NanoNet+

Annual Workshop 2021

21 – 23 September 2021

Hotel Neue Höhe, Klingenberg, Germany

HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

Venue and organization

Venue

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This workshop is supported by the Nanoelectronics Department of the Helmholtz-Zentrum Dresden - Rossendorf.

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

NanoNet+ Workshop 2021 - Klingenberg

Agenda

Place: Hotel Neue Höhe, Neuklingenberg 11, 01774 Klingenberg
Web-site: www.hzdr.de/NanoNet-Workshop2021
Updated: 13.09.2021 (PZ)

Tuesday, 21 September 2021

Start	Who	Durat.	Title	Notes
10:45			Shuttle transfer from station **Klingenberg-Colmnitz**	
12:00			Arrival/Lunch Buffet	
13:30	Erbe, A.	10	Welcome address	Chair: Erbe
13:40	Verges, J.	40+10	NanoFrazor – A Nanolithography Tool for Advanced Nanodevices	
14:30	Jagtap, N.	25+5	Top-down Fabrication of Silicon Nanophotonic Structures by Metal Assisted Chemical Etching (MACEtch) for …	
15:00	Kiriy, A.	25+5	Self-Replication of Deeply Buried Doped Si Structures, which Remotely Control the Etching Process: A New ...	
15:40		90	**Coffee + Poster Session**	10 Posters
17:30		60	**Walking Tour**	
19:00			Dinner	

Wednesday, 22 September 2021

Start	Who	Durat.	Title	Notes
09:00	Canovas, E.	40+10	Carrier dynamics in semiconductors studied by time resolved terahertz spectroscopy	Chair: Arora
09:50	Fekri, Z.	25+5	Modification of charge transport in single layer MoS_2	
10:20		30	Break	
10:50	Barth, S.	40+10	Ge-based Nanowires with Metastable Composition: Hyper-Doping and Alloy Formation	Chair: Georgiev
11:40	Echresh, A.	25+5	Size-dependent electrical characteristics of highly doped germanium nanowires using Hall bar configuration	
12:15			Lunch	
13:45	Arora, H.	25+5	Highly Stable Field-Effect Devices Based on Air-Sensitive 2D Materials	Chair: Chava
14:15	Nguyen, A.	25+5	OFET biosensors based on stretchable semiconducting polymer: a proof-of-concept application ...	
14:45	Samano, E.	25+5	DNA-based nanostructures for electronic applications	
15:15		30	Break	
16:00	Bus departure		**Sightseeing: Botanical Garden Tharandt**	
20:00			BBQ Dinner	

Thursday, 23 September 2021

Start	Who	Durat.	Title	Notes
09:00	König, T.A.F.	40+10	Functional optical surfaces by colloidal self-assembly	Chair: Jagtap
09:50	Kemper, U.	20+5	DNA mold-based fabrication of palladium nanostructures	
10:20		30	Break	
10:50	Lungwitz, F.	25+5	Tantalum-Doped SnO2 as Selective Transmitter for High-Temperature Solar Thermal Power Plants	Chair: Erbe
11:20	Krause, M.	25+5	Advanced analysis and unconventional fabrication approaches for thin films and 2D materials	
11:50	Erbe, A.; Zahn, P.	20	Annual Meeting: Status & Future of Nano(net)electronics	
12:30			Lunch incl. Student Award Ceremony	
14:00			Departure (Shuttle bus to station Klingenberg-Colmnitz)	

Breakfast will be served from 7 a.m.

Your Notes

NanoNet+ Workshop 2021 - Klingenberg

Talks

updated: 15.09.2021 (PZ)

List of Poster Contributions see page **19**.

Ge-based Nanowires of Metastable Composition: Hyper-Doping and Alloy Formation

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This talk will address the formation of nanowires and nanorods of metastable composition and demonstrate the significant changes in physical properties associated with their composition.[1] All the growth studies are carried out either in solution or by gas phase techniques using the metal to be in corporate in the Ge host lattice as a growth seed. This approach allowed the formation of highly crystalline, metastable $Ge_{1-y}Ga_y$ (y~0.03%) as well as $Ge_{1-x}Sn_x$ (x=0.13-0.28) nanowires and nanorods at low temperatures.[2-4] The materials have been characterized by different analytical methods including TEM, EDX, Raman spectroscopy as well as XRD. Generally, a homogeneous incorporation of unusually high contents of Sn and Ga in the Ge lattice has been observed. The high incorporation efficiency also alters the physical properties significantly. While hyperdoped $Ge_{0.97}Ga_{0.03}$ shows quasi-metallic behavior in temperature dependent transfer characteristics,[2] $Ge_{0.81}Sn_{0.19}$ reveals still semiconducting behavior in equivalent experiments.[5] Moreover, the formation of $Ge_{1-x}Sn_x$ with x>0.09 causes the transformation to a direct bandgap material, while the solid solubility limit according to the binary phase diagram (~ 1 at% Sn in Ge) has to be overcome. The efficient absorption and emission in the mid-IR range (<~0.55 eV) makes $Ge_{1-x}Sn_x$ very attractive for CMOS-compatible optoelectronics based purely on group IV elements. The high crystal quality of CVD-grown, epitaxial $Ge_{0.81}Sn_{0.19}$ nanowires can be illustrated by the analysis of their photoluminescence under different temperature and illumination conditions.[6]

References

[1] Chem. Mater. **2020**, *32,* 2703-2741.
[2] ACS Nano **2018,** *12*, 1236.
[3] Chem. Mater. **2017**, *29*, 9802.
[4] Chem. Commun. **2015**, *51*, 12282.
[5] Nanoscale **2018**, *10*, 19443.
[6] ACS Nano **2019**, *13,* 8047.

Carrier dynamics in semiconductors studied by time resolved terahertz spectroscopy

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Covering the frequency range from a few to about a hundred milli-electron volts, THz frequencies (1 THz = 4.2 meV = 300 μm) lie between the infrared and microwave frequency regions in the electromagnetic spectrum. Spectroscopy in this frequency range can be employed to study low energy molecular rotational and vibrational modes in matter, low energy excitations linked with the presence of quasiparticles (e.g. excitons), but also, and notably, to interrogate the motion of free charge carriers in (semi)conductors and their nanostructures.

In a conventional experiment, a freely propagating THz electromagnetic pulse is transmitted through a sample, the probe pulse, typically consisting of frequencies in the 0.3–2 THz range, can be seen as a wave packet. An appropriate detection scheme enables recording the transmitted pulse in the time domain, since the recorded time traces contain both amplitude and phase information, the data extracted from their Fourier transforms are complex valued. From this data, the frequency resolved complex conductivity $\sigma(\omega)$ of the sample can be retrieved, from which charge carrier conductivity, mobility and doping can be inferred.

By using a pump-probe scheme, time resolved terahertz spectroscopy (TRTS) allows the study of charge carrier dynamics with ultrafast time resolution in semiconductors. Being an all-optical technique, TRTS is contact-free, noninvasive and suited to time resolve the (photo)conductivity of semiconductors, and particularly to their nanostructures, that are difficult to access with contact methods. In this lecture I will present few examples in the application of the technique for the study of novel bulk and nanostructured semiconductors.

