of 3D reconstruction of the network of PDF-immunoreactive (-ir) neurons embedded into the cockroach standard brain (frontal view, modified from Wei *et al.* 2010). (B) Our neuropeptidergic clock model. Round circles (to the left) symbolize clock neurons that express oscillations of their membrane potential. PDF phase-synchronizes their potential oscillations, thereby gating information flow to the postsynaptic neuron. The clock releases specific neuropeptides (NPs) daytime-dependently, gating physiological and behavioral rhythms.

We have preliminary evidence that the circadian clock rhythmically releases the neuropeptide PDF during the light phase. Thus, during the day PDF release activates ipsilateral sleep-promoting brain circuits and suppresses at the same time activity promoting circuits. At dusk, another putative neuropeptide is released that will antagonize PDF which has to be identified in our project. With single cell transcriptomics, Ca²⁺ imaging, ELISA, multiple-label immunocytochemistry, and intracellular recordings we will identify PDF-sensitive sleep- or activity promoting cells. We will determine their morphology, their neuropeptide

equipment, and their neuropeptide/neurotransmitter receptors and implement the data in our standard cockroach brain. Furthermore, in collaboration with the Garcia lab, we will integrate the data in a computable model containing PDF neurons including their physiology as well as their specific branching patterns to identify rest-activity controlling circadian clock circuits in the insect brain. With this comparative approach we expect to identify general schemes of neuropeptide-dependent information encoding and timing invented early in evolution that appear to also work in our brains.

Further information

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Priv.-Doz. Dr. Susanne Neupert

phone: +49 561 804-4781

fax: +49 561 804-4146

e-mail: sneupert@uni-kassel.de



Prof. Dr. Monika Stengl

phone: +49 561 804-4564

fax: +49 561 804-4146

e-mail: stengl@uni-kassel.de

Animalphysiology group (homepage)

<https://www.uni-kassel.de/fb10/institute/biologie/fachgebiete/tierphysiologie>

New Members

Prof. Dr.-Ing. Hans-Peter Heim

Prof. Dr.-Ing. Hans-Peter Heim studied at the university of Paderborn. After his dissertation he worked as a temporary director of the Institute of Polymer Technology (KTP) in Paderborn from 2004 – 2007. The focus of his research work was the development and the usability of a gas injection technology for injection molding of plastic materials.

In January 2008 he moved to Kassel to become head of the "Plastics Technology" department in the Institute for Materials Technology (IfW). Since its founding in 2014 he is also the head of the Plastics Technology Application Center (Unipace) in Kassel. The institute as well as the Application Center belong to the Department of Mechanical Engineering of the University of Kassel.

His topics within the field of plastics technology include material development and composites (e.g. development of biobased polymer blends, fiber reinforcement and wood veneer composites), plastics processing technologies (e.g. multi-component injection molding, technologies for surface treatments and silicone processing), function integration (such as electroactive and electrochromic polymers and quantum dot modified films).

His team consists of 20 scientific and 12 technical employees and several student assistants. They work on the improvement and further development of plastics and material composites. In this context, special attention is focused on environmental aspect of polymers and their processing as well as recycling technologies. The scientists research on plastics for a wide range of applications, such as medical technologies, the automotive and electronics industry as well as office and outdoor supplies. In this context they use bio-based polymers, bio-based filling materials

such as wood and cellulose-fibers and bio-based additives as bonding agents or flame retardants. Additionally, they try to find innovative solutions such as lightweight hybrid materials in combination with LSR foam and electrochromic or electroactive devices.

Future research will focus, for example, on the aging and long-term properties of various bioplastics and multi-component 3D printing with surface modification.



Photo: Paavo Bläfield



Prof. Dr.-Ing. Hans-Peter Heim

phone: +49 561 804 - 3670

fax: +49 561 804 - 3672

e-mail: heim@uni-kassel.de

Awards

Two Brilliant Poster Awards for Daniel Merker and Alexander Schmidt

Alexander Schmidt and Daniel Merker from the Technological Physics, Institute of Nanostructure Technologies and Analytics (INA), CINSaT received Brilliant Poster Prizes at the Hasselt Diamond Workshop, Belgium, which took place between 10th and 13th March 2020. The 25th edition of the event brought again together leading scientists from many countries working in the field of Diamond Science and Technology.

