Epitaxial Growth of Nearly Lattice Matched Core-Shell GaAs/$Pb_{1-x}Sn_xTe$ Nanowires

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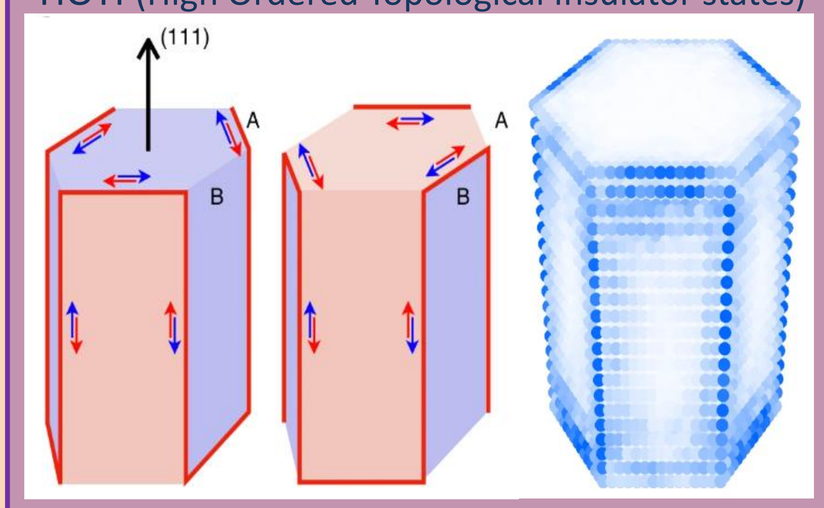
Motivation

The nanowire heterostructures enable bandgap engineering in a one-dimensional nanostructure. In the planar semiconductor heteroepitaxial systems, typically large lattice mismatch results in the low-quality interfaces and high dislocation densities, which further degrade the electrical properties of material. These effects can be avoided in the nanostructures, due to the nanoscale dimensions. Here, we studied full and half-shells of IV-VI narrow gap semiconductors on III-V nanowires (NWs). The topological crystalline insulator $Pb_{1-x}Sn_xTe$ alloy is chosen as a shell material that possesses the band inversion property for some critical concentration of Sn.

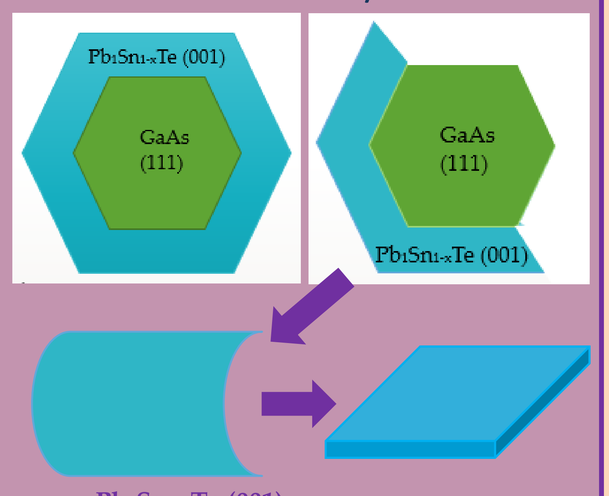
Objective

HOTI (High Ordered Topological Insulator states)

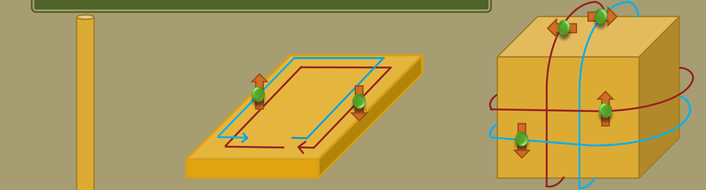


Nature Physics volume 14, pages918–924 (2018) Frank Schindler, Zhijun Wang and Titus Neupert

