









Forest of PbS Nanowire "X-mas Trees"

These nanowire tree structures demonstrate an entirely different nanowire growth mechanism that is driven by screw dislocations.

























To Twist or Not to Twist: Re-Examine the **Energy Equations** Two pathways to relieve strain energy: A $E = 2\pi\gamma r + \frac{\mu b^2}{4\pi} \ln(\frac{R}{r}) - \frac{\mu b^2}{4\pi} \frac{(R^2 - r^2)}{(R^2 + r^2)}$ b + $\frac{dE}{dr} = 0 \rightarrow b_{TOTAL} = \sqrt{\frac{8\pi^2\gamma r}{\mu}} * \frac{R^2 + r^2}{R^2 - r^2}$ R New energy minimization: D hollowing out at small b; Total с (mm) Twist Eshelby twist at large b. Tube urgers vector R = 12.6 nm $b_{TWIST} = b_{TOTAL} - b_{TUBE} = \sqrt{\frac{8\pi^2 \gamma r}{\mu}} \left(\frac{R^2 + r^2}{R^2 - r^2} - 1\right)$ 10 r = 2.9 nm 8 (mu) q 6 Twist vs. hollow at different r/R: 2 0.5 R thick tubes have little twist. 1R0 r r/R^{0.6} 0.4 0.8 1.0 thin-walled tubes have twist. Energy Minimization \rightarrow b= 1.3 nm Direct Measurement \rightarrow b= 1.9 nm Morin, Bierman, & Jin in press Science, 2010.



Solution Grown Nanomaterials of Inexpensive Semiconductors for Solar Energy Conversion

Dislocation-driven nanowire growth has advantages over VLS growth for large scale applications of nanomaterials for energy.

- No metal catalysts,
- vapor or solution phase growth
- Aqueous solution growth better for large scale synthesis!
- Heterojunctions by simple solution synthesis?
 e.g. Fe₂O₃ TiO₂

For example, solar energy from Fe₂O₃ NWs?

- Hematite is a poor semiconductor ($E_o = 2.1 \text{ eV}$)
- Cheap, stable in aqueous solutions, promising for photocatalysis
- Nanowires might circumvent the problems
- How to construct solar devices with rust nanowires?

On going – Mark Lukowski, Miguel Caban, Fei Meng, Matt Faber





Significance of the Discoveries

- ✓ a "new" nanowire growth mechanism driven by screw dislocations
- ✓ Clear demonstration of the Eshelby twist
- ✓ Spontaneous formation of single-crystal nanotubes driven by screw dislocations
- ✓ General to 1-D growth of many materials, vapor or solution growth, such as:
 - **ZnO**, *PbQ* (we have proven herein)
 - □ InN, GaN, Te, SnO₂, etc (seen in literature)
 - □ SiC, CdS, CdSe, etc.
- ✓ Used classic crystal growth theory to conclusively prove dislocation-driven growth
- ✓ Complex NW structures useful for solar energy conversion
- ✓ Large scale, low cost synthesis of NW materials

Unanswered questions and future work:

- How does the screw dislocation originate?
- The perfect platform for investigating the effects of a single dislocation on material properties.