Alexander Schmidt presented the poster “Diamond AFM tips for the integration of NV centers” with co-authors C. Osterkamp, F. Jelezko (Institute for Quantum Optics, Ulm University), J.P. Reithmaier, C. Popov (INA, University of Kassel) summarizing the results of the VW Foundation project “Quantum Coins and Nano Sensors” coordinated by Prof. Kilian Singer, CINSaT. In his poster „UNCD-based biosensor for neuropeptide and neurotransmitter detection“ with authors D. Merker, D. Bertinetti, K. Schröder, M. Stengl, F. Herberg, J. P. Reithmaier, C. Popov, Daniel Merker showed the current results of the project “Biological Clocks”, realized in cooperation with the groups of Prof. Monika Stengl and Prof. Friedrich Herberg, both CINSaT members.

The jury composed of professors from Université de Versailles Saint-Quentin-en-Yvelines, France and University of Oxford, U.K. highly evaluated the posters of Mr. Schmidt and Mr. Merker, as well as their presentations and discussions during the poster session of the event. The prizes were given to the awardees by the Conference Chair Prof. Anke Krüger, University of Würzburg, during the Conference Dinner.



From left to right: Daniel Merker, Cyril Popov and Alexander Schmidt



Group photo of the awardees and the committee

Latest Reports

Spring Colloquium 2020

CINsaT uses internal retreat to sharpen its scientific focus and intensify internal exchange.

As in previous years, the CINsaT invited to an internal retreat at the Ahorn Berghotel in Friedrichroda from 5-6 March 2020. The annual colloquium is an important communication platform not only for current research work within the focal points, it also serves to discuss the further development of the focal points and to plan coordinated joint projects. An important contribution to this is made by the doctoral candidates in the individual fields, whose contributions fill the meeting with life and thus help to create a broad-based platform for discussion. The fact that this concept has a positive effect on the development of the scientific centre was confirmed by the almost 80 participants.

After the warm welcome and opening by the CINsaT spokesperson, Prof. Dr. Johann Peter Reithmaier, the management gave an overview not only of current developments within the center, but also of the course of the colloquium. This year, a new format was introduced to further encourage interaction between the participants: in addition to the poster, the respective authors had prepared a single presentation slide. In the so-called "Poster Flash Sessions" they had the opportunity to draw attention to themselves and their research topic within one minute.



The hike through the forest following the presentation sessions of the first day, in bright sunshine and relatively mild temperatures, was welcomed by all and used for further exchange and getting to know each other.

The evening poster session in the Great Hall was a successful conclusion of the first day. The numerous research activities of the CINSaT were presented in an impressive and creative way on a total of 52 posters and offered an excellent basis for further discussions. Like last year, the end was deliberately left open, so that sufficient time was available for exchange and planning future collaborations.

The second day started with the second block of the lecture sessions. This year again, all contributions were of high quality and impressively demonstrated the success of interdisciplinary collaboration within the center.

This year's colloquium ended with the individual focal point sessions. In smaller groups ideas could be exchanged within the focal points and plans for further cooperation could be forged. In order to loosen up the format, the respective focus speakers became creative and partly carried out a "Science Speed Dating".

The new formats were very well appreciated and the new location for the poster session was also well liked by all participants, making it a successful event again this year.



Announcement

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► Science matters more than ever!

The current Covid19-pandemichighlights the crucial demand for effective and professional science communication. Scientists now increasingly need to address the public and provide council to political institutions to aid in steering society through the crisis and beyond:

With scientific processes directly affecting daily life, citizens without scientific background increasingly demand to receive information on complex topics in accessible and audience friendly terms. This poses a challenge for many scientists.

The need for scientists to prepare for such tasks by developing a sound level of skill in science communication becomes apparent: To strengthen the general public's trust in the work of scientists as well as easing communication among scientists, skill training is crucial – not only during an immediate crisis.

Writing, public speaking or visual communication – the Communication School will introduce you to all essential ways of communication.

The Communication School will support you in developing your skill in science communication and help you become a communicator yourself. The one week further education program offers you the chance to compose your own curriculum of three workshops from a selection of nine.

Different formats and initiatives of science communication will be presented during the daily get-togethers, where will also be room for exchange between participants. After one week of training, the methods developed during the workshop can be put to a test and your research can be presented at the closing event, *Science Night*.

► Choice of three out of nine offered workshops (2× two-day, 1× single-day)

Monday + Tuesday 21. + 22.09.2020	Wednesday 23.09.2020	Thursday + Friday 24. + 25.09.2020
Workshop 1 Verständlich schreiben Martin Roos (NaWik) or Talk like TED (E) Robert Kötter (21Skills) or Communication Skills for Scientists – Storytelling and Message Distilling (E) Dr. Daniel Angerhausen (Explainables)	Workshop 2 Wissenschaftskommunikation in Förderanträgen Dr. Sascha Vogel (ScienceBirds) or Authentic Branding, Professional Networking & Marketing for Scientists (E) Dr. Daniel Angerhausen (Explainables) or The Powerful Voice: Speaking with dynamism (E) Francesca Carlin	Workshop 3 Wissenschaft zum Anfassen Dr. Sascha Vogel (ScienceBirds) or Video Workshop (E) Ingo Knopf (NaWik) or Science Communication 2.0 (E) Robert Kötter (21Skills)

i Target group: PhD candidates, post docs, Masters students in the final phase of their studies

Duration: Monday – Friday

Curriculum:

- Free choice of three workshops out of nine (2 two-day-workshops, 1 single-day-workshop).
- Presentation of results at closing event.