Functional optical surfaces by colloidal self-assembly

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For the next generation of photonic devices, a novel and cost-efficient approach is needed. This future development requires both tailored control over nanometer-sized building blocks on large area and a fundamental understanding of the strong as well as coherent coupling mechanisms [1, 2]. Currently, practical demonstrations are scarce, and are limited in terms of how many devices may be fabricated in parallel. To realize fabrication on a larger scale, a synergy between optical surfaces and colloidal self-assembly will be leveraged (see Figure). This requires, on the one hand, applying concepts from applied optics and, on the other hand, using pre-existing quantum emitter and plasmonic nanoparticle building blocks, which form an organized structure on large area by reducing their free energy [3, 4]. We discuss our recent achievements in finite-difference time-domain modelling, large area self-assembly of tailored building blocks as well as time and space resolved optical characterization to fabricate cost-efficient, programmable and up-scalable photonic devices.

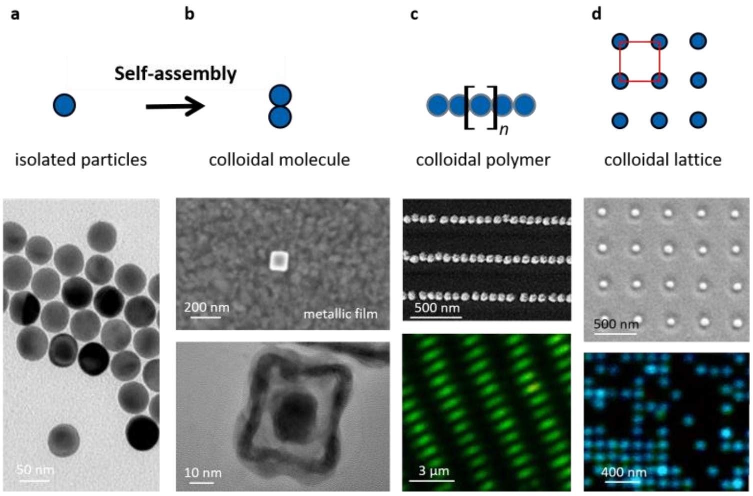

Figure: Concept of functional optical surfaces by the incremental increase in the number of nanoscaled colloids. (a) An isolated particles. (b) Near-field coupling by a colloidal molecule. (c) Collective coupling by a plasmonic polymer. (d) From near-field coupling to far-field by colloidal lattice.

1. P. T. Probst, M. Mayer, V. Gupta, A. M. Steiner, Z. Zhou, G. K. Auernhammer, T.A.F. König,* Andreas Fery,* Mechano-tunable chiral metasurfaces via colloidal assembly, *Nature Materials* **2021**, 1-5
2. O. Aftenieva, M. Schnepf, B. Mehlhorn, T. A. F. König,* Tunable Circular Dichroism by Photoluminescent Moiré Gratings", *Advanced Optical Material* **2020**, 2001280.
3. M. Mayer, M. J. Schnepf, T. A. F. König,* A. Fery,* Colloidal Self-Assembly Concepts for Plasmonic Metasurfaces, *Advanced Optical Material* **2018**, 1800564.
4. S. Sarkar; V. Gupta; T. A. F. König et al. Plasmonic Charge Transfers in Large-Scale Metallic and Colloidal Photonic Crystal Slabs, *Advanced Functional Materials* **2021**, 2011099.

NanoFrazor – A Nanolithography Tool for Advanced Nanodevices

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NanoFrazor thermal scanning probe lithography (t-SPL) tools are gaining popularity in solving complex nanofabrication challenges at research facilities worldwide. By using heatable ultra-sharp tips for material removal and modification as well as imaging the sample in parallel, the instrument has enabled sub-nanometer 3D grayscale lithography, accurate markerless overlay and the first-of-its-kind solution for nanoscale patterning of sensitive materials in a glovebox environment [1]. As no charged particles are employed, patterning can occur at ambient environment and no lithography-induced damage to sensitive materials or device layers will occur. These unique capabilities have allowed for the realization of a range of completely new kinds of nanodevices and opened up entirely new research directions [2, 3]. The technique is compatible with all the common pattern transfer processes [4, 5, 6].

Patterning 2D materials into narrow ribbons, Hall bars etc. is often required in studies on emerging materials systems. Fabricating high-quality electrical contacts presents a challenge in the realization of nanodevices based on these sensitive materials. Predominant fabrication process - i.e. EBL followed by etching or lift-off – may require complex overlay procedures and typically yields poor quality non-ohmic metal contacts with high Schottky barriers and large contact resistances. NanoFrazor lithography can be used for shaping 2D materials with very high precision and for forming high-quality metal contact electrodes [6].

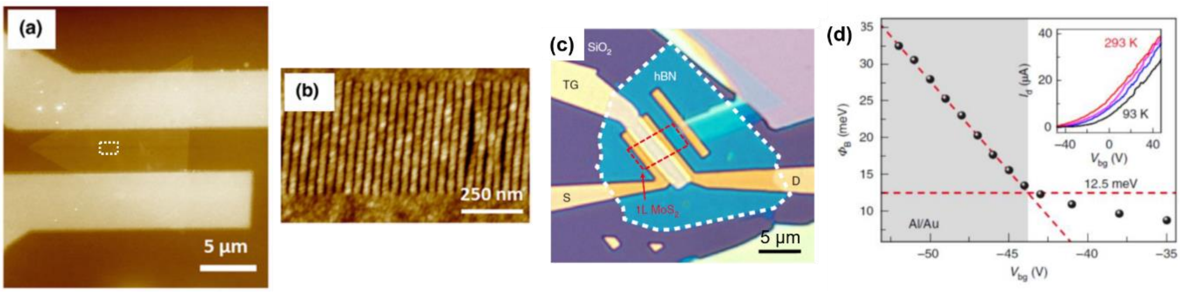

Figure 1: (a) AFM image of 18-nm half-pitch 1L MoS_2 nanoribbon array patterned along the zigzag direction. (b) A close-up of the region marked with a white dashed box in (a). Figures (a) and (b) from Ref [7]. (c) Optical image of a 1L MoS_2 FET with a h-BN gate dielectric where the source, drain and top-gate electrodes have been patterned with a NanoFrazor. (d) Gate voltage dependence of Schottky barrier height of a 1L MoS_2 FET with Al/Au contacts (V_{ds} = 2 V). The deviation from the linear response at low V_{bg} (dashed red line) defines the flat band voltage and the SBH. Inset, corresponding temperature-dependent transfer curves (V_{ds} = 2 V). Figures (c) and (d) from Ref. [6].

