# Nano-metrology for Optoelectronics

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Growth (MBE) and characterization of:
native oxides, quantum dots, and nitrides

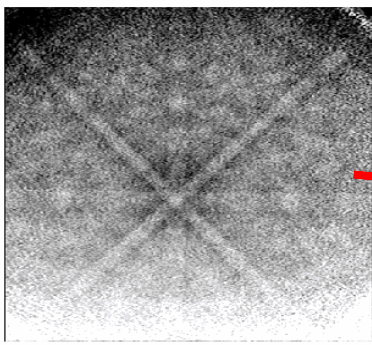
Successes and current areas of development

# Strain in Native Oxides

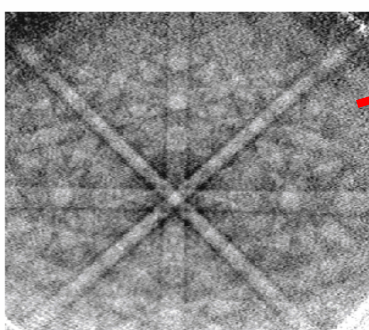
In collaboration with Roy Geiss and Bob Keller in Materials Reliability Division

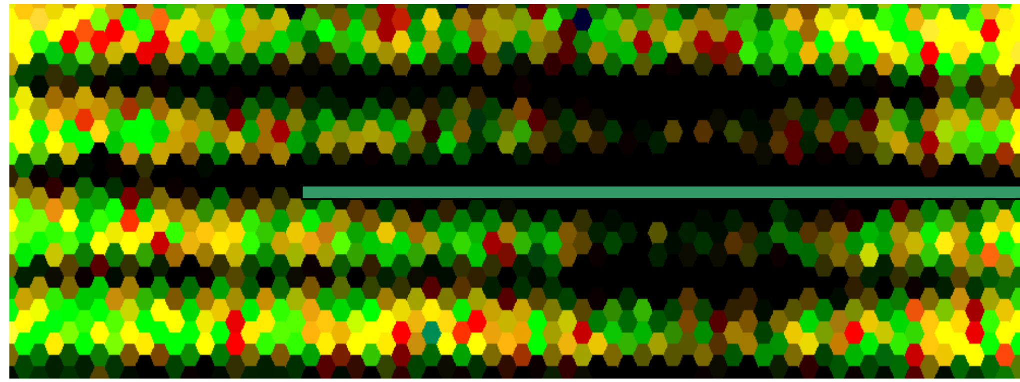
## Electron Back Scatter Diffraction (EBSD) analysis of strain