Full and half core/shell NWs



Introduction



- 1D material
- 0D topological states

- 2D material
- 1D topological states

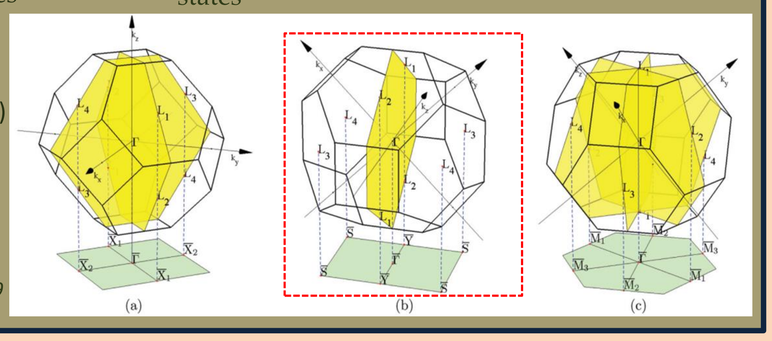
- 3D material
- 2D topological states

←TCI States

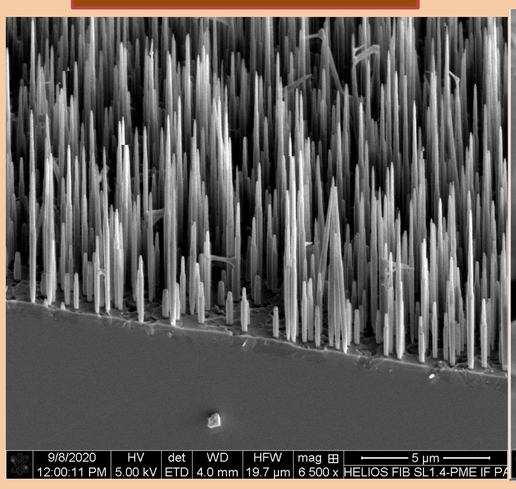
Brillion zone for a) (001) b) (110) c) (111) →

Safaei *et al.* PRB 88, 045305 (2013)

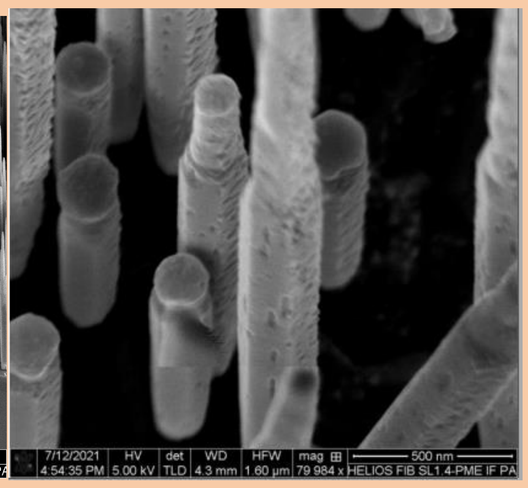
Experimental evidences of (001) *Dziawa et.al , Nat. Mat. 1206.1705 (2012),* **and (111)** *Polley et al. PRB 89 (2014)*



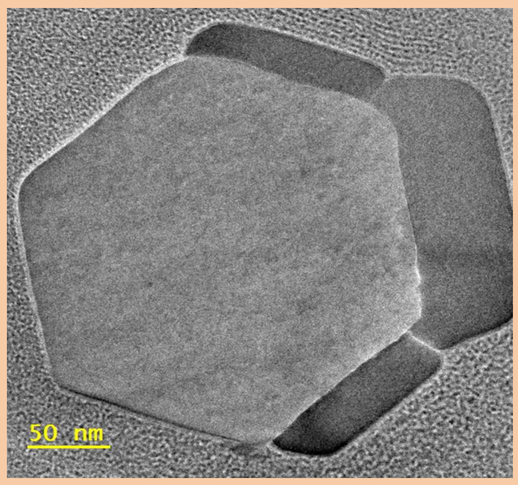
Results



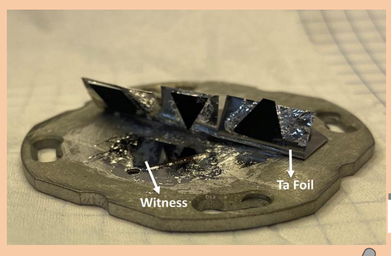
GaAs as-grown NWs (side view)