References

[1] S. T. Howell et al., *Microsyst Nanoeng* **6**, 21 (2020).
[2] P. Nicollier et.al., (2020).
[3] N. Lassaline et.al., *Nature* **582** (2020).
[4] Wolf et al., *J. Vac. Sci. Technol. B* 33, 02B102 (2015).
[5] Kulmala et al., *Proc. SPIE* 1058412 (2018).
[6] Zheng et al., *Nature Electronics* **2** 17-25 (2019).
[7] Ryu et al , Electrical AFM for Nanoelectr, 143-172 (Ed. U. Celano), Springer (2019)

Highly Stable Field-Effect Devices Based on Air-Sensitive 2D Materials

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Owing to the instability of air-sensitive 2D materials under ambient conditions, their integration into functional devices has been severely constrained. Therefore, effective encapsulation techniques are needed to protect these materials against degradation.[1]
Here, we report a hexagonal boron nitride (hBN) based encapsulation, where 2D layers (InSe, GaSe, and BP) are sandwiched between two layers of hBN; top hBN passivating the 2D layer from the environment and bottom hBN acting as a spacer and suppressing charge transfer to the 2D layer from the SiO_2 substrate. To fabricate the devices from fully encapsulated 2D layers, we employ the technique of lithography-free "via-contacts", which are metal contacts embedded within hBN flakes.[2] Based on our results, we find that full hBN encapsulation preserves the 2D layer in its pristine form and suppresses its degradation with time. Consequently, the electronic properties of encapsulated devices are significantly improved, for example a mobility and on/off ratio of 30–120 $cm^2\ V^{-1}\ s^{-1}$ and 10^4 are obtained in encapsulated InSe devices as compared to a mere ~1 $cm^2\ V^{-1}\ s^{-1}$ and 500 in unencapsulated devices, respectively. In case of BP, a sharp metal-to-insulator transition is observed in encapsulated devices, which is not observed in unencapsulated ones. In addition, encapsulated devices are stable for a prolonged period of time, overcoming their limitation to be air-sensitive.[3]
The full hBN encapsulation technique passivates the air-sensitive layers from various degrading factors and allows us to achieve both good performance and long-term stability. In the future, this technique can be applied to other 2D materials that have been restricted so far in their fundamental study and applications due to their environmental sensitivity.

References

[1] H. Arora and A. Erbe, InfoMat **3**, 662–693 (2020).
[2] E. J. Telford, A. Benyamini, D. Rhodes, D. Wang, Y. Jung, A. Zangiabadi, K. Watanabe, T. Taniguchi, S. Jia, K. Barmak, A. N. Pasupathy, C. R. Dean, J. Hone, Nano Lett. **18**, 1416–1420 (2018).
[3] H. Arora, Y. Jung, T. Venanzi, K. Watanabe, T. Taniguchi, R. Hübner, H. Schneider, M. Helm, J. C. Hone, A. Erbe, ACS Appl. Mater. & Interfaces **11**, 43480–43487 (2019).
[4] H. Arora, T. Schönherr, A. Erbe, IOP Conf. Ser.: Mater. Sci. Eng. **198**, 12002 (2017).

Size-dependent electrical characteristics of highly doped germanium nanowires using Hall bar configuration

Ahmad Echresh[1], Florian Fuchs[2], Himani Arora[1], Slawomir Prucnal[1], Artur Erbe[1], Lars Rebohle[1] and Yordan M. Georgiev[1]

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Germanium (Ge) is the most compatible material with silicon (Si)-based complementary metal-oxide-semiconductor processes. Ge has a higher electron and hole mobility compared to Si, leading to improved device performance. Moreover, Ge nanowires (GeNWs) are promising nanostructures for future nano- and optoelectronics due to their unique properties. In this work, ion beam implantation and flash lamp annealing (FLA) were used to dope phosphorous into the top Ge layer of Ge-on-insulator (GeOI) substrates, achieving a highly n-type doped semiconductor. Raman spectroscopy and Rutherford backscattering spectrometry were performed to characterize the crystallinity of the Ge layers after ion beam implantation and FLA. Subsequently, doped GeNWs were fabricated using electron beam lithography and inductively coupled plasma reactive ion etching. Electrical characterization of the GeNWs was conducted using an innovative Hall bar configuration. The effect of nanowire width on transport parameters such as resistivity and carrier mobility was investigated. Moreover, rear-side FLA were applied to induce NiGe at the Ni-Ge interface, improving the linear characteristics of Ni contacts.

Modification of charge transport in single layer MoS_2

Zahra Fekri[1,2], Phanish Chava[1,2] , Gregor Hlawacek[1], Vivek Koladi[1], Wajid Awan[1], Tommaso Venanzi[1], Antony George[3], Andrey Turchanin[3], Kenji Watanabe[4], Takashi Taniguchi[4], Manfred Helm[1], and Artur Erbe[1]

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The ability to alter properties of 2D materials through defects engineering can open a new window in the device performance improvements as well as quantum electronics and photonics. Ion beam Irradiation is a controllable technique to modify the electrical and optical properties of 2D materials by defect creation. In this work, we used 5 - 7.5 keV helium and neon ions to modify charge transport in monolayer molybdenum disulfide (MoS_2). Electrical characterization was performed in-situ immediately after ion beam irradiation. Raman and photoluminescence spectroscopy were implemented to characterize optically the effect of ion irradiation on monolayer MoS_2. Our experiments demonstrate that the electrical properties of MoS_2 strongly depend on the nature of the substrate and the ion beam used. Although 10^12-10^13 helium ions/cm^2 contributes to an increase in the current level, the same range of neon ions deteriorate the channel current. In addition, using hexagonal boron nitride (hBN) between MoS_2 flake and SiO_2 substrate resulted in a different electrical behavior compared to the MoS_2 samples which were directly placed on SiO_2.

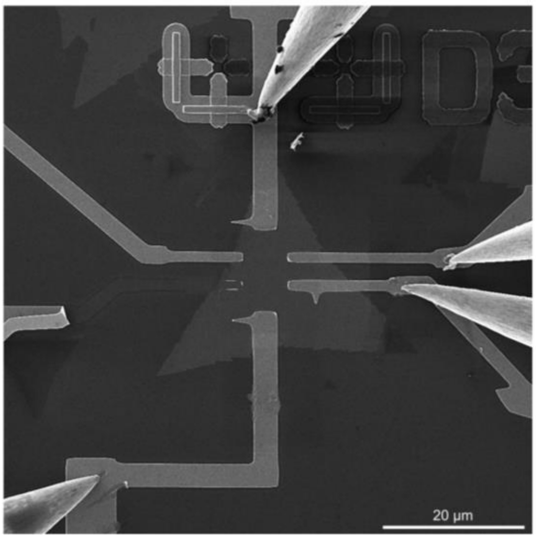

Figure 1) Image of MoS_2 flake with contacts and probes after in-situ electrical characterization was taken with helium ion microscopy. [1]

1) Hlawacek, G., Fekri, Z., Chava, P., & Erbe, A. (2020). In-situ Characterization of MoS2 Based Field Effect Transistors during Ion Irradiation. Microscopy and Microanalysis, 26(S2), 294-296.

Top-down Fabrication of Silicon Nanophotonic Structures by Metal Assisted Chemical Etching (MACEtch) for Hosting Single-Photon Emitters

Nagesh S. Jagtap[1, 2], Michael Hollenbach[1, 2], Ciarán Fowley[1], Yonder Berencén[1], Woo Lee[3], Georgy V. Astakhov[1], Artur Erbe[1], Manfred Helm[1, 2]

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Silicon, the ubiquitous material for computer chips, has recently been shown to be instrumental for hosting sources of single-photons emitting in the strategic optical telecommunication O-band (1260-1360 nm)[1], the so-called G center. To increase the brightness and the photon extraction efficiency of single G center, the coupling of these centers into photonic structures is strong.