Close to oxide interface

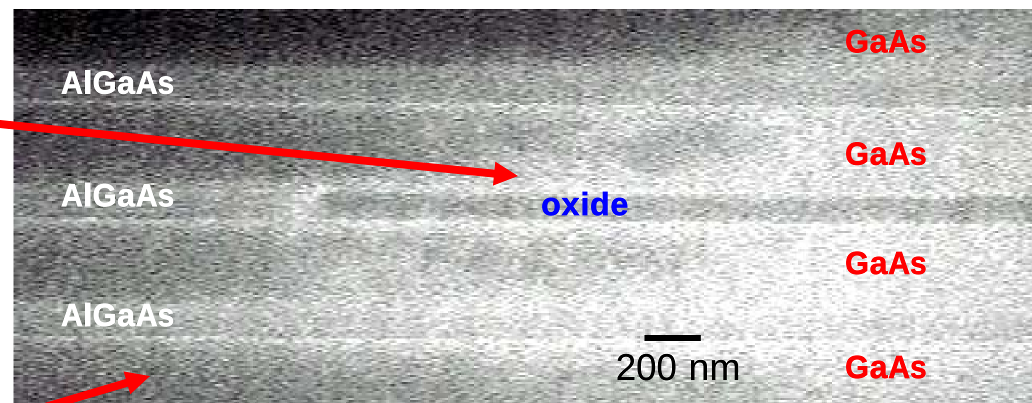


Far from oxide interface





oxide



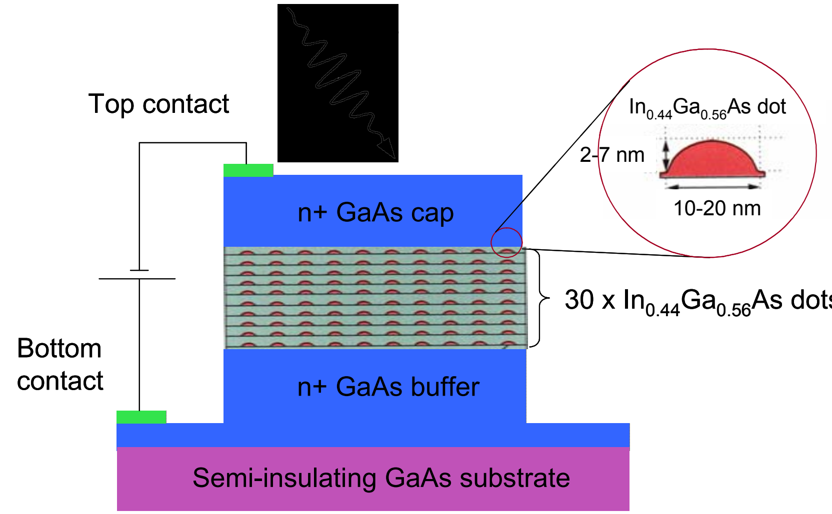

Diffuseness indicates larger strain gradient near oxide interface.

Resolution ~20 nm.

# Quantum Dots

**Challenges**

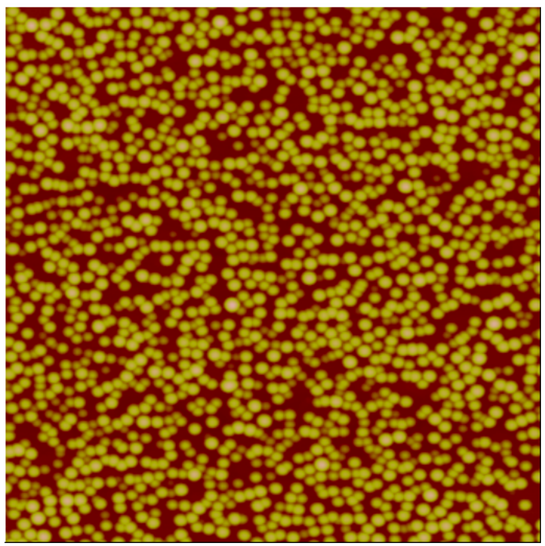
- Shape
- Size
- Strain
- Doping level
- Composition

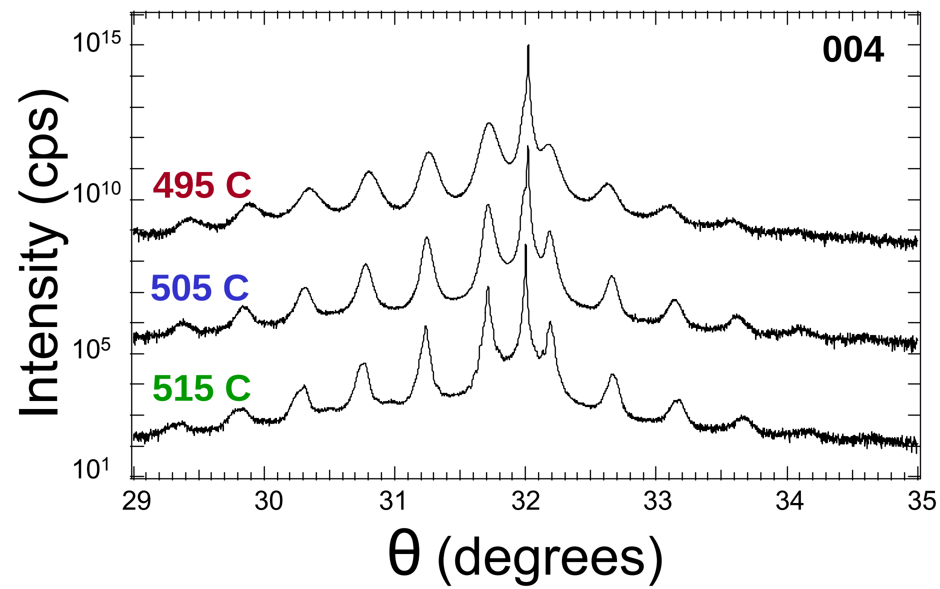



## AFM of unburied and X-ray of stacked quantum dots

2 x 2 μm$^2$

z-scale 15 nm





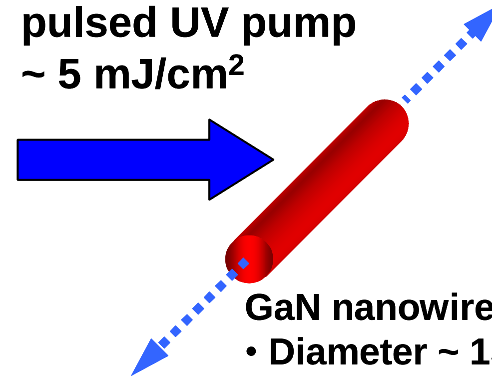

AFM reveals height and density of uncapped dots.
Measurement of buried dot size and shape not possible.