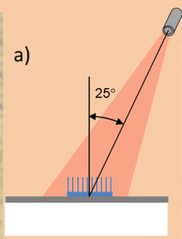


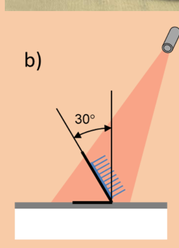
PbSnTe/GaAs core full-shell NWs (side view)

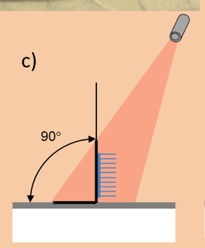


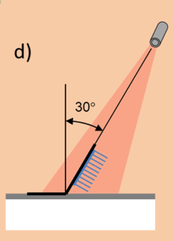
PbSnTe/GaAs core half-shell NWs (cross-sectional view)

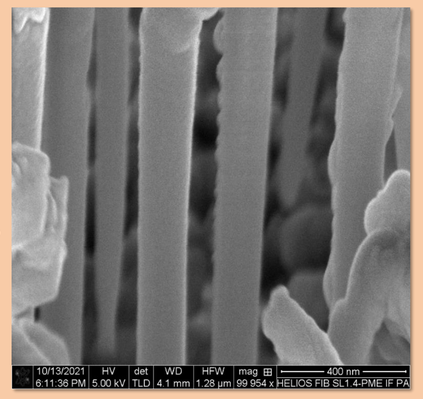




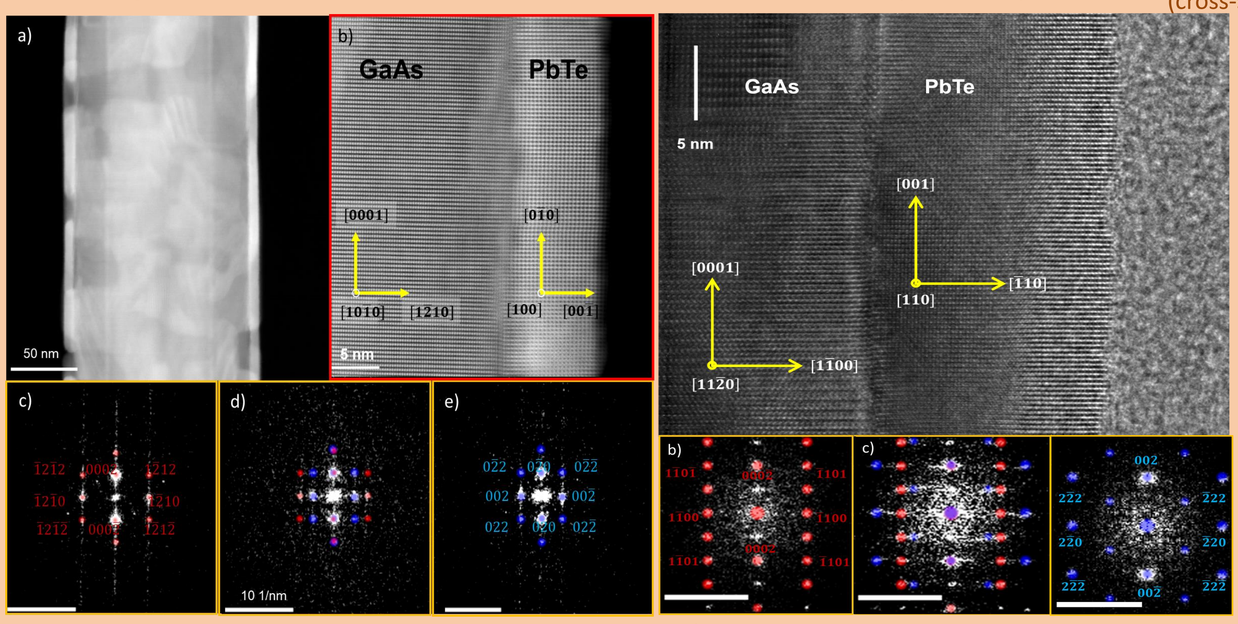




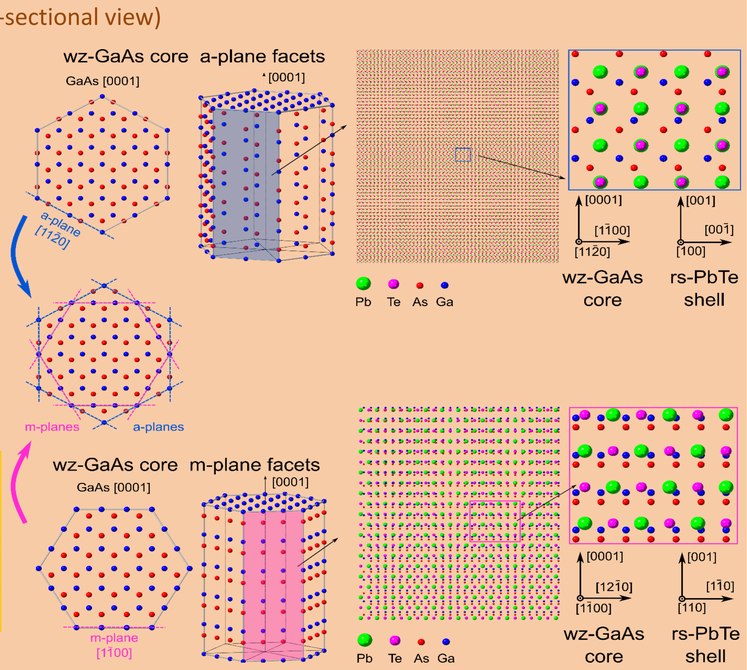




← Tilted NWs approach



High resolution TEM picture of single full-shell PbTe/GaAs Nanowire with their respective FFT images where solid red points represents GaAs and solid blue points represents PbTe



PbTe(shell) – GaAs(core) lattice mismatch:

along [0001] GaAs NW axis:

$d^{GaAs}_{(0002)} = 3.285$ Å $d^{PbTe}_{(0-20)} = 3.219$ Å

$$f^{PbTe/GaAs}_{exp} = 0.0205$$

along [11-20] direction (parallel to GaAs NW sidewall, perpendicular to the NW axis)

$d^{GaAs}_{(11-20)} = 1.9922$ Å $d^{PbTe}_{(220)} = 2.2839$ Å

$$f^{PbTe/GaAs}_{exp} = 0.1125$$

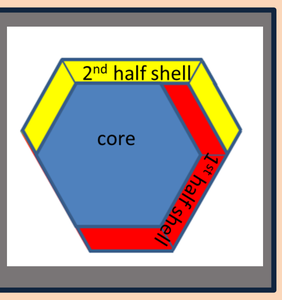
In case of bulk, $f \approx 14$ %

Conclusions

- We are able to grow full and half shells of IV-VI on III-V nanowires
- It's easier to grow smooth and unbroken shells on inclined nanowires as compared to perpendicular one
- We got nearly lattice matched shell on the side walls of (-110) GaAs nanowire

Future plans:

- To obtain completely smooth and unbroken core-shell nanowires to observe their TCI states and expected HOTI states
- To grown second half shell on the side of nanowires



Acknowledgement

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Details

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