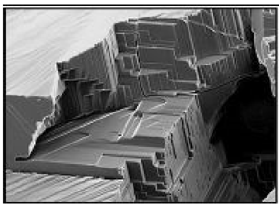
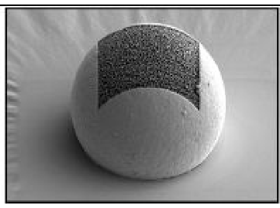
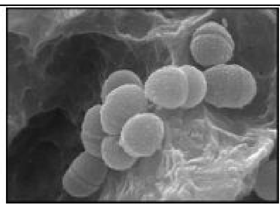
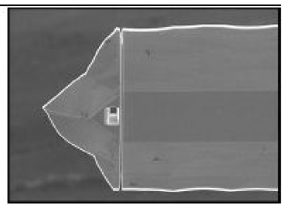
University of Basel
Swiss Nanoscience Institute

SNI
Swiss Nanoscience Institute
Exzellenzzentrum
der Universität Basel und
des Kantons Aargau

NANO IMAGING LAB

Newsletter February 6, 2024

Report Overview of the NI lab's participation in publications in 2022 and 2023

The Nano Imaging Lab (NI Lab) not only offers a service in various microscopy techniques but is also involved in current research topics and can make an important contribution. Two examples are given below. Information about further publications can be found at: https://nanoscience.unibas.ch/de/services/nano-imaging-lab/publikationen/

2022

Transparent Josephson Junctions in Higher-Order Topological Insulator WTe_2 via Pd Diffusion [1]

The higher-order topological insulator WTe2 was shown to turn superconducting when placed on palladium (Pd) bottom contacts. We were asked if we could show the Pd diffusion along the edges of such contacts. In order to investigate the uniformity of the $PdTe_x$ diffusion layer, two lamellae had to be cut using a focused ion beam (FIB). Figure 1 (a) shows a SEM image of the positions where the two lamellas, marked with 1) and 2) were cut out. The image was taken before the lift-out. The regions near the physical edges of WTe2 are of particular interest, since additional Pd is available there due to the Pd bottom contacts extending beyond the crystal. The first lamella was cut out through the middle of the bottom Pd contact in a sample with molybdenum-rhenium (MoRe), top contacts, as illustrated by position 1 in Figure 1 (d). Figure 1 (b) presents two EDX spectra obtained at the two edges. Outside of the WTe_2 flake we observe a layer of Pd with uniform thickness sandwiched between the MoRe top layer and the Ti bottom layer. Further from the edges, Pd is evenly distributed throughout the WTe_2 crystal. Visible in the energy-dispersive x-ray spectroscopy (EDX) measurements there is an increased intensity of the Pd signal at the edges of the crystal compared to the bulk. The increased Pd concentration is also visible by the enhanced EDX signal in the line cuts taken along the direction pointed out by the horizontal arrow in Figure 1 (c). If you are more interested in the topic, there is more information in the publication [1].

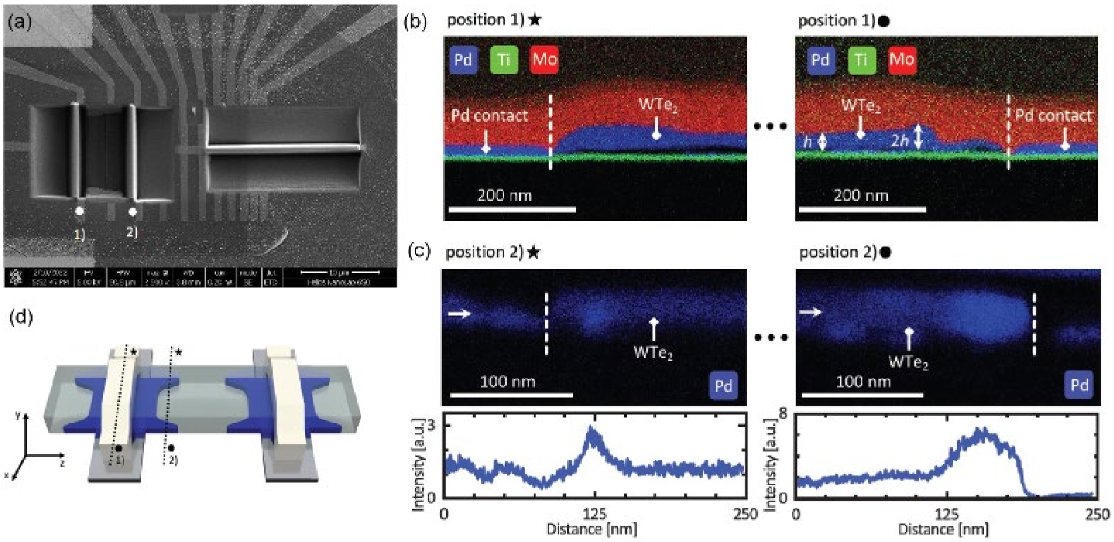


Figure 1: (a) SEM image of the lift out positions. (b) EDX analysis of a cross section taken on the Pd contact along position 1, as indicated in the schematics in (d). EDX signal and extracted intensity (Int.) profile taken towards the inside of the junction, indicated by position 2 in panel (d). Figure 1 (b), (c) and (d) are taken from Ref. [1].