Participation fee:

- 150,-€ (University of Kassel early career researchers)
- 1250,-€ (Non-Members)

Any questions? Contact us!

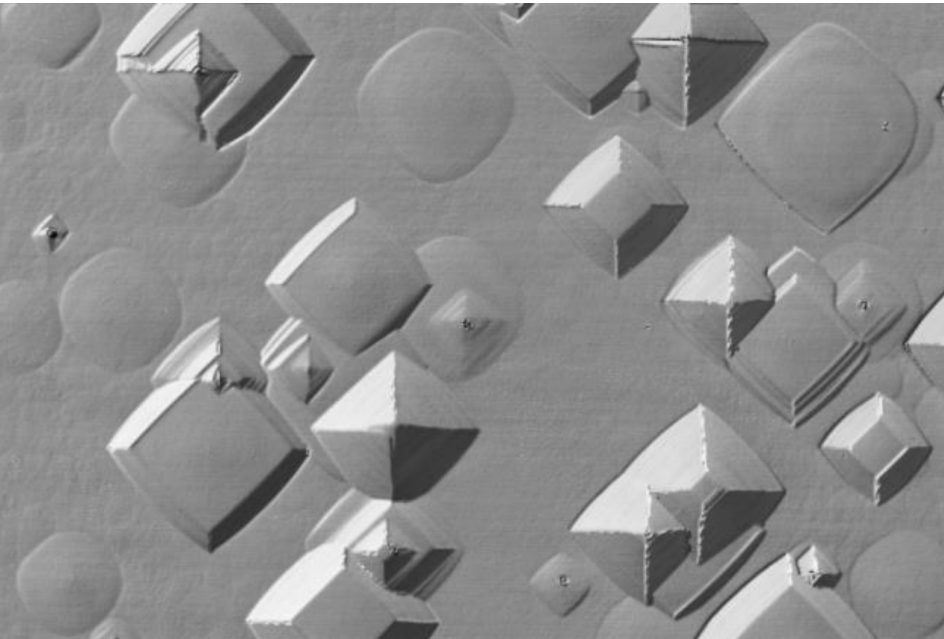
Gianna Dalfuß
Graduate Academy
Mönchebergstr. 19
34109 Kassel
☎ +49 561 804 -1968; -2427
✉ nachwuchsfoerderung@uni-kassel.de

The Communication School also means diversity of topics, as illustrated by the *Mural* from 2019, in which the research topics of the participants were visualized. Can you guess what topics the early career researchers are working on?

