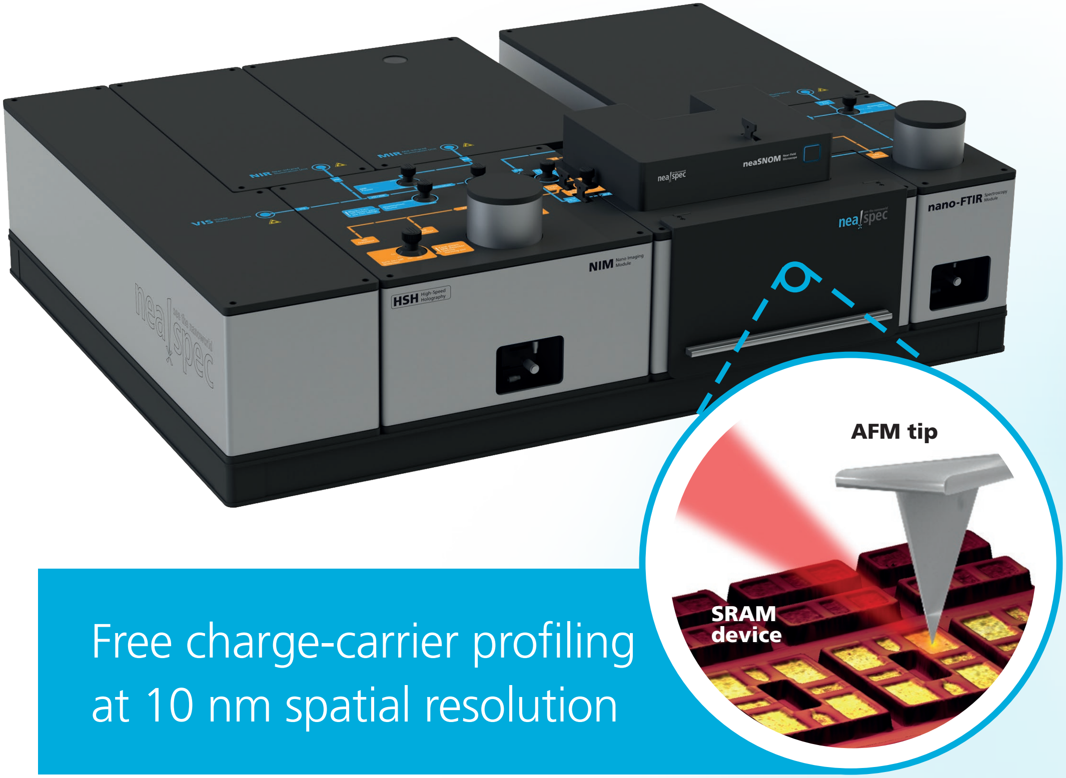
E-Book

characterization of semiconductors at the nanoscale

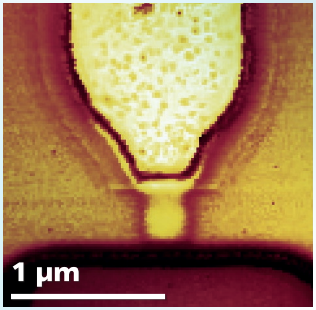
The neaSNOM is the most advanced and versatile optical platform for charge-carrier profiling, contamination analysis, defect analysis, and quality control of semiconductors at the nanoscale.



Free charge-carrier profiling at 10 nm spatial resolution

see the nanoworld
nea spec

SRAM doping profile



SRAM device: neaSNOM mid-IR imaging resolves doping gradient over 100 nm distance near the device contacts

