Peritectic melting behavior of β-boron at the boron end side of B-C binary phase diagram

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Abstract

Melting behavior of β-boron at the boron-end side of the B-C binary phase diagram was investigated by floating zone method. The result indicated that β-boron peritectically melts by addition of carbon. Partition coefficient of carbon is $\approx$2.6.

Keywords

melting behavior of β-boron, B-C binary phase diagram, boron-end side, peritectic melting, floating zone method,

1. Introduction

Main feature of the B-C binary system is the existence of only one intermediate phase B_4C and many investigations have been done to determine the congruent composition, the optimized liquidus and solidus curves for the B_4C phase. On the other hand, the melting behavior of β-boron at the boron-rich side of the B-C binary phase diagram has long been an un-clarified problem because of difficulty of determining small carbon solubility gap between the liquidus and solidus curves. Schwetz and Karduck reported B-C binary system but there was no indication for melting behavior of β-boron [**?**]. Beauvy reported peritectic melting behavior without experimental evidences [**?**]. The latest B-C phase diagram has been presented by Okamoto [**?**], where he adopted eutectic melting behavior of β-boron on the basis of the phase diagram presented by Elliot [**?**].

The zone melting method is a very convenient method for determining a relation between liquidus and solidus curves; i.e., if the zone melting crystal growth experiment
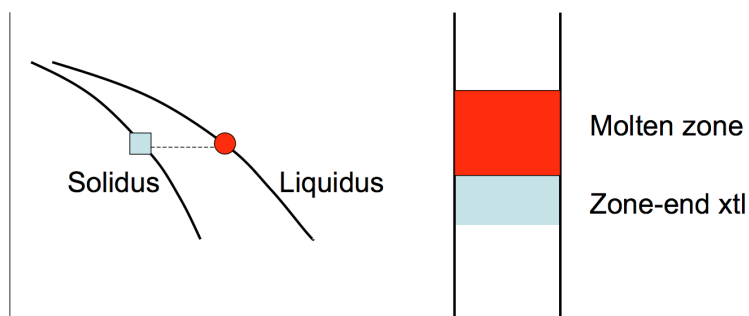
Figure 1. Schematic illustration of determining melting behavior by zone melting method.

is quenched, the chemical composition of the quenched molten zone and that of the zone-end part crystal correspond to one set of data points on the liquidus curve and the solidus curve at the same temperature (crystal growth temperature), respectively. By repeating such experiment using raw rods having a different chemical composition we can determine the liquidus and solidus curves. This concept is schematically illustrated in figure 1.

In this study we determined the relation between liquidus and solidus curves of β-boron at the boron end side of B-C phase diagram using floating zone method. The higher carbon solubility in solidus than in liquidus confirmed peritectic melting behavior of β-boron.

2. Experimental details

Floating zone (FZ) technique using a xenon lamp image furnace (Crystal systems, Inc., Japan) was used for the zone melting of β-boron because of unavailability of crucible materials that can contain very reactive boron melt above approximately 2100 °C.

Starting powders for FZ were amorphous boron (SB-Boron Inc., USA) and hydrocarbon. A desired small amount of carbon was added to the amorphous boron to form a FZ feed sintered rod that was fired at 1700 °C in a graphite susceptor under vacuum for 1 h. After the molten zone was passed through the feed rod ~4 times of the zone length the zone pass was quenched. Then the frozen molten zone and the zone-end part of the crystal obtained were cut by a spark erosion cutter. Both samples were crushed to powders by a stainless-steel mortar and the stainless-steel contamination was washed by a dilute HCl solution and rinsed away. Only carbon contents were determined by volumetric combustion method using a carbon determinator (WR-12, Leco Co., USA). Standard deviation of the chemical analysis was within ±2%.

3. Results and discussion

Six data sets that represent carbon contents of liquidus and solidus curves were obtained and listed in table 1. The average partition coefficient of carbon is ≈2.6, i.e., the addition of small amount of carbon to β-boron increases melting temperature of β-boron, which is the same tendency as that of other borides.

Table 1. Data sets of chemical composition of the frozen molten zone and the zone-end part of the grown β-boron crystals.

Set No.	Chem. comp. zone (atm%)	Chem. comp. z-end xtl (atm%)	Partition coeffic.
1	0.53	1.33	2.5
2	0.35	1.10	3.1
3	0.38	0.94	2.5
4	0.12	0.27	2.3
5	0.08	0.18	2.3
6	0.04	0.11	2.8

The data sets enabled us to depict liquidus and solidus curves of β-boron at the boron end side of the B-C phase diagram as shown in figure 2, where temperature scale is not given because the temperatures have not been measured in our image furnace system. The present result clearly indicates that the melting behavior of β-boron is not eutectic but peritectic for carbon addition.

4. Conclusion

We confirmed that β-boron peritecitically melts at the boron end side of the B-C binary phase diagram.

As indicated in this study the FZ method is a powerful tool to investigate a phase diagram of high melting temperature materials. Especially the FZ method is advantageous for determining a small solubility gap as compared with conventional phase analysis techniques. We have also reported eutectoid decomposition of tungsten carbide (WC) on the basis of the FZ investigation [?] contrary to the widely relied phase diagram reported by Rudy, which indicates that WC peritectically melts [?]. Versatility of the FZ method should be more acknowledged for phase diagram investigation.
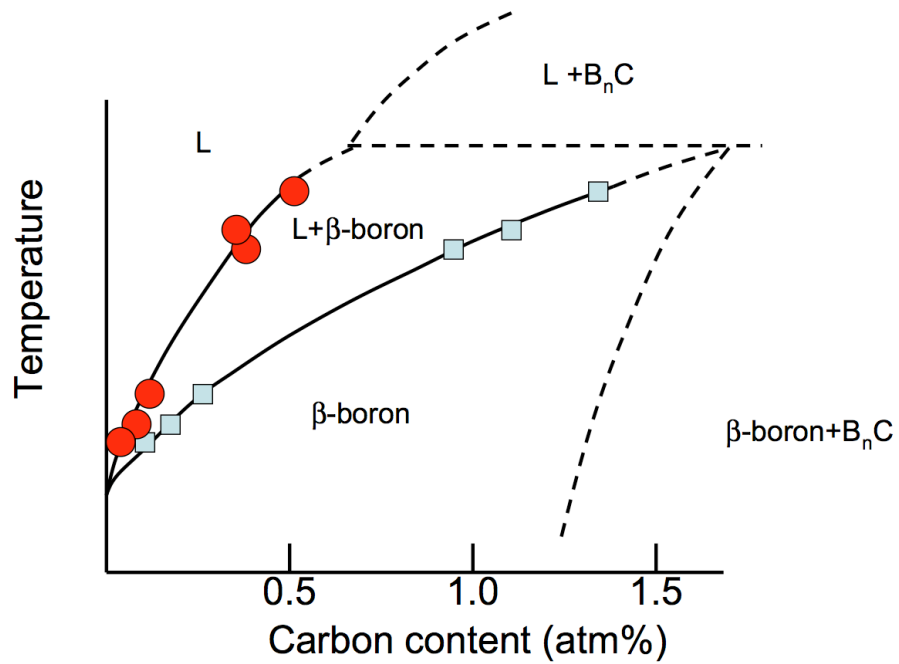
Figure 2. Liquidus and solidus curves of B-C binary phase relation at the very boron-rich side.

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