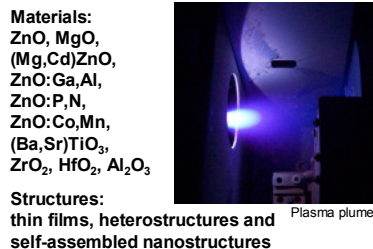
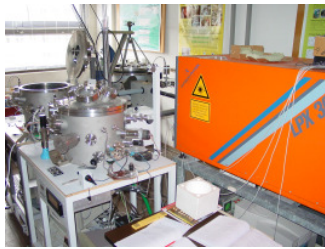


Our Methods

Materials Preparation



Materials:
ZnO, MgO,
(Mg,Cd)ZnO,
ZnO:Ga,Al,
ZnO:P,N,
ZnO:Co,Mn,
(Ba,Sr)TiO₃,
ZrO₂, HfO₂, Al₂O₃

Structures:
thin films, heterostructures and self-assembled nanostructures

Plasma plume

Excimer laser and three vacuum deposition chambers^{3,6}

Pulsed laser deposition (PLD)
Annealing chamber
Tube furnace
Polishing, metal evaporation, lithography, etching, bonding



Annealing² of ZnO substrate at 1200°C in O₂

in cooperation with Institute for Inorganic Chemistry (Dr. Gottschalch)
Metal-organic vapor deposition (MOVPE) for III-V semiconductors
Plasma-enhanced chemical vapor deposition (PECVD)

Structural Characterization



FEM/FIB nanolab¹



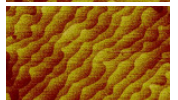
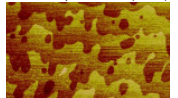
High resolution X-ray diffractometry¹



Atomic force microscopy⁴

Field emission scanning electron microscopy with focussed ion beam nanolab (FEM/FIB, EDX)
High resolution X-ray diffraction (HRXRD)
Reflection high energy electron diffraction (RHEED)
Atomic force microscopy (AFM, STM)
Surface profilometer
Secondary neutral mass spectroscopy (SNMS)

Atomic steps on ZnO (000 $\bar{1}$)



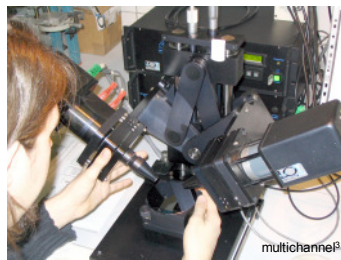
in cooperation with IMKM (Dr. Wagner)
Transmission electron microscopy (TEM, EDX)

DC	1Hz - 10MHz	10MHz - 50GHz	10meV-500meV	500meV-1.5eV	1.5eV-3eV	3eV-10eV	1-50keV
	Electrical	HF Electronic	FIR/MIR	NIR	VIS	UV/DUV	X-ray

Ellipsometry



IR-VIS-UV¹



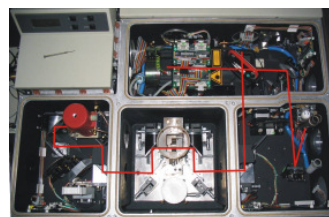
multichannel³



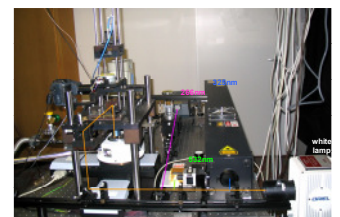
MIR²

Ellipsometers for MIR, IR-VIS-UV, and DUV spectral ranges
UHV low temperature ellipsometer
Multichannel ellipsometer

Optical Spectroscopy

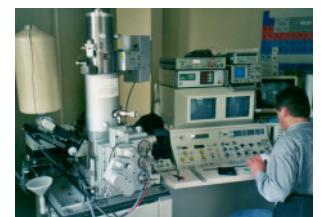


Fourier-transform infrared spectroscopy²



Mikro-PL-reflection and -Raman spectroscopy^{2,5,6}

Photoluminescence spectroscopy (PL)
Micro-photoluminescence imaging (μ -PL)
Optical Pumping
Micro-reflection & -Raman spectroscopy
Scanning cathodoluminescence (CL)
Fourier-transform IR spectroscopy (FTIR)
Transmission spectroscopy
Calorimetric absorption spectroscopy (CAS)
Magneto-optical Kerr effect (MOKE)



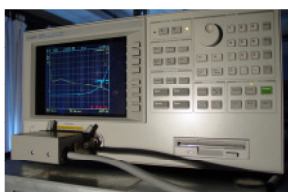
Low-temperature scanning cathodoluminescence¹



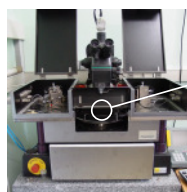
Pump laser (green), Ti:Sa laser (red) and 2HG (blue)



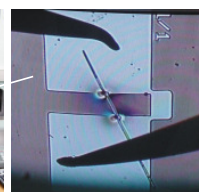
Electrical Characterization



Precision Impedance Analyzer¹

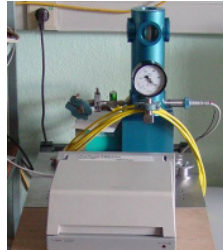


Wafer prober¹



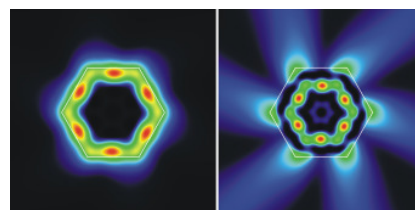
Probe tips testing a ZnO wire

Current-voltage spectroscopy (I(V,T))
Temperature-dependent Hall effect and magnetotransport
Capacitance-voltage spectroscopy (C(ω , V, T))
Photocurrent spectroscopy (MIR/FIR, VIS/UV)
Electron beam induced current (EBIC)
Deep level transient spectroscopy (DLTS)
Sampling oscilloscope (electr., opt.)
Frequency analyzer and noise measurements
S-parameter and network analyzer
Semiautomatic wafer prober
Laser device characterization, electroluminescence



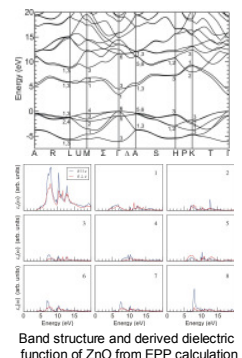
I(V) and I(V,T) measurements

Theory



Light intensity in whispering gallery modes in hexagonal ZnO nanowires

Band structure calculations with empirical pseudopotentials (EPP)
Optical modes in dielectric waveguides
Poisson equation and depletion layers



Band structure and derived dielectric function of ZnO from EPP calculation