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Investigations of Nanowire-Substrate Growth Interfaces

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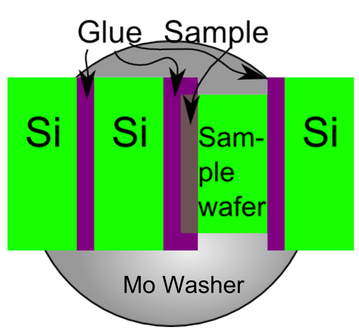
Abstract

A common approach for analysing nanowires using transmission electron microscopy (TEM) involves removing them from their substrate and subsequently transferring them onto carbon films. This sample preparation method is fast and usually results in little structural change in the nanowires [1]. However, it does not provide information about the interface between the nanowires and the substrate, whose physical and electrical properties are important for many modern applications of nanowires. In particular, strain and crystallographic defects can have a major influence on the electronic structure of the material. An improved method for the characterization of such interfaces would be valuable for optimizing and understanding the transport properties of devices based on nanowires.

Sample preparation

- Sandwiched and cut in 1 mm thin slices.
- Glued to a Molybdenum washer.
- Thinned down to ca 15 µm.
- Polished down to ca 5 µm.
- Ion milled in two steps to get a thin area.



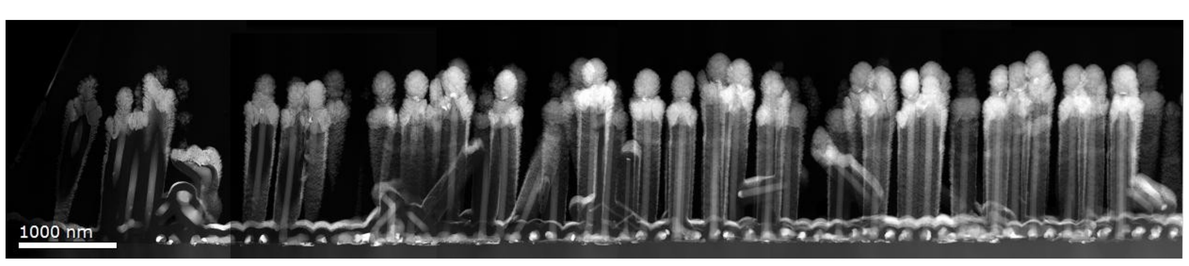


Figure: A stitched monage of the final result. This particular sample was a particularly tricky system: InP nanowires on a Si-substrate, with a oxide shell and a gold coating.

Chemical composition at the interface

- Energy dispersive x-ray spectroscopy

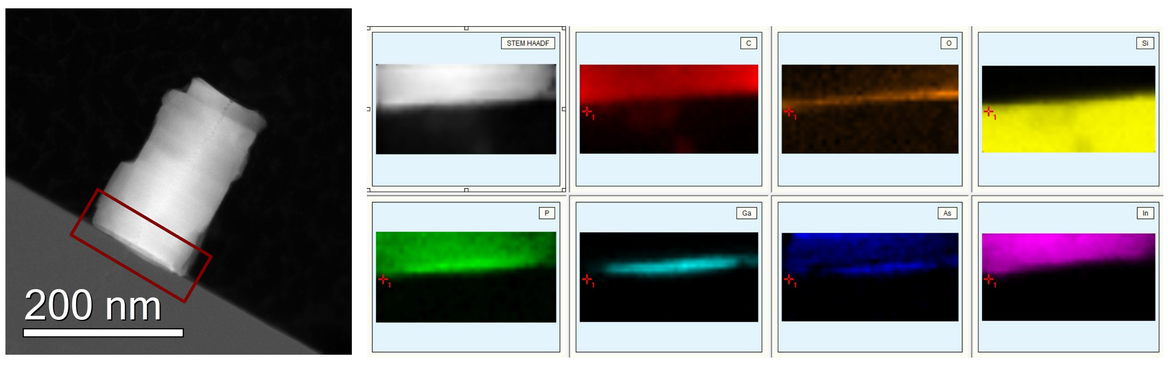


Figure: Energy dispersive x-ray spectroscopy of a nanowire substrate interface. This measurement gave a hint on the incorporation of Gallium in the bottom of the nanowire, an unintended result from a purging of the growth chamber.

