# Wettability and Surface Tension of Molten InGaAs

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Wetting behavior of molten $In_{0.8}Ga_{0.2}As$ on substrates of graphite, BN, $SiO_2$, pBN, AlN, SiC and $Al_2O_3$ and surface tension of molten $In_{0.8}Ga_{0.2}As$ were measured using the growing melt drop method so as to identify a possible crucible material for use in growing crystals. The relationship of the magnitude of the contact angles between the melts and the substrates was as follows: pBN, BN, graphite>AlN>SiN>$SiO_2$>$Al_2O_3$,SiC.

The surface tension of $In_{0.8}Ga_{0.2}As$ was $\gamma$ =418～480mN/m(at 1100～1300℃)

The effect of roughness of $SiO_2$ container was investigated from 0.1 to 4 $\mu$ m amplitude of surface. As a result, the molten InGaAs/container wetting behavior was related to the roughness of container.

**1. Introduction**

The contact angle of ceramic surface with molten materials and surface tension of molten materials is a significant thermophysical properties to be taken into consideration in cases where crucibles for space experiments are designed or when it serves as a tool for analyzing data obtained from such experiments.

InGaAs that was measured this time is paid attention in recent years as a high speed IC and an optoelectronics materials like a laser diode.(1) However, the manufacturing of the ternary compound semiconductor with high uniform monocrystalinity is difficult on the ground. Although the utilizing microgravity environment upon crystal production is conceivable for the detailed characteristic research, no reporot has benn published on the wettabilities of crucible materials with molten InGaAs and Surface tension of molten InGaAs. And that was expected.

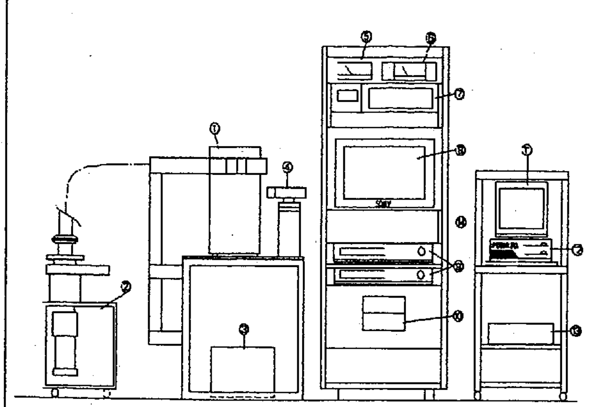
In this report ,contact angles between molten InGaAs and 8 kinds of crucible material and surface tension of molten InGaAs were measured.

**2. Experimental method**

Molten sample is $In_{0.8}Ga_{0.2}As$,the melting point is about 1100℃. Crucible materials are $SiO_2$, BN,pBN,graphite,AlN,$Al_2O_3$,SiC and SiN. Each substrate material is processed in a disk state and has a hole of 0.5mm in diameter at the center and from which the molten sample is pushed out from a lower part to the surface. The shape of disk is 10mm in diameter and 3mm thick.

Figure 1 shows a schematic diagram of the wettability measurement apparatus. A procedure of growing drop is shown in Fig.2.

The image of the liquid drop on a solid substrate is taken with CCD camera and the contour of the liquid drop is extracted with the image processing by a computer. The theoretical contour curve guided from Laplace's equation is made repeated fitting to a contour curve that was obtained, and is calculated a contact angle and surface tension with a final optimal approximation curve.(2)



| | |
|---|---|
| 1 | Tungsten Mesh Heater Furnace |
| 2 | Diaphragm pump +Turbo Molecular Pump |
| 3 | Transformer |
| 4 | CCD Camera |
| 5 | Pirany Gauge |
| 6 | Lonizatiom Vacuum Gauge |
| 7 | Temperature Controller |
| 8 | Monitor |
| 9 | VTR |
| 10 | Video Printer |
| 11 | CRT |
| 12 | CPU |
| 13 | Printer |
| 14 | Holder Controller |

Fig. 1 Schematic diagram of Wettebility Measurement Unit

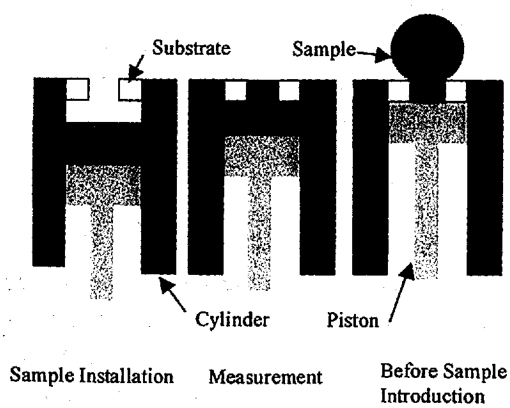



Fig.2 Procedure of the growing drop

Before the experiment the uncertainty in measurement is evaluated by measuring the contact angles of steel sphere. The difference between the theoretical and measured contact angles is within ±1%.

