Temperature Dependence of the Dielectric Function of Indium Antimonide

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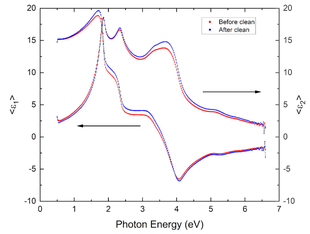
Abstract:

- Measurement of the dielectric function of bulk InSb from 80 to 800k near the direct band gap (E_0)
- Using FTIR spectroscopic ellipsometry in an ultra-high vacuum (UHV) cryostat with diamond windows.
- Calculations indicate that InSb should undergo a topological phase transition from semiconductor to semi-metal (and topological insulator) at 600 K (negative band gap).

Sample Preparation:

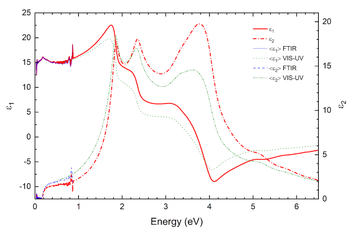
InSb cleaning process (on a Branson Ultrasonic Cleaner):
• Indium Antimonide sample was cleaned using water and isopropanol on the ultrasonic cleaner for 15 minutes on each (respectively) to remove organic layers before the temperature dependance ellipsometry measurements.



	Oxide Thickness (Å)
Before Clean	28.2
After Clean	22.5

Indium Antimonide:

VIS-UV and FTIR spectra (dielectric functions)



Band Structure at 300 K

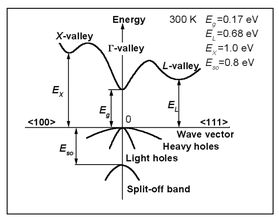
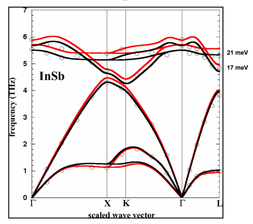


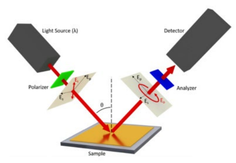
Figure from: http://www.ioffe.ru

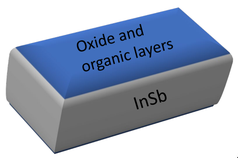
Phonon Dispersion



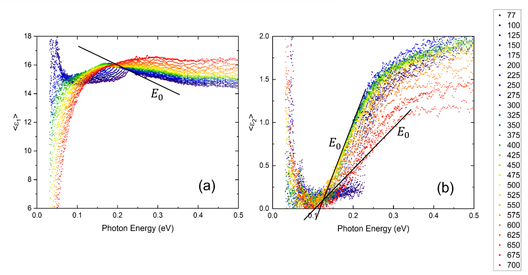
L. Lindsay et. al., Phys. Rev. **B** 87, 025901 (2013)

Experiment:

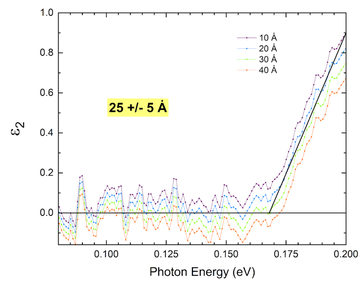




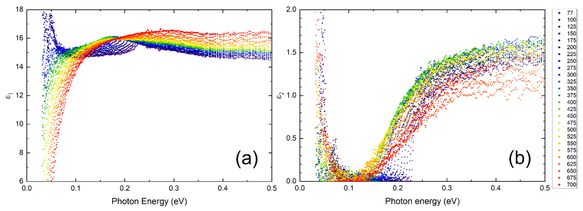
Pseudo Dielectric Functions:



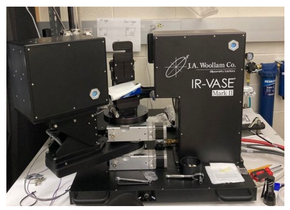
Oxide Correction:



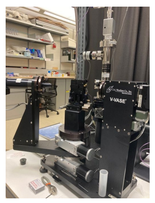
Dielectric Functions:



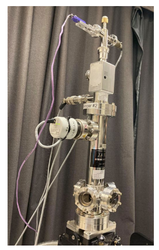
Equipment:



J.A. Wollam IR-VASE

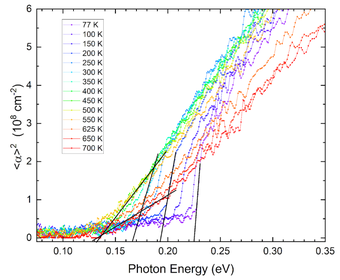


J.A. Woollam V-VASE



Cryostat with diamond windows

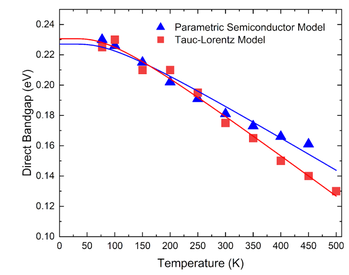
Tauc Plot:



Direct Bandgap Models:

Tauc-Lorentz Oscillator Model: $\varepsilon_2(E) = \theta\,(E - E_g)\left[\frac{\left(AE_0C(E-E_g)^2\right)}{[(E^2-E_0^2)^2 + C^2E^2]E}\right]$

Bose-Einstein Model: $E(T) = a - b\left[1 - \frac{2}{e^{\frac{\theta}{kbT}} - 1}\right]$



Conclusions:

- Dielectric functions of InSb was measured from 80 to 700K with an oxide correction of 25 +/- 5 A
- Band gap is difficult to determine:
  1. Tauc-Lorentz extrapolation was made
  2. Parametric semiconductor model yields different results
- Band gap shrinks with increasing temperature:
  1. Follows Bose-Einstein relationship up to 500K
- First measurements of InSb band gap above 300 K
- Does InSb become a topological insulator like α-tin at high temperatures (negative band gap)?

References:

[1]C. L. Littler and D. G. Seiler, Appl. Phys. Lett. **46**, 986 (1985).

[2] S. T. Schaefer, S. Gao, P. T. Webster, R. R. Kosireddy, and S. R. Johnson, J. Appl. Phys. **127**, 165705 (2020).

[3] http://www.ioffe.ru/SVA/NSM/Semicond/InSb/bandstr.html

[4] S. Zollner, S. Gopalan, and M. Cardona, SSC, **77**, 485-488 (1991).