**BAPVC Annual Project Report**

**Project Title: SnS based photovoltaics**

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**Summary:**

Phase-pure polycrystalline and epitaxial SnS thin films with good optical and electrical properties were deposited by vapor transport deposition. SnS solar cell devices were produced with a variety of buffer layers and transparent conductors. The choice of materials and deposition conditions were shown to significantly affect device performance.

**Key Accomplishments:**

The group built a reactor to deposit phase-pure SnS by vapor transport deposition, a proven low-cost manufacturing method for CdTe-based solar cells. Both epitaxial and polycrystalline films were demonstrated. Electrical and optical properties, including mobility, bandgap, refractive index and absorption, were measured (see Figure 1). Epitaxially grown films demonstrated high mobility (385 $cm^2V^{-1}s^{-1}$) compared to polycrystalline films. The absorption coefficient measured is also high ($\sim10^5$ $cm^{-1}$) above the SnS bandgap (1.0 eV).

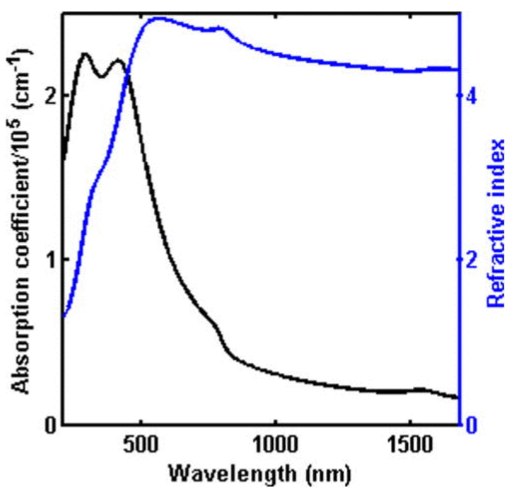


**Figure 1.** Refractive index and absorption coefficient derived from ellipsometry measurements.

Polycrystalline SnS solar cell devices were produced with efficiencies ranging from 0.5 to 1% efficiency. A variety of transparent conductors and buffer layers along with their deposition methods were studied (see Table I). Of all the material combinations, the highest efficiency device consisted of SnS/CdS/ZnO/ITO.

**Table I.** Summary of transparent conductors and buffer layers used for SnS solar cells.

| Material | Purpose | Deposition method | Result |
|---|---|---|---|
| ZnO | Buffer | Sputter deposition | • Open-circuit voltages of 300 mV, but low short-circuit current |

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| | | | • Possible sputter damage on SnS |
| ZnO | Buffer | Atomic layer deposition | • No rectification behavior, device shunted |
| Zn(O,S) | Buffer | Chemical bath deposition | • Low open-circuit voltage, low short-circuit current |
| CdS | Buffer | Chemical bath deposition | • Highest short-circuit current achieved of all devices, but low open-circuit voltage of 200 mV |
| AgNWs | Transparent conductor | Stamping | • No rectification behavior, device shunted |
| AgNWs | Transparent conductor | Spray coating | • No rectification behavior, device shunted |
| AZO | Transparent conductor | Sputter deposition | • High shunting and series resistance |
| ITO | Transparent conductor | Sputter deposition | • Best performance |

**Future Work:**
Going forward, impedance spectroscopy will be applied to elucidate why certain materials and deposition conditions outperform others, and in particular why chemical bath-deposited CdS outperforms Zn(O,S) as a buffer layer. The electrical properties at grain boundaries in polycrystalline SnS deposited with and without Na in the substrate will also be investigated. Ultimately such findings will be applied to produce solar cell devices from higher-quality, epitaxially-grown films. Metrics to evaluate progress in the next year include increasing open-circuit voltage beyond 500 mV and efficiency above 5%.