The experiment were conducted at temperatures of 1100℃, 1200℃, 1300℃, and in the atmosphere of argon to all substrate materials. The vacuum of the furnace was $2 \times 10^{-4}$ Torr before introducing argon gas.

### 3. Experimental results

### 3.1 The crucible materials effect

Molten InGaAs spouted through a hole of substrates right away, as soon as a top of the melt appeared just above the hole. This phenomenon is observed well repeatedly and the control of liquid drop formation by the move of a piston was impossible. This might be due to high arsenic dissociation pressures at measurement temperatures. It is conceivable that melt is pushed out from a hole of substrates by this pressure.

Figure 3 shows measurement results of contact angles.Figure4 is a side view of molten InGaAs drop on substrates.

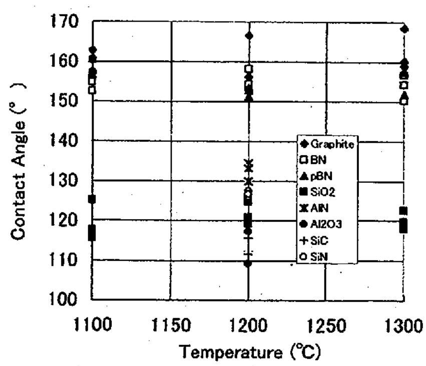
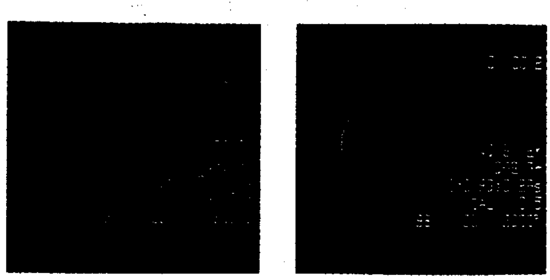



Fig.3 Contact Angle of InGaAs



Substrate : BN
Temperature: 1200℃

Substrate : $SiO_2$
Temperature: 1200℃

Fig.4 Side view picture of InGaAs drop

Table1 shows measurements data of contact angles. The standard devitation of contact angles is below five degrees. The contact angles with pBN, BN and graphite substrates showed large values, the contact angles with AlN, SiN, $SiO_2$, $Al_2O_3$ and SiC substrates showed comparatively small values.

pBN, BN, graphite>>AlN>SiN> $SiO_2$> $Al_2O_3$, SiC

These substrate materials are useful as crucible. Non-wettable characteristics with sample is desirable as crucible materials. The above trend was considered to be suggesting the compatibility of crucible material to molten InGaAs.

Tab.1 Contact Angles of InGaAs (1/2)

| Substrate | Temp (℃) | Roughness (μm) | Angle (° ) | Sur. Tention (mN/m) |
|---|---|---|---|---|
| BN | 1100 | 1.5 | 156 | 447 |
| | | 1.5 | 153 | 424 |
| | | 2 | 155 | 442 |
| | 1200 | 1.4 | 154 | 428 |
| | | 1.4 | 154 | 435 |
| | | 1.4 | 158 | 428 |
| | 1300 | 1.5 | 150 | 460 |
| | | 1.5 | 157 | 436 |
| | | 1.4 | 154 | 418 |
| pBN | 1100 | 1.2 | 157 | 481 |
| | | 1.4 | 158 | 473 |
| | | 1.1 | 161 | 431 |
| | 1200 | 1.1 | 153 | 457 |
| | | 1.1 | 156 | 443 |
| | | 1.2 | 151 | 463 |
| | 1300 | 1.3 | 158 | 461 |
| | | 1.2 | 152 | 492 |
| | | 1.4 | 158 | 437 |
| SiO2 | 1100 | 0.03 | 118 | 494 |
| | | 0.02 | 125 | 410 |
| | | 0.05 | 117 | 413 |
| | 1200 | 0.21 | 119 | 457 |
| | | 0.01 | 125 | 459 |
| | | 0.06 | 121 | 497 |
| | 1300 | 0.02 | 123 | 421 |
| | | 0.03 | 120 | 431 |
| | | 0.11 | 118 | 491 |
| Graphite | 1100 | 0.3 | 158 | 425 |
| | | 0.3 | 161 | 418 |
| | | 0.4 | 163 | 425 |
| | 1200 | 0.3 | 167 | 414 |
| | | 0.4 | 158 | 453 |
| | | 0.4 | 156 | 430 |
| | 1300 | 0.3 | 169 | 418 |
| | | 0.3 | 158 | 482 |
| | | 0.4 | 160 | 429 |