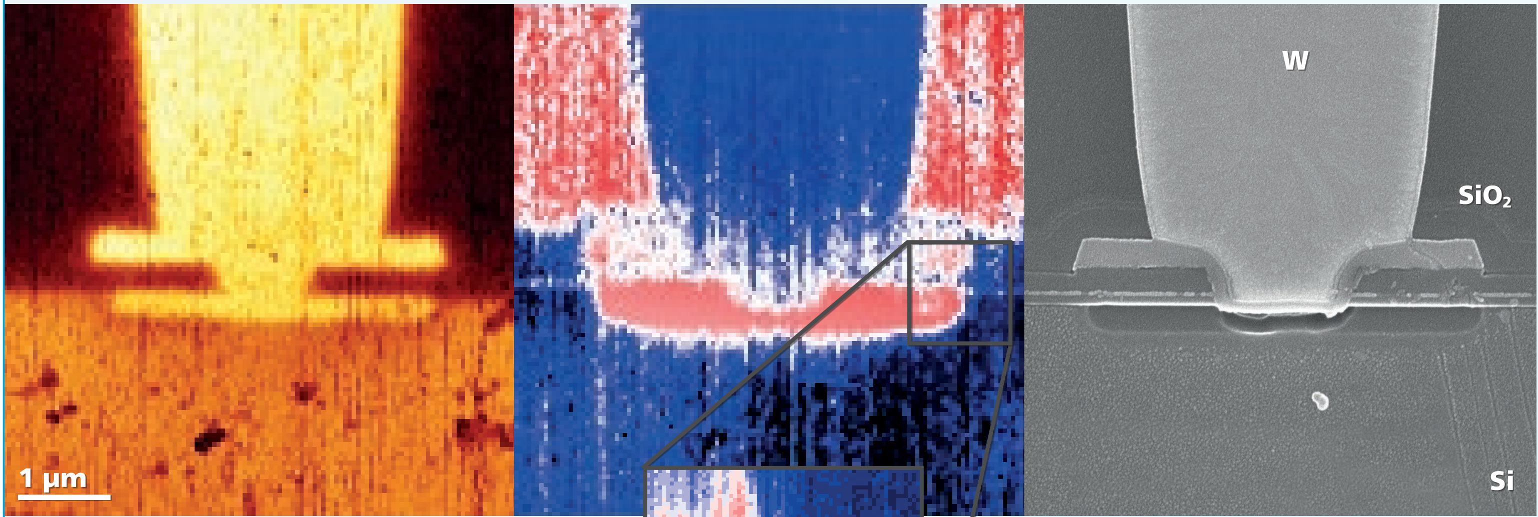
OSA The Optical Society

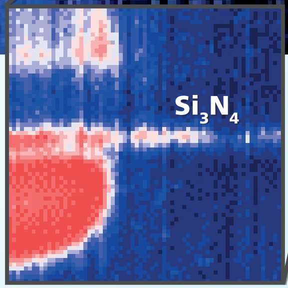
C. Liewald et al., Optica 2018, 5, 159.

Nanoscale IR nanoscopy of metal-oxide-semiconductor transistor

neaSNOM IR nanoimaging with sub-10 nm resolution directly probes charge carriers and provides high level of insight into device composition, doping concentration and carrier diffusion. This makes neaSNOM an excellent tool for interface and strain analysis, device engineering and optimization.

Optical amplitude **Optical phase** **SEM**





Defect analysis in device contacts

IR imaging of a MOS transistor cross section reveals local doping and material variations not detected in SEM images. An ultra-thin Si_3N_4 liner of only 10 nm width is clearly visble.
In collaboration with Infineon.

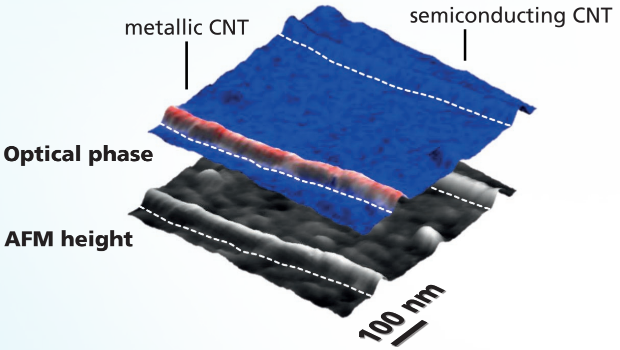
ADVANCED MATERIALS *A. J. Huber et al., Advanced Mater. 2007, 19, 2209.*

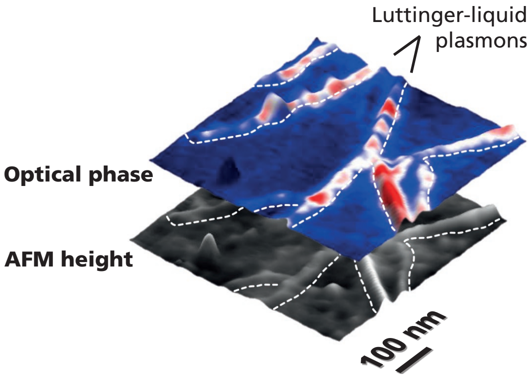
IOP Publishing *A. J. Huber et al., Nanotech. 2010, 21, 235702.*

neaSNOM is a perfect tool for nanoscale quality control & failure analysis of semiconductor devices.

Observation of Luttinger-liquid plasmons in single-walled carbon nanotubes

State-of-the-art patented technologies allow neaSNOM to perform artifact-free phase imaging at the nanoscale—an ultra sensitive technique for noninvasive contact-free analysis of low-dimensional materials.





