Detached Melt and Vapor Growth of InI in SUBSA Hardware

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OVERVIEW

• Introduction

• SUBSA furnace

• Wetting angle results for InI on different substrates

• Ampoule setups

• Conclusions
INTRODUCTION (I)

- Monovalent Indium Iodide, InI, is a promising candidate for $\gamma$-ray and X-ray detectors

<table>
<thead>
<tr>
<th>Material</th>
<th>Cd$<em>{0.9}$Zn$</em>{0.1}$Te (CZT)</th>
<th>Hgl$_2$</th>
<th>InI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average atomic number, Z</td>
<td>49.1</td>
<td>62</td>
<td>51</td>
</tr>
<tr>
<td>Density, g/cm$^3$</td>
<td>5.78</td>
<td>6.4</td>
<td>5.31</td>
</tr>
<tr>
<td>Band gap, eV</td>
<td>1.55</td>
<td>2.14</td>
<td>2.0</td>
</tr>
<tr>
<td>Melting point, °C</td>
<td>~1100</td>
<td>259</td>
<td>351</td>
</tr>
<tr>
<td>Structure</td>
<td>Zincblende</td>
<td>Tetrahedral-layered</td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>Knoop Hardness, kg/mm$^2$</td>
<td>92</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>Molecule Disassoc. Energy eV</td>
<td>1.2</td>
<td>0.35</td>
<td>3.43</td>
</tr>
<tr>
<td>Herzberg’s tables [19]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Resistivity, Ohm·cm</td>
<td>$3 \times 10^{10}$</td>
<td>$10^{13}$ to $10^{14}$</td>
<td>$5 \times 10^{11}$</td>
</tr>
</tbody>
</table>
INTRODUCTION (II)

- The low melting point and congruent sublimation allow both melt growth and vapor growth.
- InI is not toxic and not hygroscopic.
Current problems with InI are:

- Purity of the starting material. IIT has developed considerable experience in purifying In and I, synthesizing InI from the elements, and further purifying InI by zone melting.
- The formation of small inclusions in the grown material. These are thought to be responsible for the reduced electronic properties, compared to theoretical values.

Growth under µg

- allows vapor growth under purely diffusive conditions, which has shown to lead to a significantly increased $\mu$-$\tau$ product in the case of HgI$_2$ [1]
- enhances the chance for detachment in the case of Bridgman growth to reduce stress in the crystal

SUBSA FURNACE

- Was developed for a series of InSb experiments with a submerged baffle in the ISS MSG (microgravity science glovebox) rack.

- One heating zone, low power consumption

- Transparent gradient zone to visualize the growth interface
WETTING: SESSILE DROP TESTS

Fused silica

pBN
**Wetting: Sessile Drop Results**

- Wetting angle of InI on fused silica: 105±2.6°
  temperature coefficient: -0.64±0.06 degree/K(!), sample slides off the substrate easily

- Wetting angle of InI on pBN: 128±2.3
  temperature coefficient: -0.03±0.03 degree/K, but sample sticks and reacts with the substrate
  
  \(3\text{InI} + 2\text{BN} \rightleftharpoons \text{In}_3\text{BN}_2 + \text{BI}_3\)

- Wetting angle of InI on Al$_2$O$_3$ ceramics: 101.6±2.1°
  temperature coefficient: -0.315±0.007 degree/K [1]

- Wetting angle of InI on carbon: 93.4±0.7°
  temperature coefficient: -0.102±0.006 degree/K [1]

VAPOR PHASE AMPOULE

Modified Markov method setup

- Inl
- Fused silica
- Fused quartz frit

heating zone

45 mm

98 mm

103.5 mm
CONCLUSIONS

- InI has promising properties as room temperature γ-ray detector
- The low melting point allows Bridgman growth and CZ growth, although diameter control is difficult with the latter method
- Determination of the wetting angles with different crucible materials showed the highest value (128°) for pBN, but InI and pBN react, whereas fused silica (105°) does not react. Other materials better suitable for detachment have to be tested, e.g. DLC coatings.
- The congruent sublimation also allows vapor phase growth in comparison to melt growth
- The μg experiments in the “SUBSA“ furnace on the ISS are planned for 2017
ACKNOWLEDGEMENTS

Funding for this project is provided by the Center for the Advancement of Science in Space (CASIS)
THANK YOU FOR YOUR ATTENTION!

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