Advanced Transmission Electron Microscopy of Semiconductor Nanowires for Solar Cell Applications

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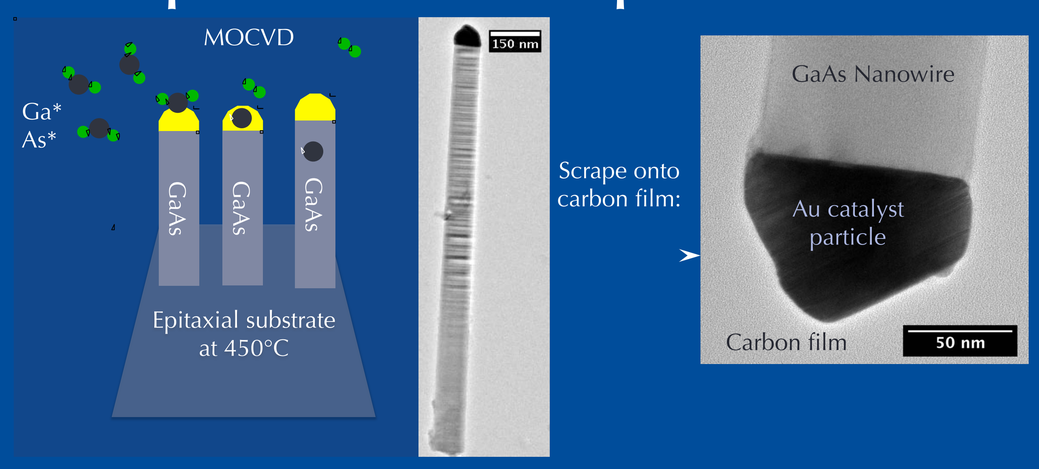
Abstract

Semiconductor nanowires are of interest for applications including solar cells and light-emitting diodes. Their accurate and quantitative characterization requires the development of advanced transmission electron microscopy (TEM) techniques [1].
Here, we analyze GaAs nanowires capped with Au catalyst particles are heated in-situ in the TEM to study their catalytic dissolution, thereby also providing relevant insights into their growth.

Transmission Electron Microscopy

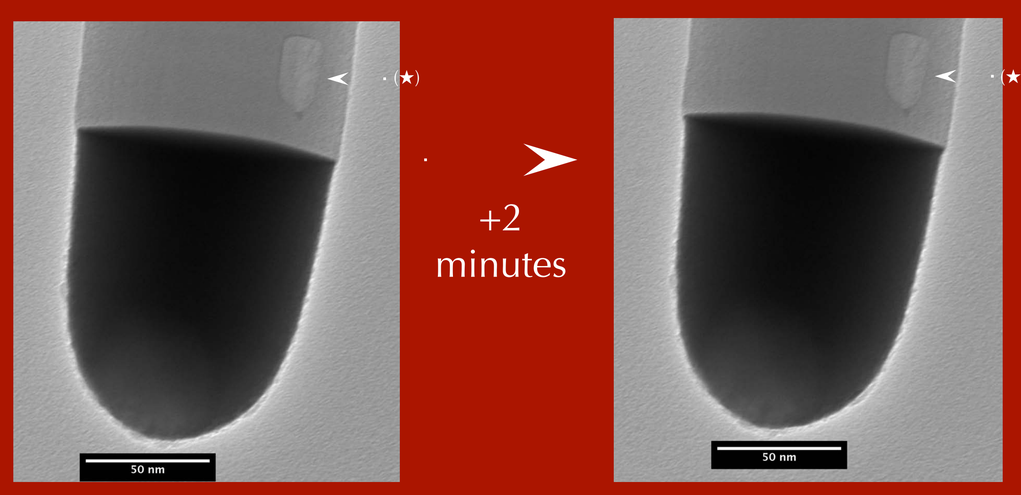
Transmission electron microscopy (TEM) is a characterization instrument which operates on length scales from microns to sub-Ångström, depending on technique, and that allows for many different modes of operation, both in imaging and diffraction regimes. With specialized specimen holders and microscopes, in-situ experiments involving applying heat, light, or gases are possible. [1]
The experiments presented here were performed in the Environmental TEM at the Center for Electron Nanoscopy, an FEI Titan 80-300 operated at 300kV in conventional high-vacuum mode.