CNT conductivity

The extreme sensitivity of the neaSNOM allows for probing conductive properties of individual single-wall carbon nanotubes (CNT) (diameter ~3 nm). While being nearly in-ditinguishable in the AFM topography, metallic nanotubes exhibit strong contrast compared to the semiconducting CNTs in the nanoscale optical phase image due to their higher carrier densities.

G. Nemeth et al., Phys. Status Solidi B. 2017, 1700433.

Luttinger-liquid in metallic CNT

High resolution IR nanoscopy images reveal Luttinger-liquid plasmons in metallic CNTs (diameter ~1 nm). The unprecidented sensitivity of neaSNOM allowed for the first time to directly observe the optical signature of this quantum phenomenon in one-dimensional electron gas of single-wall CNTs.

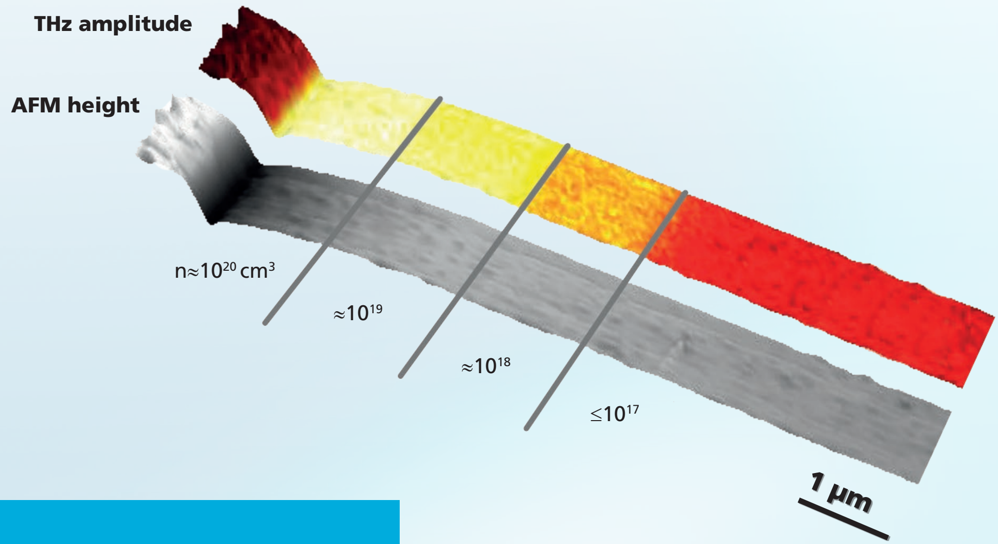
X. Tian et al., Nanoscale 2018, 10, 6288.

Z. Shi et al., Nature Photonics 2015, 9, 515.

IR imaging provides unique insights into optical properties of nanometer-sized carbon allotropes

Quantitative mapping of the freecarrier concentration in As-doped Si by THz nanoimaging

neaSNOM THz nanoimaging and spectroscopy is an excellent ready-to-use solution for quantitative carrier density profiling at 20 nm scale, which does not require complicated calibration procedures and can be applied to any doped semiconducting material.

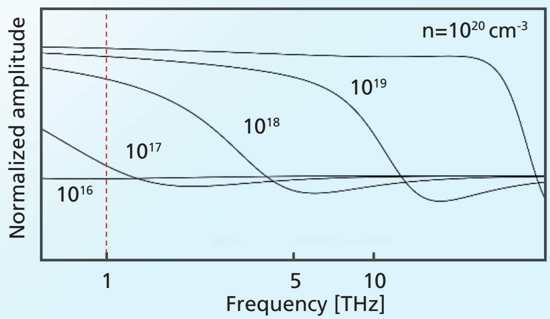


Carrier density quantification

Reflectance image at 1 THz acquired by neaSNOM on the IMEC calibration sample exhibits contrast that depends on the free carrier density. Comparison of this contrast with the calculated reflectance at the imaging wavelength (red dashed line in the bottom plot) for p-doped Si of different doping levels allows for calibration-free extraction of the carrier concentration with nanoscale spatial resolution.

