Doctoral Student in Physics: X-ray Spectroscopy of Nanostructure Devices

Project title:	Operando X-ray spectroscopy of semiconductor nanostructure devices
PRISMAS Research Area:	Clean Energy
Supervisor:	Rainer Timm
Hosting University:	Lund University
Partners:	Forschungszentrum Jülich (Prof. Regina Dittmann)
Link to position:	Apply here

1. Project summary:

Today's electronic devices are downscaled to a size of a few nm, and their device performance is typically determined by materials science properties of atomically thin surfaces and interfaces. This is even more valid for complex next-generation device structures such as tunnel field effect transistors (FETs), ferroelectric FETs, or resistive memories, which are strongly needed for realizing neuromorphic networks and energy-efficient internet-of-things applications.
In this project, we will study interfaces and understand physical mechanisms of such novel semiconductor devices, even by in situ experiments during device operation. We will use X-ray based spectroscopy methods at MAX IV and other European synchrotron facilities, complemented by lab-based microscopy techniques. This will be realized in close collaboration between the Division of Synchrotron Radiation Research and the Nano Electronics group at Lund University as well as researchers at MAX IV, especially the FlexPES beamline.

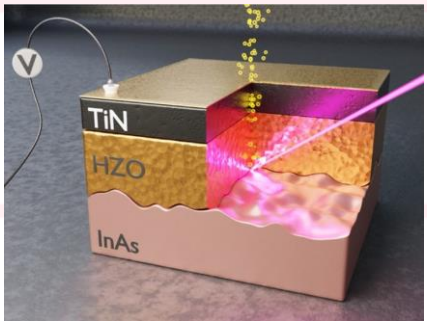
2. Keywords

Semiconductors, Nanotechnology, Device characterization, X-ray photoelectron spectroscopy, Operando studies

3. Project outline

- **Project objectives:**

We want to understand the physics and improve the performance of novel semiconductor devices which are relevant for internet-of-things applications and other important technology challenges.
For this, we will explore interfaces of advanced metal-semi-conductor-oxide structures at the atomic scale. We will develop and use methods for surface and interface characterization during sample processing and during device operation, including ferroelectric or resistive switching.



Sketch of a proposed experiment: Operando XPS of a ferroelectric metal-oxide-semiconductor

- **Implementation:**

The project will be hosted by Lund University at the Division of

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Synchrotron Radiation Research [1], Department of Physis (Assoc. Prof. Rainer Timm), in close collaboration with the Nanoelectronics group [2], Department of Electrical and Information Technology (Prof. Lars-Erik Wernersson). This well-established collaboration combines materials science expertise and characterization with state-of-the-art device processing [3,4].
The main characterization techniques will be based on X-ray photoelectron spectroscopy (XPS) and X-ray absorption spectroscopy (XAS) [5], including approaches specialized on high-energy X-rays, nm-scale spatial resolution [6], or near-ambient environments [7]. Complementary characterization tools including scanning probe microscopy [6] and scanning electron microscopy are available at Lund University. Experiments and method development at the MAX IV Laboratory are an essential part of the project, co-supervised by Dr. Alexei Preobrajenski at the FlexPES beamline [5]. As a doctoral student, you will perform beamtimes at FlexPES and other beamlines of MAX IV and other European synchrotrons. The project includes an additional short secondment at the Forschungszentrum Jülich in the group of Prof. Regina Dittmann [8], focusing on operando X-ray studies of electrical devices.
The research of this project is embedded in the NanoLund Center for Nanoscience, and it is part of Lund University's profile area "Light and Materials".

- **References:**

[1] https://www.sljus.lu.se/
[2] https://www.eit.lth.se/index.php?gpuid=500
[3] M. S. Ram et al., *High-density logic-in-memory devices using vertical indium arsenide nanowires on silicon,* Nature Electronics **4**, 914 (2021).
[4] Z. Yong et al., *Tuning oxygen vacancies and resistive switching properties in ultra-thin HfO_2 RRAM via TiN bottom electrode and interface engineering*, Appl. Surf. Sci. **551**, 149386 (2021).
[5] https://www.maxiv.lu.se/beamlines-accelerators/beamlines/flexpes/
[6] S. R. McKibbin et al., *Operando Surface Characterization of InP Nanowire p-n Junctions*, Nano Letters **20**, 887 (2020).
[7] R. Timm et al., *Self-cleaning and surface chemical reactions during HfO_2 atomic layer deposition on InAs,* Nature Communications **9**, 1412 (2018).
[8] https://www.fz-juelich.de/en/institutes/pgi

Link to PRISMAS overview: https://www.maxiv.lu.se/prismas/