Specimen Preparation



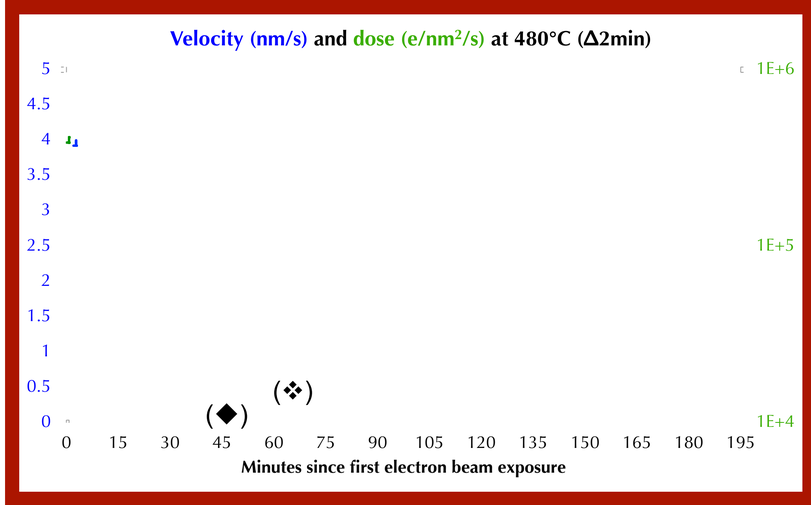
- Nanowires were grown at Lund University, and subsequently prepared for TEM by mechanical harvesting onto 3mm grids.
- For high temperature experiments, Au-supported carbon-coated grids were used.

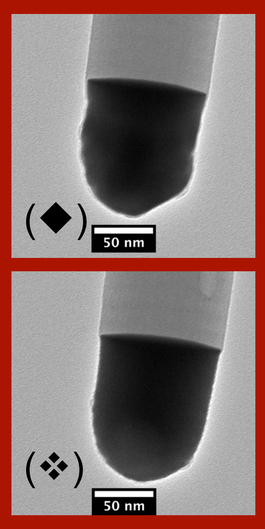
In-situ TEM Dissolution



- When heated in the TEM to 480°C, the wires are observed to dissolve via ledge propagation along the Au-GaAs interface, as has been previously reported elsewhere.[2]
- Above images are from a time-lapse series.
- Some wire decomposition (★) is also seen.

Quantitative Analysis





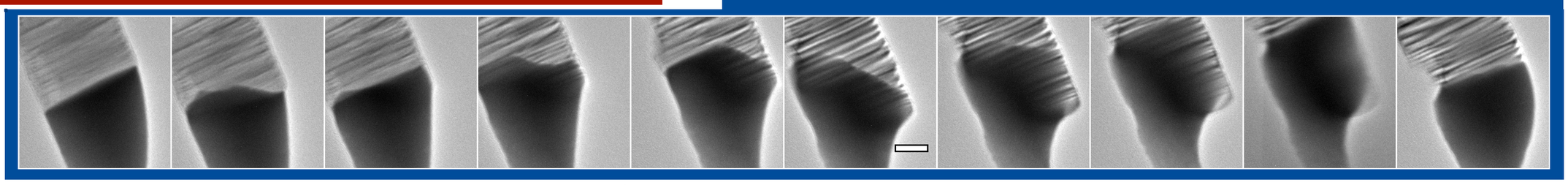
- Tracking of the dissolution front across images.
- Increase in dissolution speed with electron dose
- Non-steady rate and additional high-velocity changes.
- Correlations between velocity changes and changes in particle morphology are being investigated. See ◆ and ❖ above.

Conclusions

- When Au-catalyzed GaAs nanowires are heated in the TEM, they dissolve along the Au-GaAs interface.
- This dissolution process can be characterized as it occurs, and the rate can be affected by electron dose.
- Rapid changes can occur in morphology.

Future Work

- Effect of the electron beam – dose dependence
- Effect of specimen temperature
- Effect of applying gas in the TEM
- Stochastic effects: non-ledge-propagation dissolution
  - see results below acquired at 560°C (1 minute interval, 25nm scale bar)



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References
[1]: Williams and Carter. **Transmission Electron Microscopy: A Textbook for Materials Science**, 2nd ed. 2009.
[2]: Persson et al. **Nature Materials** (2004) vol. 3 (10) pp. 677-681.