THz nanoscopy accurately determines the doping concentration of semiconductor materials

THz amplitude calculation for doped Si



OSA The Optical Society — *C. Liewald et al., Optica, 2018, 5, 159.*

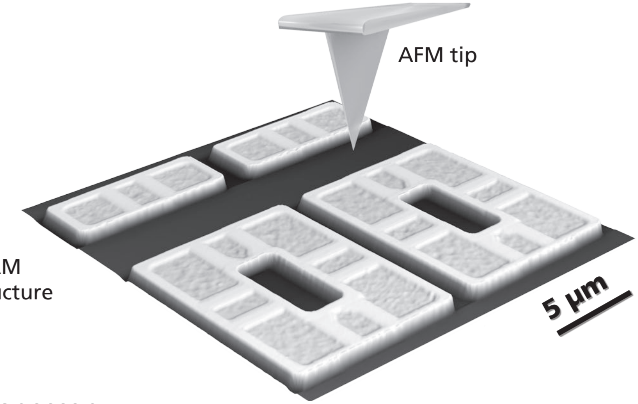
NANO LETTERS — *A. J. Huber et al., Nano Lett. 2008, 8, 3766.*

OSA The Optical Society — *H.-G. von Ribbeck et al., Opt. Express 2008, 16, 3430.*

Correlative nanoscopy of a commercial SRAM device at 10 nm spatial resolution

neaSNOM is built on the highest quality AFM platform and can utilize all well-established AFM-based techniques such as KPFM, EFM, etc. A combination of these techniques with state-of-the-art IR & THz imaging and spectroscopy paves the way towards better understanding of semiconductor nanostructures.

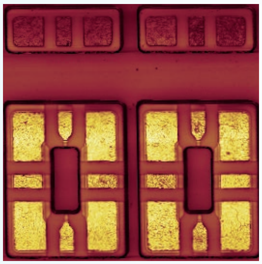
Correlative nanoscopy enables all-around nanoscale characterization of functional devices in a single instrument.



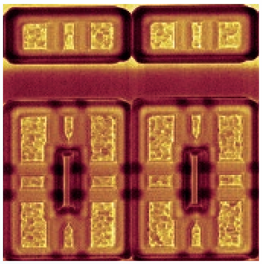
Near-field correlation nanoscopy

neaSNOM IR and THz imaging of a commercial SRAM device allows for the quantitative free-carrier profiling of functional structures in the whole technologically relevant range of doping concentrations. KPFM and EFM can be used to correlate these profiles with the structures electronic properties, differentiating between p- and n-doped regions.

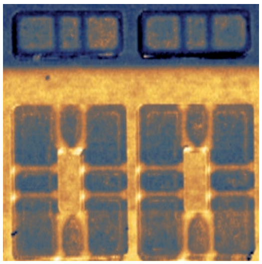
IR image



THz image



KPFM image



EFM image

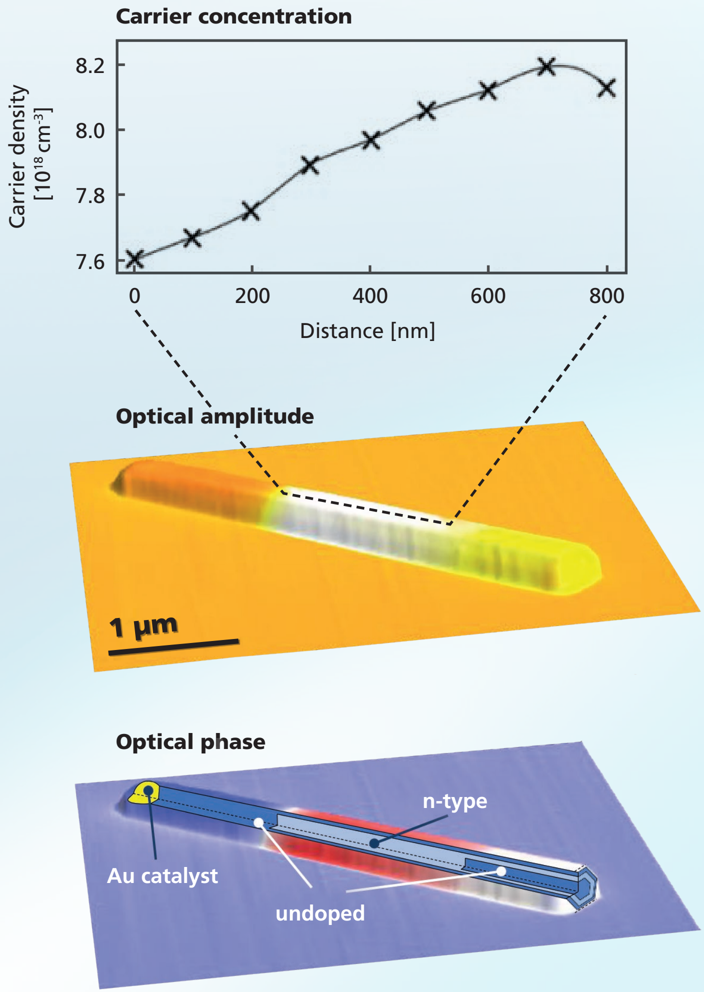
Offset 0 mV

EFM image

Offset 700 mV

Nanoscale investigation of growth-related doping profile in InP nanowires

IR nanoimaging measures the local conductivity without the need for electrical contacts. Thus, local conductivity changes at interfaces or defects can be mapped in real-space at 10 nm spatial resolution.