This work presents a top-down approach avoiding the use of ion beam-based etching methods for fabricating high-quality defect-free photonic structures such as silicon nanopillars, which can host single photon emitters. This method builds upon a wet-chemical process known as MACEtch. We report the successful fabrication of two-dimensional arrays of vertically directed wave guiding silicon nanopillars. The confocal microscopy after carbon ion implantation shows presence of ensembles of G centers.

References: [1] M. Hollenbach, et al. Opt. Express 28,26111-26121

DNA mold-based fabrication of palladium nanostructures

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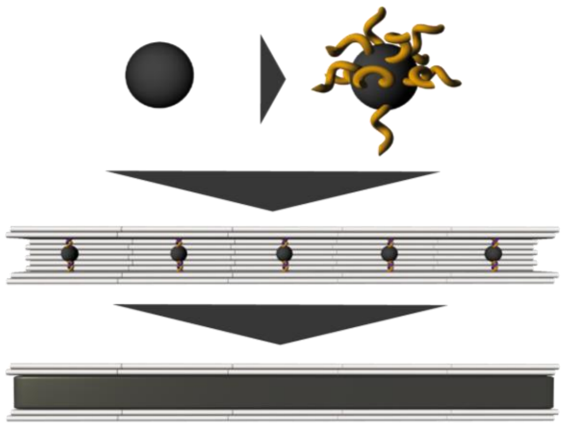

A challenge for the bottom-up fabrication of nanoelectronic devices is the accurate spacially-resolved material deposition on the nanometer scale. Concerning biomolecular materials, DNA nanotechnology meets this challenge by being highly precise at building DNA structures of nearly any desired form. To exploit this concept for other materials, we recently developed a DNA origami mold-based nanoparticle synthesis scheme that allows the fabrication of metallic nanoparticles with DNA-programmable shape. Particularly, we demonstrated the fabrication of gold nanostructures with aspect ratios of up to 7 grown from single seeds [1] as well as the fabrication of rolling-pin-, dumbbell-, loop- and T-shaped gold nanoparticles [2].

Here, we expand the mold-based fabrication method to palladium. To allow a seeded-growth of palladium inside the origami molds, nucleation centers needed to be introduced into the mold cavity. We therefore synthesized palladium nanoparticles and established an efficient functionalization protocol of the particles with single-stranded DNA. The functionalized particles were bound to complementary DNA strands inside the mold cavity from which a seeded palladium deposition was initiated. This provided grainy rod-like palladium nanoparticles with an average diameter of 25 nm. Using an annealing procedure, homogeneous palladium nanowires were obtained. In combination with the seeded growth of gold these two metals can even be deposited within one DNA template structure.

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[2] Jingjing Ye, Olha Aftenieva, Türkan Bayrak, Archa Jain, Tobias A. F. König, Artur Erbe, and Ralf Seidel. Advanced Materials 2021, 2100381.

Self-Replication of Deeply Buried Doped Silicon Structures, which Remotely Control the Etching process: A new method for forming a silicon pattern from the bottom up

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A typical microstructuring process utilizes photolithographic masks to create arbitrary patterns on silicon substrates in a top-down approach. Herein, a new, bottom-up microstructuring method is reported, which enables the patterning of n-doped silicon substrates to be performed without the need for application of etch-masks or stencils during the etching process [1]. Instead, the structuring process developed herein involves a simple alkaline etching performed under illumination and is remotely controlled by the p-doped micro-sized implants, buried beneath a homogeneous n-doped layer at depths of 0.25 to 1 µm. The microstructuring is realized because the buried implants act upon illumination as micro-sized photovoltaic cells, which generate a flux of electrons and increase the negative surface charge in areas above the implants. The locally increased surface charge causes a local protection of the native silicon oxide layer from alkaline etching, which ultimately leads to the microstructuring of the substrate. In this way, substrates having at their top a thick layer of homogeneously n-doped silicon can be structured, reducing the need for costly, time-consuming photolithography steps.

[1] C. Schutzeichel, N. Kiriy, A. Kiriy, B. Voit, Adv. Funct. Mater. **2021**, 31, 2100105.

Advanced analysis and unconventional fabrication approaches for thin films and 2D materials

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The combination of different processing and analytical techniques in one experimental setup allows a comprehensive understanding of complex processes in thin films. As an example, the Raman, RBS and ellipsometry maps recorded during the layer exchange of amorphous silicon and Ag are presented and discussed. Raman mapping of MoS_2 microcrystals using different laser wavelengths is demonstrated as powerful tool for estimating the layer thickness of these 2D materials. The second part of the presentation is dedicated to unconventional fabrication techniques for 2D materials and nanostructured thin films: metal-induced crystallization of amorphous carbon and ion-induced nanowire and pattern formation.

Tantalum-Doped SnO_2 as Selective Transmitter for High-Temperature Solar Thermal Power Plants

Frank Lungwitz[1], Erik Schumann[1], Daniel Janke[1], Ramon Escobar-Galindo[2], Matthias Krause[1]

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Solar thermal power plants provide important contributions in the quest towards an energy supply free of greenhouse gas emissions. These facilities capture concentrated sunlight to deposit heat into a transfer fluid, which, via turbine and generator, is used to produce electricity. The transparent conductive oxide (TCO) SnO_2:Ta is developed as a selectively solar-transmitting coating for concentrated solar power (CSP) absorbers. Upon covering with an antireflective layer, a calculated absorptivity of 95% and an emissivity of 30% are achieved for the model configuration of SnO_2:Ta on top of a perfect black body (BB). High-temperature stability of the developed TCO up to 1073 K is shown in situ by spectroscopic ellipsometry and Rutherford backscattering spectrometry. The universality of the concept is demonstrated by transforming silicon and glassy carbon from non-selective into solar-selective absorbers by depositing the TCO on top of them. Finally, the energy conversion efficiencies of SnO_2:Ta on top of a BB and an ideal non-selective BB absorber are extensively compared as a function of solar concentration factor C and absorber temperature T_H. Equal CSP efficiencies can be achieved by the TCO on BB configuration with approximately 50% lower solar concentration. This improvement could be used to reduce the number of mirrors in a solar plant, and thus, the levelized costs of electricity for CSP technology.

OFET biosensors based on stretchable semiconducting polymer: a proof-of-concept application in COVID-19 pandemic

Trang Anh Nguyen Le[1,2*], Kristina Ditte[3,4*], Oliver Ditzer[3,4], Diana Isabel Sandoval Bojorquez[1], Soosang Chae[3], Michael Bachmann[1,2], Larysa Baraban[1], and Franziska Lissel[3,4,5]

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The COVID-19 pandemic has shown us the importance of early diagnosis and pushed us toward the point-of-care direction. As a result, more attention has shifted to exploring novel biosensing platforms' potentials to prepare for the next outbreak. Among the family of transistor-based biosensors, organic field-effect-transistor (OFET) have grown enormously in recent years, presenting a reliable, compact, inexpensive platform with the possibility of integration into wearable devices. Here, we introduce a sensing platform based on an organic semiconducting polymer that is intrinsically stretchable. The realization of this OFET biosensor is relatively easy thanks to the straightforward synthesis of the polymer film and the utilization of the physical adsorption for bio-functionalization. The platform can detect both SARS-CoV-2 antigens for virus detection and anti-SARS-CoV-2 antibodies for vaccine surveillance in less than 20 minutes with high sensitivity. Furthermore, thanks to the softness and stretchability of the active layer, a fabrication of a fully stretchable biosensor is now in process.