XRD reveals strain in matrix surrounding dots.
More satellites on the left of the substrate peak suggest that the 30-period superlattice is under compression

# Nitride Nanowires

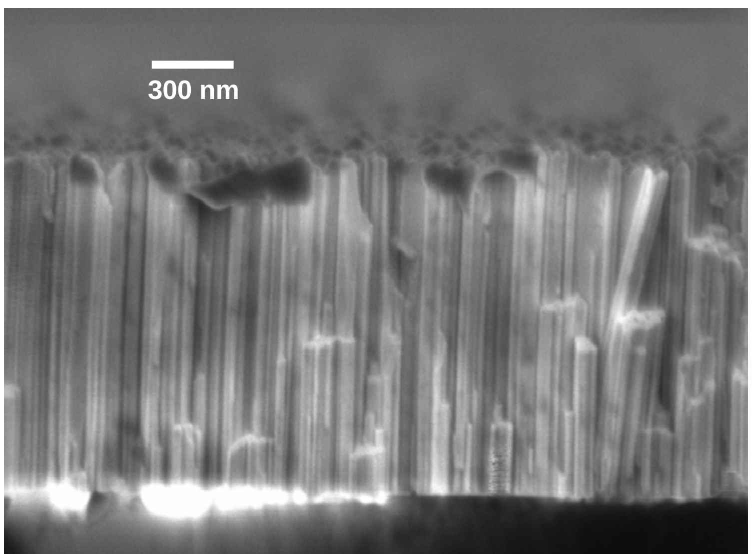
**Challenges**
- Size
- Separation
- Crystal quality
- Defect structure
- Doping level
- Optical properties

**pulsed UV pump**
**~ 5 mJ/cm$^2$**

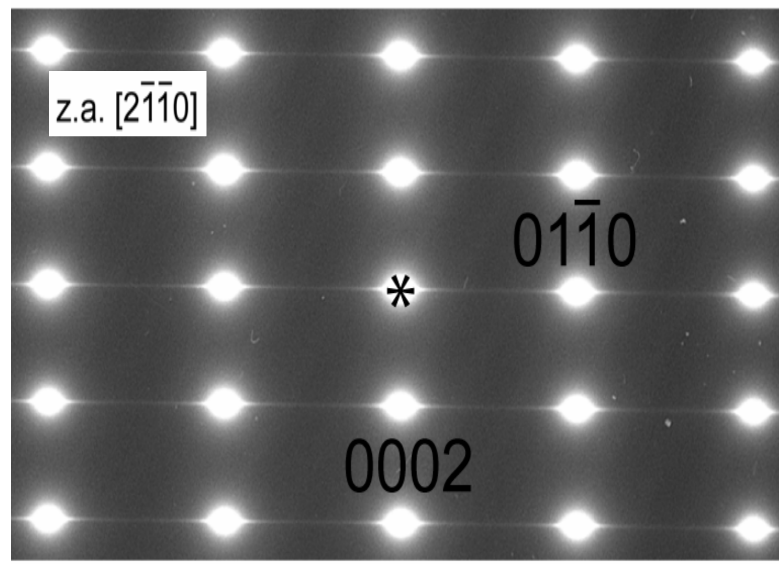


**GaN nanowire laser**
- **Diameter ~ 150 nm**
- **Length ~ 30μm**

FESEM and TEM of GaN/$Al_2O_3$




FESEM reveals wire size and shape.
Assessment of isolation difficult




TEM reveals crystal quality and defect structure.
No streaks parallel to [0001], low density of basal plane stacking faults.
Streaks parallel to [0 1 1 0]

image by I. Levin MSEL

## How does metrology affect your present work in nanomaterials?

- Using different techniques – high resolution electron microscopy, scanning probe microscopy, and x-ray much more important.
- Assessment of material crystalline quality more important and more difficult.

## What metrology issues are of the most significance to you for your work in the coming 5 to 10 years?

- Nanoscale strain measurement.
- Nanoscale electrical characterization (conductivity, dopant type, concentration and distribution).
- Measurement of structure size and shape.
- Assessment of material defect structure.
- Nanoscale optical spectroscopy (photoluminescence, cathodoluminescence).
- High spatial resolution: deconvolution of sample-probe interaction.