Development of crystalline silicon suspension structures

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Materials aspects - crystal suspension

Needed:
  single crystal
  few impurities
  smooth surface
  few defects
  low stress

As-drawn:
  polycrystalline
  thermally induced stress
  smooth core surface

Improvements possible via:
  interface coatings
  laser annealing/tapering
  addition (then removal) of other elements
Fiber drawing technique

- Wide range of core diameter
  - 10 - 300 micron (so far)
  - (fiber - cane)

- Glass as processing vessel for recrystallization

Source: Cover Image of Draic and Ballato article in the Journal of the American Ceramic Society.

**CO$_2$ laser treatment**

- Recrystallization
- Thermal stress/strain relief
- In situ observation of solidification process


Crystal structure

XRD

(Not $\theta$-2$\theta$)
rotation of fiber allows determination of crystallite #, orientation

As drawn

Laser annealed

Lonsethagen, K.  http://hdl.handle.net/11250/2615575
Interface coatings

Early Si draws - cladding damaged, oxygen inclusion

Interface layer
compliant -- reduced stress
blocks oxygen transport
X-ray Diffraction DA30518 Si fiber

recent results -coating can limit nucleation
(and possibly affect orientation)
Addition of element - alloy SiGe

Addition of Ge lowers m.p.

Translation of melt zone allows regrowth of single crystal

Reduced temperature, alloy

Travasso, et al.
DOI: 10.5281/zenodo.3820523
**Addition - GaSb/Si eutectic**

CO₂ laser draws low mp material to center of beam

Lower temperature melt translating through core leads to crystallization further from the nucleation temperature

Low solid solubility → pure silicon left behind
**Addition- Au/Si eutectic**

XRD/TEM shows bicrystal; IR & THz transmission $\rightarrow$ high quality material

**Challenge:** Au introduced during draw - how to remove excess?
Possible future directions

Longer single crystals -
• eutectic management

Larger cores - stress management
• interface coating
• glass composition
• rectangular cross-section?

Crystal orientation
• seeds for regrowth

Isotopically pure Si?
potential 1.5x improvement in thermal cond.
Summary

• Why glass-clad semiconductor fiber?
  – High quality surfaces
  – Terminal cones can be fabricated as part of the draw
  – Purification, crystallization processes developed
  – Doping possible if desired

• Fabrication of semiconductor fibers
  – Fiber drawing technique
  – CO2 laser treatment

• Status
  – Progress in formation of single crystals of ‘large’ dimensions
Thank you