DNA-based nanostructures for electronic applications

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The convergence of recent advances in DNA-based self-assembly approach and surface modification chemistry promises to bridge bottom-up and top-down methods, enabling efficient construction of a new generation of electronic devices. The DNA origami technique allows the generation of 2D and 3D structures and controlled positioning of metal nanoparticles that serve as nucleation centers for increasing their sizes by means of electroless metal deposition methods. The design, fabrication and characterization of two nanostructures using this technique are presented here. The first one is a 3D nanostructure with the shape of a cylinder having an ¨almost¨ circular cross section. This basic cylinder is based on the assembly of five DNA origami modules with a unique coupling by means of sticky ends. At each module, two Au NPs are attached at specific binding sites for guaranteeing a homogeneous and continuous metallic nanowire after electroless gold deposition, or metallization. The second nanostructure is a 2D nanostructure with the shape of a ¨washer¨, a flat ring having a finite thickness. In this case, eight Au NPs will be placed equally spaced along the outer edge of the ring and, similarly, four Au NPs along the inner edge. After merging the Au NPs by metallization, each concentric circle might conform a coil-type metallic nanostructure. According to previous results in our group[1,2], this approach might produce a split-ring resonator (SSR). The SRR consists of a pair of concentric metallic rings on a dielectric substrate with small gaps on opposite sides. This structure behaves as an effective medium with negative effective permeability in a narrow band above resonance if an array of split-ring resonators is excited by a time dependent electromagnetic field. The manufacturing of these two nanostructures might be a proof-of-concept about the feasibility of bottom-up nanofabrication using self-assembling systems, a long-sought goal.

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Your Notes

NanoNet+ Workshop 2021 - Klingenberg

Posters

updated: 16.09.2020 (PZ)

Presenter	No.	Title	Pg.
Akcay, Aleyna	P1	Design of A Field Effect Biosensor (FEB) Platform For BNP Protein Detection	20
Chava, Phanish	P2	Band-to-band tunnelling in two-dimensional van der Waals heterostructures	21
Ghosh, Sayantan	P3	Fabrication and Initial Electrical Characterisation of Silicon Junctionless Nanowire Transistors for Gas Sensing	22
Janićijević, Željko		Standalone extended gate FET-based multiplexed sensing platform	23
Jazavandi, Shima	P4	Fabricating ohmic contacts on III-V core-shell nanowires	24
Khan, Moazzam	P5	Fabrication & Electrical characterization of Silicon-Germanium Nanowire Schottky Barrier Transistors	25
Krause, Johannes	P6	Contacting 2D materials using photolithography	26
Lambeva, Nikol		Morphology Dependence of the Triplet Excited State in Platinum Containing Polyfluorene Copolymers	27
Mitrofanov, Andrei	P7	Low-Dimensional Hybrid Perovskites with Novel Conjugated Organic Cations	28
Sondhi, Harpreet	P8	Charge Transport Through C60 Molecules Using Mechanically Controllable Break Junctions	29

10

1) Posters can be mounted on arrival. The posters should be on display the whole time.
2) Please, remove your poster latest on Friday noon.

Design of A Field Effect Biosensor (FEB) Platform For BNP Protein Detection

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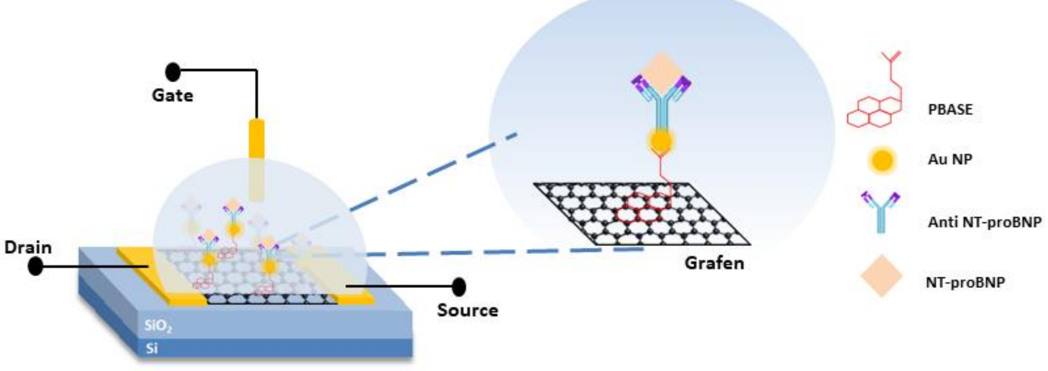
Cardiovascular diseases are the leading cause of death in many countries around the world. One of the most important clinical manifestations of this disease is heart failure. Therefore, there is a need for a reliable, highly sensitive rapid diagnostic kit based on Brain Natriuretic Peptide (BNP) protein detection that can provide results within minutes after sample collection from the patient. Graphene field-effect transistor (GFET) biosensors have the potential to meet the criteria outlined above due to their ability to perform fast, label-free, electrical sensing with potentially low cost, high sensitivity, and specificity. Graphene is a single-atom-thick nanomaterial with a honeycomb structure made up of sp^2 bound carbon atoms. High carrier mobility, high specific surface area, and excellent electric conductivity are just a few of outstanding attributes of this two-dimensional nanomaterial. Graphene has a lot of potential in a variety of applications, including the creation of chemical and biosensors. Graphene-based sensors, particularly GFET, have recently gotten a lot of attention. A typical GFET consists of a graphene sheet that acts as a conducting channel between two metal electrodes (the drain and source electrodes), via which current is passed. A GFET have the potentials to meet the aforementioned criteria because of their capability of performing rapid, label-free, electrical detection with potentially low cost, high sensitivity, and specificity. In this study, single-layer graphene (SLG) was synthesized on Cu foil using the Chemical Vapor Deposition (CVD) method, and a FET-based biosensing platform was developed using a laser lithography method for the detection of the target analyte for NT-proBNP (Scheme 1). Using laser lithography, we made different distance contacts for I_{DS}-V_G curve measurement of GFET biosensor, designed gate, source, and drain configuration that used with Au/Cr electrodes.



Scheme 1: Schematic representation of the planned GFET biosensor platform.