Tab.1 Contact Angles of InGaAs (2/2)

| Substrate | Temp (℃) | Roughness (μm) | Angle (° ) |
|---|---|---|---|
| AlN | 1200 | 0.07 | 135 |
| | | 0.07 | 133 |
| | | 0.07 | 130 |
| Al2O3 | | 0.03 | 109 |
| | | 0.02 | 117 |
| | | 0.03 | 117 |
| SiC | | 0.12 | 112 |
| | | 0.07 | 116 |
| | | 0.08 | 112 |
| SiN | | 0.01 | 128 |
| | | 0.03 | 126 |
| | | 0.05 | 127 |

Tab.2 Contact Angle of InGaAs

| Substrate | Temp (℃) | Roughness (μm) | Angle (° ) |
|---|---|---|---|
| SiO2 | 1200 | 3.5 | 160 |
| | | 3.1 | 162 |
| | | 3.8 | 163 |
| | | 1.4 | 159 |
| | | 0.7 | 155 |
| | | 0.73 | 159 |
| | | 0.69 | 153 |
| | | 0.81 | 141 |
| | | 0.20 | 152 |
| | | 0.24 | 156 |
| | | 0.26 | 154 |

### 3.2 The roughness of container effect

Figure 5 shows measurement results of contact angles. Table.2 shows measurements data of contact angles.

As the roughness of substrates decrease, the contact angle is smaller. The movement of drops on substrates is easy. The rich wettability of substrates with molten InGaAs was considered to cause such movement.

### 3.3 The measurement of surface tension

Figure 6 shows measurement results of surface tension.

The surface tension of InGaAs was $\gamma$=418～480mN/m(at 1100 ～ 1300 ℃). At the same temperature, scattering of results are at almost ± 10%.

In this experiment, the diameters of drop range from 3 to 4 mm. The drop shape is determined by the balance of gravity and surface tension. The diameters of drop range from 3 to 4 mm shaped in this experiment is very little. Therefore there is no effect of gravity, and scattering of results were brought about.[3]

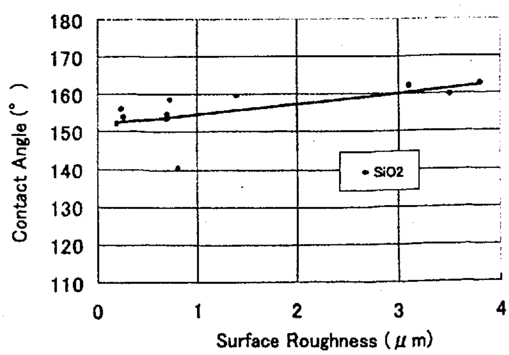



Fig.5 Contact angle vs. roughness of the container surface

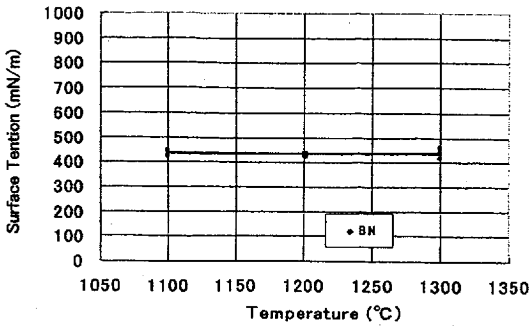



Fig.6 Surface tensions of InGaAs

**Conclusion**

For the purpose of evaluating compatibility between molten InGaAs and 8 kinds of crucible material , the contact angles were measured by growing drop method in a temperature range between 1100 and 1300℃. The spouting of molten InGaAs through a hole of substrates was observed at the time of the growing drop. This was conceivable that high dissociation pressure of arsenic is a cause.

It understood by the measurement results of contact angles that pBN, BN and graphite are good materials as crucible for InGaAs and that the use of AlN, $Al_2O_3$, SiC, SiN and $SiO_2$ must be paid attention.

The relationship between the wettability and the roughness of container was investigated using $SiO_2$ container. The contact angles are measured by grouwing drop method increase when surface roughness increase.

The surface tension of molten InGaAs was measured from 1100 to 1300℃.
The surface tension of the molten InGaAs is $\gamma$ =418 ~480mN/m.

**References**

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