[1] Martin Endres, Artem Kononov, Michael Stiefel, **Marcus Wyss**, Hasitha Suriya Arachchige, Jiaqiang Yan, David Mandrus, Kenji Watanabe, Takashi Taniguchi, Christian Schönenberger
Transparent Josephson Junctions in Higher-Order Topological Insulator WTe_2 via Pd Diffusion
Phys. Rev. Materials 6, L081201 (2022) doi.org/10.1103/PhysRevMaterials.6.L081201

2023

Enhanced Electron-Spin Coherence in a GaAs Quantum Emitter [2]

In this project, the NI lab was asked whether it would be possible to map a self-assembled GaAs quantum dot (QD), which are near-perfect emitters of on-demand coherent photons. Such QDs are small and the difficulty is to have such a QD exactly localized in the lamella, so that it can be detected despite thinning from both sides during lamella production using a FEI Helios NanoLab 650 DualBeam. The Jeol JEM-F200 cFEG has been in operation in the Nano Imaging Lab since the end of 2021, which has a sufficiently good spatial resolution in the TEM (0.19 nm) and the STEM mode (0.14 nm) to realize such a project. Figure 1(a) shows a high-angle dark-field scanning transmission (HAADF-STEM) image of a GaAs QD and (b) a SEM image of the cross-section of the whole lamella milled and thinned down using a focused ion beam (FIB). The QD is embedded in a p-i-n diode structure such that the QD charge is stabilized via the Coulomb blockade. The Jeol JEM-F200 cFEG provides also the possibility to perform energy-dispersive x-ray spectroscopy (EDX) measurements. Figure 1(c) shows EDX intensity as a function of x-and y- position around the QD for (a) arsenic, (b) gallium, and (c) aluminium atoms. The arsenic EDX intensity is homogeneous as expected. The arsenic concentration is constant throughout the growth of the QD layer and matrix material. The EDX intensity for gallium atoms shows a high signal below the QD and a low signal above. This is expected as the matrix material below the QD is $Al_{0.15}Ga_{0.85}As$ and the QD is grown on and capped with $Al_{0.33}Ga_{0.67}As$. The EDX signal for aluminium atoms shows a low aluminium signal below the QD and a high signal above. If you are more interested in the topic, there is more information in the publication [2].