Band-to-band tunnelling in two-dimensional van der Waals heterostructures

Phanish Chava [a,c], Kenji Wantanabe[b], Takashi Taniguchi[b], Manfred Helm[a,c], Artur Erbe[a]

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Quantum mechanical band-to-band tunneling (BTBT) is a particular type of carrier injection mechanism, which is responsible for the electronic transport in tunneling based devices like Esaki/tunnel diode and tunnel field effect transistor (TFET) [1]. Ultrathin two-dimensional (2D) layers of transition metal dichalcogenides (TMDCs) are promising semiconducting materials for realizing such devices owing to their sharp interfaces. The absence of surface and bulk traps in two-dimensional materials enables the reduction of parasitic components arising along with BTBT such as trap assisted tunneling (TAT) [2].

In this work, we demonstrate BTBT in a MoS-WSe2 van der Waals (vdW) heterojunction channel. This channel is encapsulated with few-layered hexagonal-boron nitride (h-BN) on the top and bottom, which serves as the gate dielectric material. In addition, few-layered graphene is used as the contact material to the TMDC heterojunction thereby forming a 2D-2D vdW contact. Moreover, we also investigate graphene as the gate electrode thereby realizing a novel 'all 2D vdW system' for a TFET by using a 2D gate electrode, gate dielectric and contact layer in addition to the channel itself. We performed electrical measurements at low temperatures to identify the different mechanisms of charge transport through the heterojunction. The transfer curves at lower temperatures show promising sub-threshold switching behavior approaching values of 125 mV/dec for about 4 orders of magnitude. The device also shows negative differential resistance (NDR) at low temperatures (30K – 80 K) depending on the polarity of the top and the bottom gates. The occurrence of the NDR peak suggests that the dominant transport mechanism is BTBT instead of thermionic emission.

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[2] Sajjad, Redwan N., et al. "Trap assisted tunneling and its effect on subthreshold swing of tunnel FETs." IEEE Transactions on Electron Devices 63.11 (2016): 4380-4387.

Fabrication and Initial Electrical Characterisation of Silicon Junctionless Nanowire Transistors for Gas Sensing

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Silicon nanowire (Si NW) sensors[1] are very promising because of their fast, low-cost, label-free, real-time detection of chemical and biological species. They have already demonstrated outstanding sensitivity and selectivity towards a large number of analytes in both liquid[2] and gas[3] phases. In particular, silicon junctionless nanowire transistors (JNTs) have recently detected record low concentrations (down to the zeptomolar range) of the protein streptavidin in liquid phase.[4] However, JNTs have not yet been tested for sensing in gas phase.

Here we present the fabrication and initial electrical characterisation of JNT-based sensors for detection of atmospheric free radicals such as hydroxyl (•OH) and nitrate (•NO_3), which are the main drivers of chemical processes in the atmosphere.

Silicon-on-insulator wafers have been used for device fabrication. The wafers have first been doped by a chain phosphorous implantation with nine different energies to form a box-like dopant profile across the 20 nm thick top Si layer. Subsequently, flash lamp annealing has been performed for defect healing and dopant activation. Device patterning has been based mainly on electron beam lithography, inductively-coupled reactive ion etching, metal deposition and lift-off processes.

Initial electrical characterisation of fabricated devices by back-gating has proven their good performance and potential suitability for detection of atmospheric free radicals.

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The RADICAL project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 899282.

Standalone extended gate FET-based multiplexed sensing platform

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Reliable biosensing is crucial in demanding fields such as theranostics and drug discovery. Multiplexing can improve biosensing performance and stability by enabling simultaneous multimarker sensing, more accurate differential measurements, and robust measurement statistics. Biosensing platforms based on field-effect transistors (FETs) comprising extended gate (EG) as a disposable cost-effective sensing element and reusable FET transducer are widely used for electrical label-free detection of biological and chemical analytes. EG electrodes can be modified to detect various analytes while allowing for easy integration of many sensing elements within the same chip. Useful features of EG open the possibility for multiplexed analyte sensing with an EG electrode array and a single FET transducer. Current EG FET-based platforms do not include large-scale multiplexing and rely on external modules such as specialized instruments for electrical measurements and bulky reference electrodes. We present the concept of a standalone EG FET platform for multiplexed sensing based on custom-built electronics interfaced with the EG chip comprising a common integrated reference electrode and microfluidic reservoir. Arduino Uno board enables the digital control of the reed relay-based multiplexing module and FET transducer readout circuit. Readout of the sensor signal is performed by sweeping in constant charge mode. Our platform is a practical and versatile laboratory tool adaptable for sensing different analytes.

Fabricating ohmic contacts on III-V nanowires

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GaAs/InAlAs core/shell nanowires used in this work with existence of tensile strain in the GaAs core and reduced effective electron mass at the Γ-point of the Brillouin zone show potential for high-mobility transistors without need for lattice matched InP substrates.
In this work, in order to use such nanowires in electronic devices, electron transport through the wire has been accomplished. A serious challenge is to reach to the conductive core/shell interface since it is isolated by the InAlAs shell layer.
In order to gain ohmic contacts, we used Ti/Pd/Au and Ge/Ni/Au layer systems, and using flash lamp annealing (FLA) and rapid thermal annealing (RTA) approaches for improving the contact resistances.

Fabrication & Electrical characterization of Silicon-Germanium Nanowire Schottky Barrier Transistors

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Recent developments in semiconductor technology demand high speed and high performance devices. A possible way to achieve this is by replacing silicon as a channel material with high-mobility materials. The silicon-germanium alloy has shown to have increased carrier mobility as compared to silicon, which leads to faster and more energy-efficient devices. In particular, the Schottky Barrier Field Effect Transistor (SB FET) based on silicon-germanium nanowires can be used to realize the concept of Reconfigurable FET (RFET) [1]. RFET is a device in which a single transistor can be operated as an N or P channel just by controlling the potential applied at the gate terminal. Here we report on top-down fabrication of such devices having nickel metal pads on both sides of the silicon-germanium nanowire. Flash lamp annealing was done to have metal diffusion into the nanowires and form nickel-germano-silicide schottky junctions. Transfer characteristics of these devices with back gate are measured which gives information about the transistor properties.

[1] Heinzig, A., Slesazeck, S., Kreupl, F., Mikolajick, T., & Weber, W. (2011). Reconfigurable Silicon Nanowire Transistors. Nano Lett, 119-124. doi:10.1021/nl203094h

Contacting 2D materials using photolithography

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In recent years 2D materials have garnered much attention. Among them Transition metal dichalcogenides (TMDC) are especially interesting due to strong light-matter interaction and valley effects. Here, we present a technique for defining electrical contacts to individual flakes of TMDC monolayers. Flakes are deposited on structured SiO_2 wafer dies and subsequently covered with a thin film of gold using thermal evaporation. A custom contact design is defined using photolithography and excess gold is removed by an etch-off process. We utilize photoluminescence to track the 2D material properties during various processing steps and characterize our devices with I-V curves.

Figure 1 Optical microscope image (50x magnification) of a WS_2 monolayer flake contacted with a thin gold film.

Morphology Dependence of the Triplet Excited State in Platinum Containing Polyfluorene Copolymers

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The triplet states play a vital role in the optoelectronic properties of organic semiconductors with direct consequences for their use in devices. It is, thus, vital to have a deep understanding of the formation, transport and harvesting of triplet excitons in such materials.