neaSNOM facilitates development of the next generation semiconducting materials

Conductivity analysis of InP nanowires

IR nanoscopy of a single modulation-doped InP nanowire highlights three differently doped, ca. 1-µm-long, segments along the nanowire growth direction. Measured reflectance and absorbance maps yield the local free-carrier concentration, revealing a ca. 10% variation along the center segment that directly relates to the specific growth conditions, thus allowing for the optimization of growth procedures.

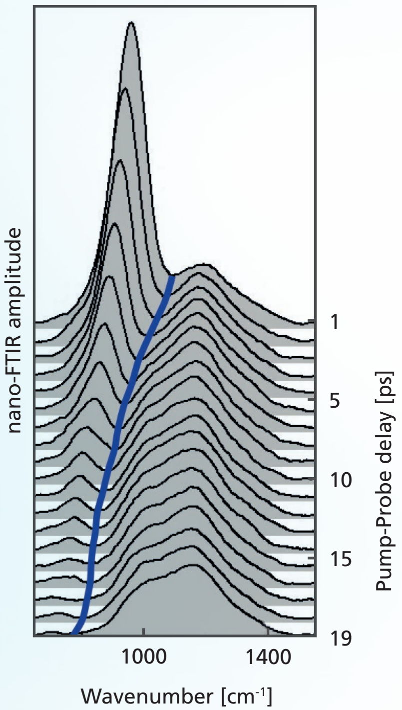
NANO LETTERS *J. Stiegler et al., Nano Lett. 2010, 10, 1387.*

nature COMMUNICATIONS *J. Stiegler et al., Nature Commun. 2012, 3, 1131.*

Probing femtosecond carrier dynamics in InAs nanowires at the nanoscale by ultrafast nano-FTIR

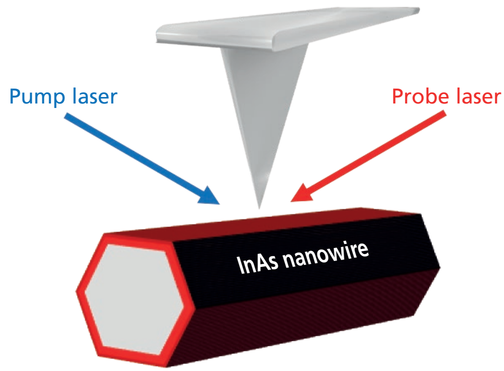
The unique, patented dispersion-free dual beam-path design of neaSNOM naturally supports pump-probe experiments with visible, IR and THz beams, and enables the nanoscale investigation of carrier dynamics in semiconductors with fs temporal resolution.

Ultrafast nano-FTIR

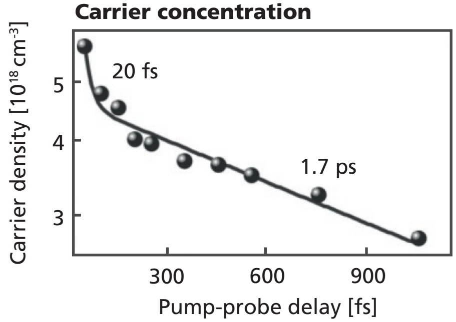


Ultrafast nano-FTIR of InAs

Ultrafast carrier injection due to femtosecond near-IR photoexcitation of InAs leads to the formation of a pronounced dip (blue line) in the nano-FTIR spectra (left), whose spectral position is determined by the plasma resonance of the created hot electrons and directly relates to the carrier concentration. Changing the pump-probe delay allows for monitoring of the carrier relaxation dynamics. Such an analysis performed with neaSNOM on a single InAs nanowire (right) with 10 fs temporal and 10 nm spatial resolution reveals the ultrafast formation of a surface depletion layer and even allows for the characterization of its depth.



Carrier concentration



Ultrafast nano-FTIR opens path towards efficient electronics and laser sources

nature photonics — *M. Eisele et al., Nature Photonics 2014, 8, 841.*

NANO LETTERS — *M. Wagner et al., Nano Lett. 2014, 14, 4529.*