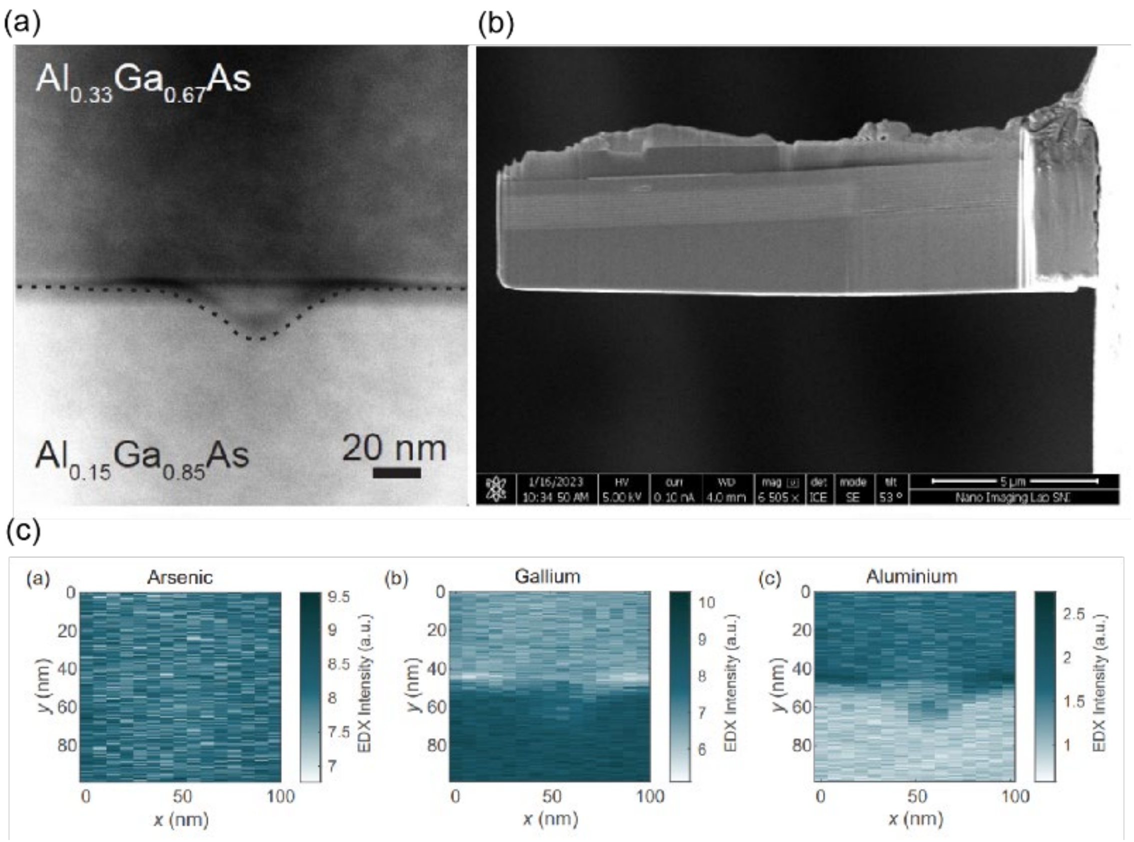


Figure 1: (a) shows a high-angle dark-field scanning transmission (HAADF-STEM) image of a GaAs QD. (b) SEM image of cross-section of the whole lamella. (c) EDX intensity as a function of x-and y- position around the QD for (a) arsenic, (b) gallium, and (c) aluminium atoms. Figure 1 (a) and (c) are taken from Ref. [2].

[2] Giang N. Nguyen, Clemens Spinnler, Mark R. Hogg, Liang Zhai, Alisa Javadi, Carolin A. Schrader, Marcel Erbe, **Marcus Wyss**, Julian Ritzmann, Hans-Georg Babin, Andreas D. Wieck, Arne Ludwig, and Richard J. Warburton
Enhanced Electron-Spin Coherence in a GaAs Quantum Emitter
Phys. Rev. Lett. 131, 210805 doi.org/10.1103/PhysRevLett.131.210805

FEI Helios NanoLab 650

This device was used for creating the FIB lamellas in the previous mentioned publications.

Typical applications and accessories

- Imaging, analysis, milling, patterning of specimens down to the nanoscale
- TEM lift out / TEM lamella
- Nanofabrication and micromanipulation
- Multiple gas injection system for Pt-, W-, C-, Co- and H20- deposition
- Correlative Microscopy (LM – SEM)
- Micromanipulator from Kleindiek
- Lift Out Shuttle from Kleindiek
- Eucentric five Axis Table from Kleindiek
- Micromanipulator OmniProbe 200

Technical specifications

- High Resolution Field Emission (Schottky) Scanning Microscope (Dual Beam)
- Resolution of the electron beam:
  – 0.8 nm at 15 kV
  – 1.5 nm at 200 V
- Resolution of the ion beam:
  – 4.0 nm at 30 kV using preferred statistical method
  – 2.5 nm at 30 kV using selective edge method
- Maximum sample size: 150 mm in diameter, 55 mm in height
- Maximum sample weight: 500 g (incl. sample holder)

Detectors and micro analysis

- Elstar in-lens SE detector (TLD-SE)
- Elstar in-lens BSE detector (TLD-BSE)
- Everhart-Thornley SE detector (ETD)
- Energy Dispersive X-Ray Spectroscopy (EDX), Genesis & Team software

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Jeol JEM-F200 cFEG (STEM)

This device was used for EDX analysis in the above mentioned publication Endres et. al (2022).

Typical applications

- Analytics of biological samples
- Characterization of nanoparticles and layers (EDS)
- Atomic resolution

Technical specifications

- Cold field emission gun
- 20 to 200 kV acceleration voltage
- Resolution:
    - TEM, point to point: 0.19 nm
    - TEM, lattice image: 0.10 nm
    - STEM-HAADF: 0.14 nm
- Magnification TEM from x 20 to x 2.0 M; STEM from x 200 to x 150 M
- Energy Dispersive X-Ray Spectrometer (EDS)

Imaging modes

- HAADF STEM (High-angle annular dark-field scanning transmission electron microscopy)
- Bright-field (BF) & dark-field (DF) TEM and STEM, as well as analysis from various types of detectors
- 3D-EDS tomography: reconstruction method of three-dimensional internal structures through computer image processing of many projection images, which are acquired from sequential tilt-series images of a specimen