The spectral diffusion of singlet and triplet excitons in a platinum containing polyfluorene copolymer is investigated using photoluminescence spectroscopy in the temperature range between 5 and 300 K. The platinum atom is introduced through a cyclometalated PyTPAPt(acac) complex embedded into the backbone of the light emitting polymer poly(9,9-dioctylfluorene) (PFO). The heavy platinum atom increases the spin-orbit coupling in the copolymer leading to the radiative decay of the triplet state. It is demonstrated that the copolymer is able to adopt both the glassy and β phase chain conformations characteristic of PFO. The phosphorescence spectral diffusion in the two phases of the copolymer is compared to give information about the triplet exciton transfer in disordered polymer films with different conjugation lengths. It is found that in the glassy phase the triplet exciton relaxation becomes frustrated due to thermally activated hops necessary to advance spectral diffusion becoming kinetically frozen out at low temperature. In contrast, in films containing β phase chain segments frustration is lifted due to the increased conjugation length in the β phase making more hopping sites available. Therefore, the triplet explores a larger number of acceptor sites raising the probability for nonactivated triplet exciton transfer.

This work is the first demonstration of the use of a molecular level chain conformation change to control the triplet diffusion properties of a fluorene-based copolymer.

Low-Dimensional Hybrid Perovskites with Novel Conjugated Organic Cations

Andrei Mitrofanov[1], Nataliya Kiriy[1], Elaheh Sadrollahi[2], Hendrik Weiske[3], Agnieszka Kuc[3], Elke Beyreuther[4], Anton Kiriy[1], Brigitte Voit[1]

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Organic-inorganic hybrid low-dimensional perovskites have attracted great attention for optical and optoelectronic applications due to their excellent stability and structural diversity. The use of various organic cations leads to the formation of 2D, 1D or 0D-structures depending on how the metal halide octahedra are connected to each other. Even insignificant differences in the structure of organic cations can lead to a sharp change in the structural and, as a consequence, optoelectronic properties of perovskite systems.

In this work, a series of low-dimensional hybrid perovskites, based on isomeric naphthalene amine cations and lead iodide were fabricated and their structures and properties were investigated. Examination of the influence of organic cation on the structure-property relationship reveals that the number and position of amino groups in naphthalene rings has an effect on the perovskite dimensionality and related optoelectronic properties.

Charge Transport Through C_{60} Molecules Using Mechanically Controllable Break Junctions

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Molecular electronics is a fundamental science of using organic molecules to make highly stable and robust electronic devices, for its investigation Au/C_{60}/Au junctions were fabricated using Mechanically Controllable Break Junctions (MCBJ) technique. The effect of mechanical stress on the charge transport is very crucial in terms of molecular vibrations in single molecules, were investigated using a unique lock-in amplifier-based measurement setup at low temperatures. The frequent opening/closing of the Au/C_{60}/Au junction is done to measure the conductance values. Results were measured in terms of *I-V*, *dI/dV-V*, and d^2I/dV^2-*V* (IETS) spectra. The bending due to mechanical control results in mechanical stress which may cause the changes in the molecule configuration and its attachment to the metal leads. It strongly influences the conductance measured through the junction. We have shown that by controlling the bias applied and the influence of mechanical stress, characteristic changes in the *I-Vs* on conductance values can be observed.

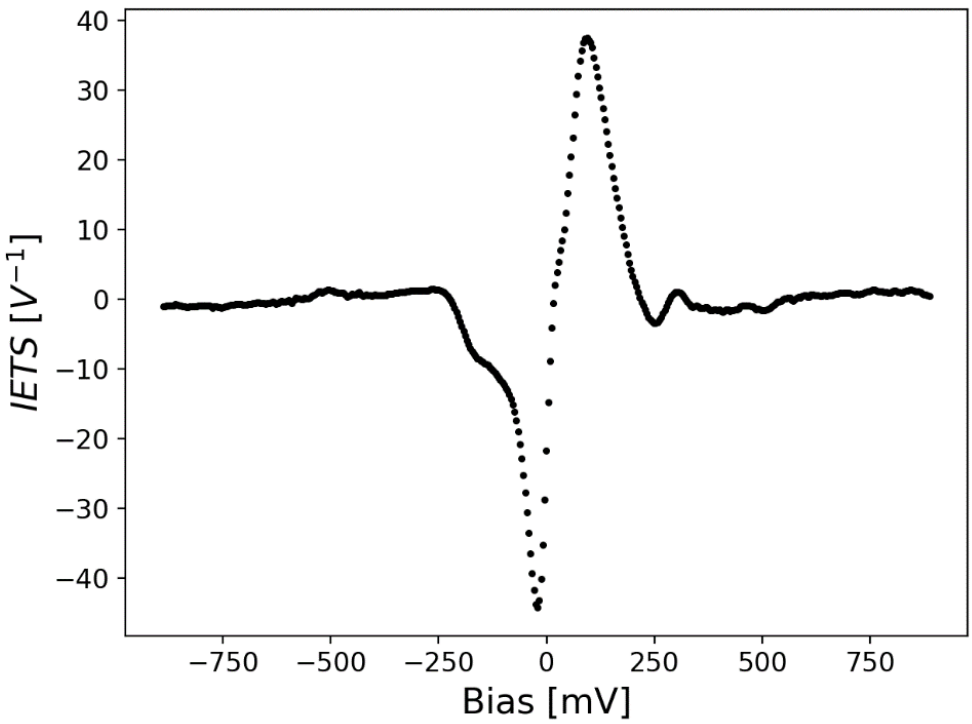


Figure-1: Normalized IETS signal scatter plot.