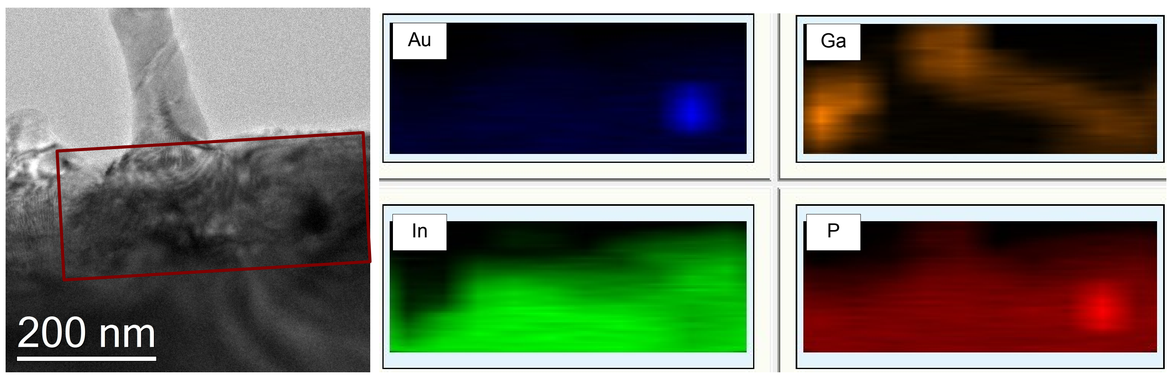


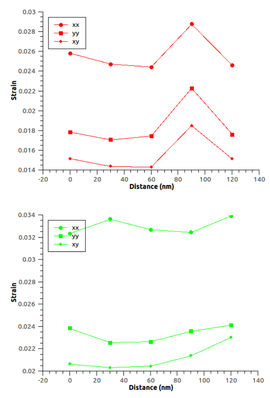
Figure: Energy dispersive x-ray spectroscopy of a nanowire substrate interface. This Nanowire was indeed intended to incorporate Gallium, (InGaP), but a large area of the substrate around the nanowires is covered in GaP, wich was not intended. There is also the incorporation of Gold, probably from the catalytic growth process, into the surface.

Strain analysis of the interface

Geometric phase analysis for strain information

As described by [2], using software from [3].

- Quick and easy
- Lattice resolution (the graph here is for demonstration)
- Software is readily available
- A thin sample is necessary



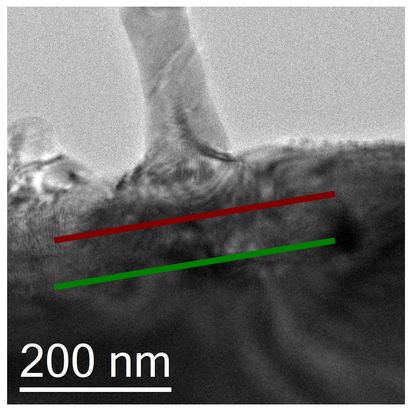
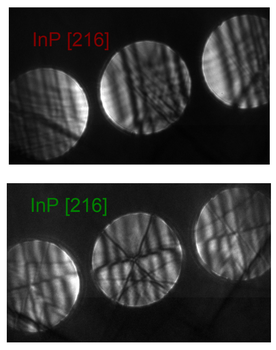


Figure: Strain in the horizontal direction, avaraged for each point over 60x60nm squares. The colours correspond to the lines in the image.

Convergent beam electron diffraction for strain information

As described by [4] and using the JEMS simulation software [5].

- Gives good results even for very thick samples
- Can be tricky to analyse
- Cannot be used close to interfaces between structures



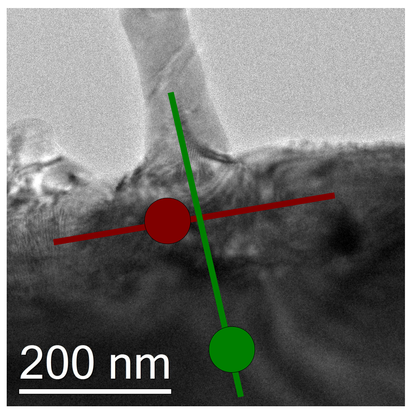


Figure: It is possible to use convergent beam electron diffraction measurments for strain analysis. Unfortunately in the above case, the GaP:InP area below the wire (see the section on chemical mapping on the left) made this impossible. This is an obvious weakness with this method.

Future outlook

- Improve reliability of the sample preparation.
- Examine and evolve the reliability of the strain methods.
- Examine more methods for strain analysis: Dark-field holography and Nano beam diffraction.

References

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