Intercalation of Cu into N-Type Polycrystalline Bi₂Se₃

Juntai Chen¹, Deyi Fu², Junqiao Wu²
¹City College of San Francisco; ²Department of Materials Science and Engineering, UC Berkeley

2013 Transfer-to-Excellence Research Experiences for Undergraduates Program (TTE REU Program)

Abstract

The intercalation of copper into bismuth selenide (Bi₂Se₃) was investigated using aqueous electrochemical methods together with post-annealing. Carrier concentration ranged from the order of 10¹⁸ to 10²⁰ cm⁻³ were obtained. Fourier Transform Infrared (FTIR) Spectroscopy measurements showed that the optical absorption edge of Bi₂Se₃ changed with the doping level, which was attributed to possible Burstein-Moss effect.

1. Introduction

Bismuth selenide (Bi₂Se₃) is a narrow-band-gap semiconductor known for its efficient thermoelectric material. It draws much more attention as a 3-D topological insulator recently. The structure of Bi₂Se₃ can be considered as layers made up of 5 atom thick (Se-Bi-Se-Bi-Se) covalently bound sheets held together by much weaker van der Waals forces. The existence of van der Waals gap between such covalently bound layers makes the intercalation of copper into the bulk relatively easy. We modulated the carrier density in Bi₂Se₃ by intercalating copper and observed changes of the optical absorption edge. The calculation of band gap energy with consideration of electron-ion and electron-electron interaction corrections shows strong conduction-band nonparabolicity.

2. Methods

Material: N-type polycrystalline Bi₂Se₃ thin films (~200 nm) grown by Molecular Beam Epitaxy (MBE) technique

- **Electroplating**
  - Condition: 1~10 uA for 20 s ~ 300 s

- **Post-Annealing**
  - Condition: N₂ (1 atm), 300°C, for up to 25 min

3. Results

Fig.3 (a) Carrier concentration of Cu-doped Bi₂Se₃ vs. annealing time; (b) Squared optical absorption coefficient of Bi₂Se₃ vs. photon energy; (c) Absorption edge vs. carrier concentration comparing theoretical and experimental results

4. Summary

- Copper was intercalated into Bi₂Se₃ successfully by electroplating and post-annealing method
- Carrier concentration increases and stabilizes with annealing time after each electroplating process
- Carrier concentration was modulated by almost two orders of magnitude
- The optical absorption edge changes with carrier concentration, which was explained in the frame work of Burstein-Moss effect

Reference


Acknowledgements

Thanks to the Center for Energy Efficient Electronics Science for the opportunity to do research at UC Berkeley. Also, thanks to the National Science Foundation for funding this great experience. Last, thanks to the members of the Wu Group for guidance and sharing their knowledge.

Contact Information

Juntai Chen, jchen291@mail.ccsf.edu