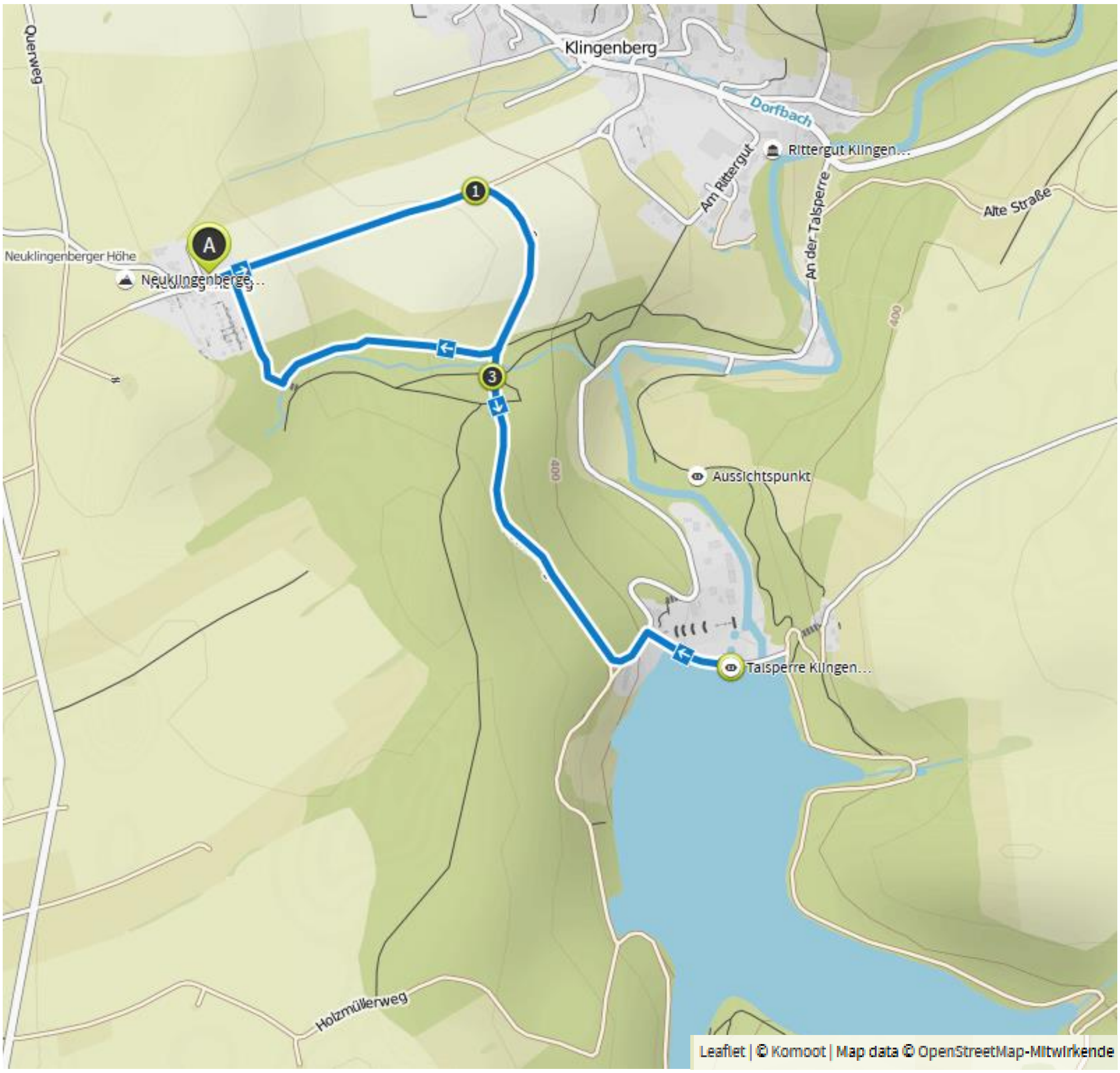
Your Notes

Hiking Tour to the Klingenberg Dam (3.9km, 1:09h)

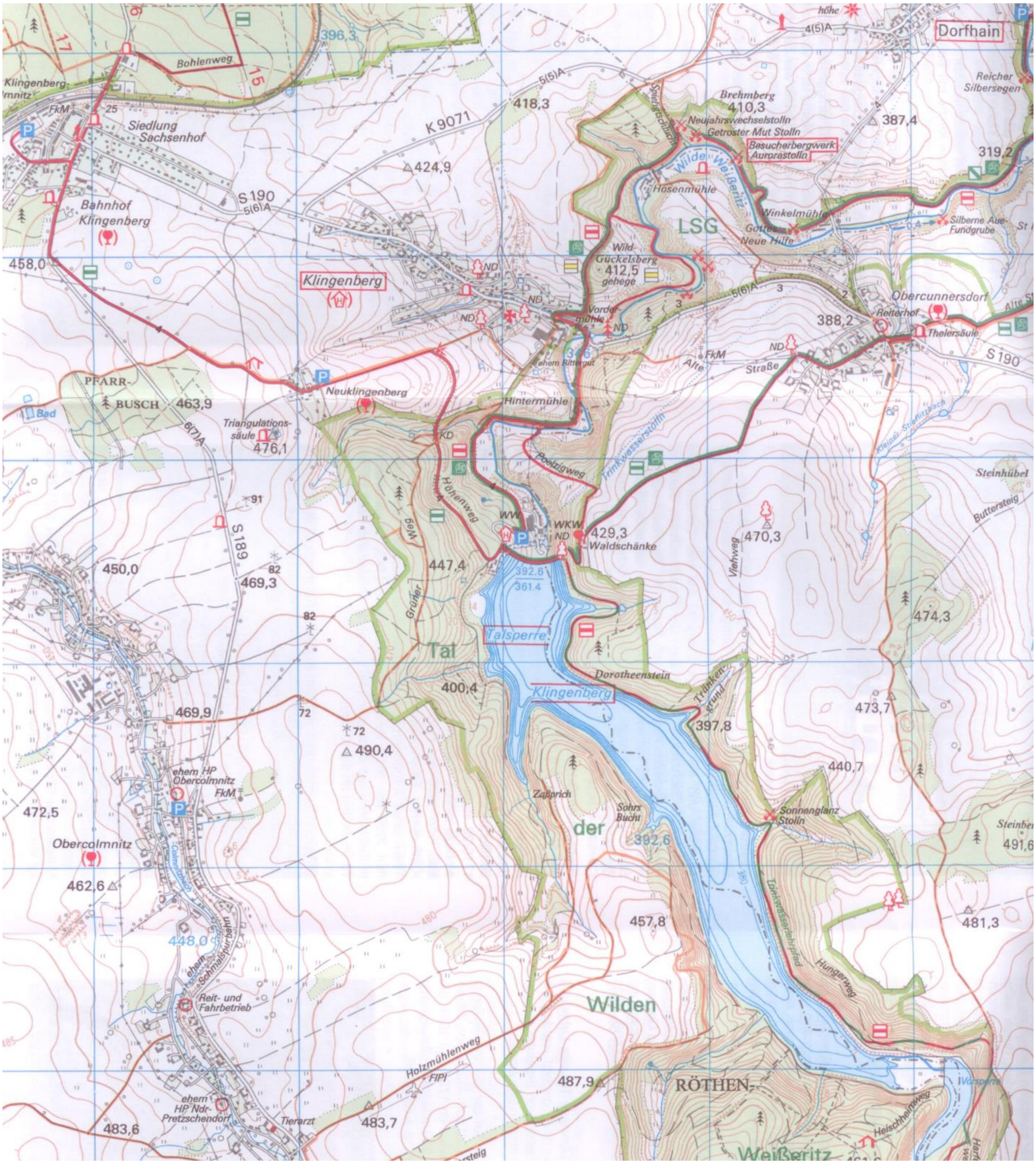
A: Hotel Neue Höhe
1: turn to the right
2: View from the top of the Dam (Talsperre Klingenberg)

The dam was erected between 1908 and 1914. It provides the drinking water for the Dresden area to a large extent.

3: Streichholzbrücke – Fire match Bridge built between 1910–1911 as wooden railway bridge, changed to a Road Bridge in similar form in 1924, today a technical monument.



Map of the Area



NanoNet+ Workshop 2021 - Klingenberg

Participants (partially on-line) Updated: 15.09.2021 (PZ)

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Akcay	Aleyna	Ms.		HZDR
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Canovas	Enrique	Mr.	Dr.	IMDEA Madrid
Chava	Phanish	Mr.		HZDR
Echresh	Ahmad	Mr.		HZDR
Erbe	Artur	Mr.	PD Dr.	HZDR
Fekri	Zahra	Ms.		HZDR
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Georgiev	Yordan	Mr.	Dr.	HZDR
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