MESA+ INSTITUTE FOR NANOTECHNOLOGY

NANOELECTRONICS

NANOELECTRONICS GROUP

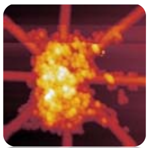
WHERE THE FUTURE IS BEING MADE TODAY

Nanoelectronics comprises the study of the electronic and magnetic properties of systems with critical dimensions in the nanoregime, i.e. below 100 nm. Hybrid inorganic-organic electronics, spin electronics and quantum electronics form important subfields of nanoelectronics.

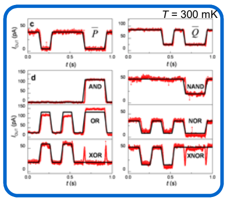
The research goes above and beyond the boundaries of traditional disciplines, synergetically combining aspects of electrical engineering, physics, chemistry, materials science, and nanotechnology

Brain-inspired nanoelectronics

Brain Inspired computing: The Center for Brain-Inspired Nano Systems (BRAINS) combinis core expertise in nanoscience and nanotechnology with expertise from computer science, artificial intelligence and neuroscience, to lay the scientific foundations for a new generation of powerful, energy-efficient computing hardware. Artificial and biological neural networks, in particular the brain, form a main inspiration. we aim to develop efficient hardware for information processing. We do this by exploiting the behavior of disordered nanomaterial systems that have tunable nonlinear behavior.



In such systems we look at the possibilty to use machine learning techniques to train these system to perform the desired task. We look at the connection between our hardware and conventional (CMOS) electronics to discover in which area of computation it can improve the computational power.



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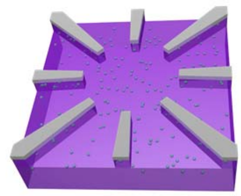


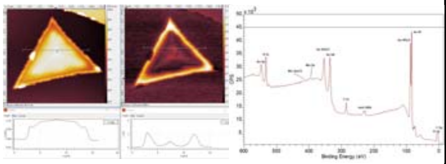
Left: Au nanoparticle network assembled onto an array of electrodes using dielectrophoresis. The Au particles are covered with an organic shell, electrons tunnel between particles, Coulomb blockade results in strongly nonlinear behavior,

***Right**: Dopant network in Si, charge hopping between dopant sites enables similar behavior at higher temperature.*

2D electronic systems

The project integrates **2D materials** with newly developed free-standing nanolayers of organic semiconductors to create van der Waals heterostructures for applications in electronic and optoelectronic systems.

Progress in nanotechnology has led to an enormous interest in two-dimensional (2D) materials, having a huge market potential in electronics. In addition to exploiting the novel properties of individual 2D crystals, van der Waals heterostructures (vdWh) comprising several different materials hold promise for novel devices with designed properties.



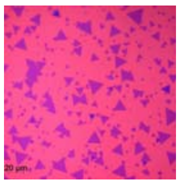
Left: AFM image of Chemically-Vapor Deposited (CVD) monolayer of MoS_2 on Si/SiO_2 substrate
Center: KPFM image (potential map) of the same sample
Right: XUV spectrum of CVD MoS_2 nanolayer

Fabrication methods

To address these challenges, this project will utilize novel methods to fabricate vdWh with 2D materials while retaining their structural integrity and high interface quality. We will develop 5-10 nm of OSC that are mechanically stable and transferable by crosslinking and layer transfer methods. Specifically, we will produce p–n junctions of OSC and atomically thin CVD grown transition metal dichalcogenides (TMDCs), in a lateral and vertical configuration for demonstration of devices such as diodes and transistors.

Characterization

For basic understanding of vdWhs we plan to use our experience in (synchrotron based) photoemission spectroscopy for characterization of electronic structure, electrical transport measurements for understanding the charge transport properties, optical characterization by photocurrent spectroscopy measurements.