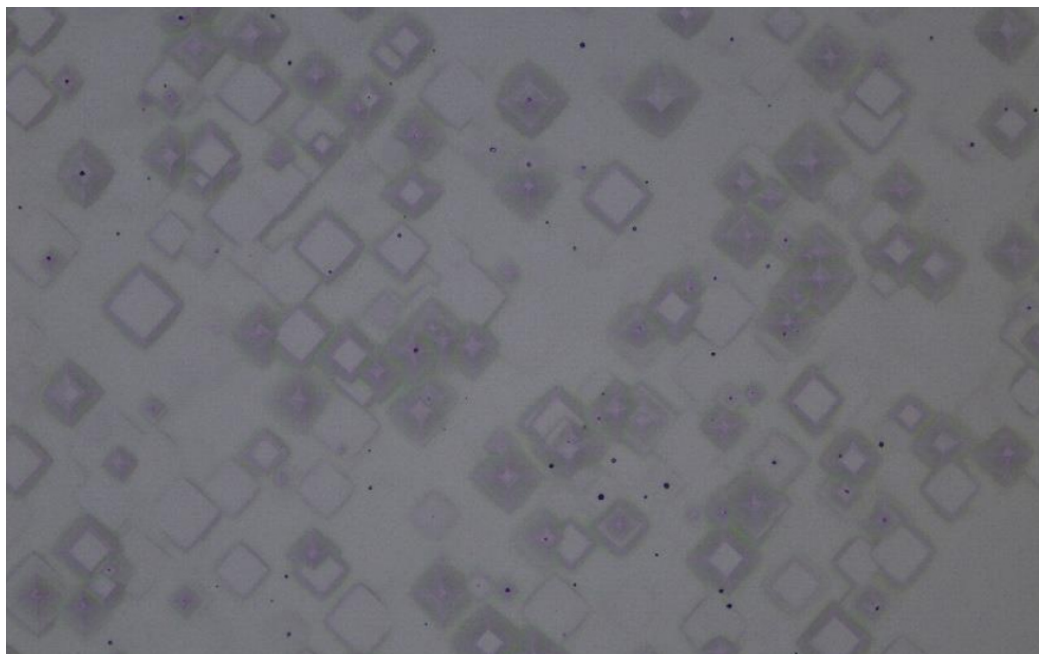


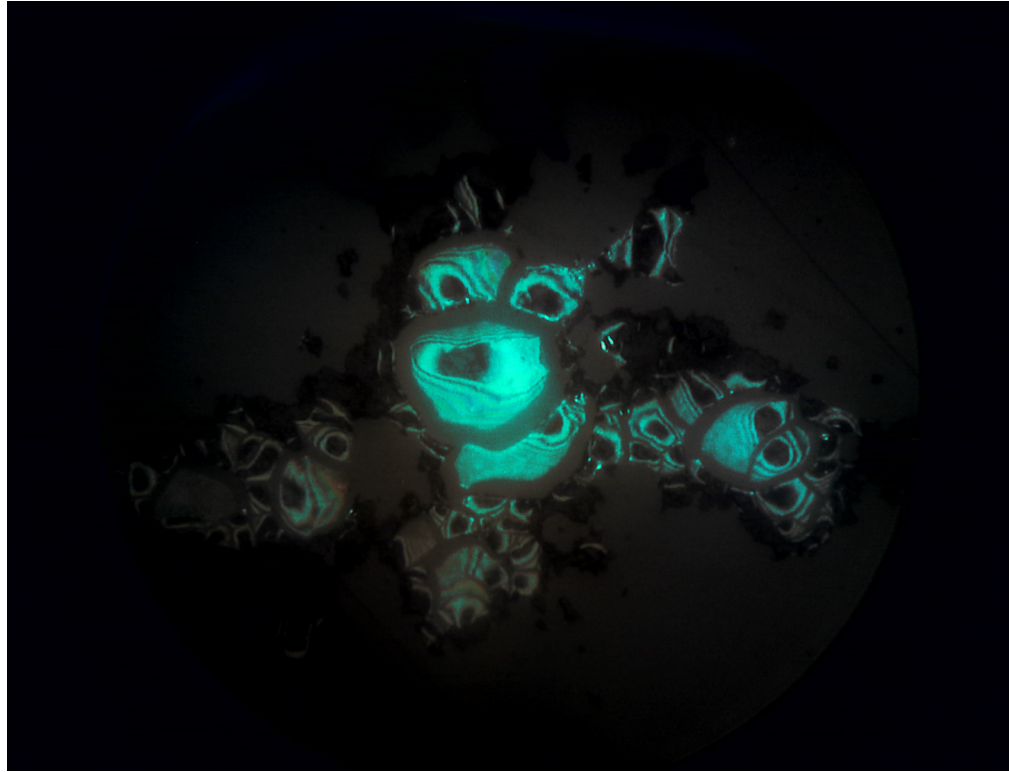
Nano Art

In this section, artistically appealing images from the CINSaT groups will be presented. If you obtain any kind of visually appealing and fascinating data during your experiments with focus on micro-and nanometer length scales, you are cordially invited to submit your contribution to the editors.



Laser optical image (top) and microscope image (bottom) featuring flat and pyramidal monodiamond structures, grown on monocrystalline diamond substrate by hot filament chemical vapor deposition (HFCVD). These images correspond to the sample of the cover image.
(Julia Heupel, Technological Physics)





Light microscope image (incident light) of a silicate precipitation without polarizer
(Benedikt Mohr, Macromolecular chemistry and Molecular materials)



Photo: Campus Heinrich-Plett-Straße, Press and Public Relations Office University of Kassel, Studio Blåfield

Imprint

address

University of Kassel
Center for Interdisciplinary Nanostructure Science and
Technology (CINSaT)
Heinrich-Plett-Straße 40
34132 Kassel

contact

phone: +49 561 804-4384
e-mail: info@cinsat.uni-kassel.de
website: www.cinsat.de

editorial

Prof. Dr. Johann Peter Reithmaier,
Dr. Nina Felgen

layout

Dr. Nina Felgen
Florian Ott

print

viaprinto
Martin-Luther-King-Weg 30a
48155 Münster

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