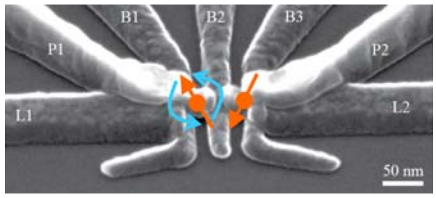


Optical image of monolayer TMDs

Silicon quantum electronics

Silicon quantum electronics studies the quantummechanical behavior of isolated electrons in silicon. We confine single electrons in quantum dots, and probe their spin states in transport measurements at low temperatures.

With our research we want to gain a better understanding and control of quantum systems with future applications such as a quantum computer.



Scanning Electron Microscope image of a silicon double quantum dot in a nanoMOSFET structure. Aluminium gate electrodes on a silicon substrate define two quantum dots at the interface of Si and SiO_2. We isolate single electrons in both dots and try to control their spin states.

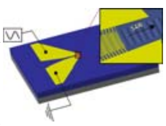
Spin quantum bits in silicon quantum dots

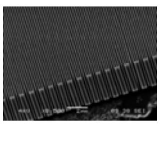
We aim at controlling the spin states of individual electrons in silicon double quantum dots with the ultimate goal of realizing silicon single-electron spin quantum bits as building blocks for future solid-state quantum computers. In NE we use Si quantum dots defined by electrostatic gating of an electron gas at the Si/SiO_2 interface. The design with three layers of gates allows control of all quantum dot components: the quantum dots themselves, the tunnel barriers and the densities of states in the reservoirs.

In collaboration with the group of Prof. Dzurak at the University of New South Wales in Sydney, we are further developing the Si quantum dots technology towards few-electron double quantum dot devices. The goal is to observe Pauli spin blockade in few-electron Si double quantum dots. Spin blockade can be used to detect single-electron spin resonance, a basic requirement for quantum information processing with single electron spins.

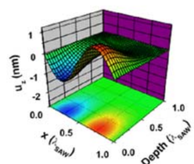
Acousto-electronics

In acoustoelectronics, acoustic waves are utilized to manipulate and transport charge carriers. Particularly interesting are **surface acoustic waves** (SAWs) in which virtually all acoustic energy is confined within one wavelength of the surface. SAWs typically have a propagation velocity of a few km/s, wave amplitudes of ~1 nm, and the wavelengths range from submicron to ~100 microns. SAWs can be generated and detected by interdigital transducers (IDTs) on a piezoelectric substrate.

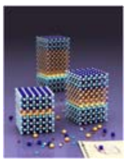




We have developed a reproducible method for fabricating interdigital transducers (IDTs) with characteristic dimensions well below 100nm. To this end, we have employed a recent and exciting lithographic technique: nano-imprint lithography (NIL), currently the most sophisticated form of nano-pattern reproduction by means of 'printing' or 'stamping'. The application of NIL ensures (i) access to large numbers of nanostructured samples from single masters, (ii) easy translation into different semiconductor and non-semiconductor materials, (iii) a large number of degrees of freedom for patterning, such as feature height and pattern inversion.



Oxide electronics



Complex oxide heterostructures featuring a significant degree of electronic polarization at the interfaces form exciting systems for the creation of novel 2-dimensional electronic and magnetic phases.

We elaborate new techniques for patterning such heterostructures, based on interfaces between **$SrTiO_3$ (STO) and $LaAlO_3$ (LAO)**, with the goal to realize (magneto)electronic charge transport devices.

in collaboration with ICE and IMS groups

Would you like to do your BSc or MSc project in NE?

During your BSc or MSc project you can choose one of the research themes above. You will get the responsibility for your own project, and are supposed to be a full member of the team under supervision of a PhD student or a post-doc. Would you like to get an idea of every-day life in NE? Please look at the other poster on the website, www.nano-electronics.nl.

If you are interested to do a project in NE, then have a look at our webpage for more detailed descriptions of the research directions and up-to-date projects. Often it is difficult to choose based on these short descriptions. We therefore invite you to make an appointment with Prof Floris Zwanenburg (f.a.zwanenburg@utwente.nl, room CR1435).

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NanoElectronics (University of Twente)

NE Themaposter 2012