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DEVELOPMENT OF PURE BORON PELLET FOR FUSION REACTOR

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Abstract

Boron (B) is an attractive element for proton-boron (p-B11) fusion reactions, also attracts attention as an element for inducing high-temperature plasmas and as an operational boronizing element in the deuterium (D)-tritium (T) reaction.. In previous the injection experiment of boron, small cylindrical capsules contained boron powder and powder dropper have been employed. However, in previous injection experiments using small cylindrical capsules, critical issues remained, such as the small amount of injected element and the contamination of impurities from the small cylindrical capsule, and there was also the issue that the powder dropper method could not be used to inject into the core plasma. As the solution of the critical issue, author(s) proposed simple pure boron pellet without small cylinder capsule and powder dropper method, suggested the sintering process of pure B, which showed advantage of processability and withstand pellet injection. In this paper, the production process and the B pellet injections experiments were introduced.

1. INTRODUCTION

Boron (B) is an attractive element for fusion reaction on proton-boron (p-b) [1], and an important element inducing the high temperature plasma [2]. For this reason, plasma experiments using boron are being conducted at the Large Helical Device (LHD) at Japan's National Institute for Fusion Science (NIFS). Considering the injection of boron into the plasma core, the pellet injection method is superior to the free-fall method using it as a powder dropper. Therefore, the demand for pure boron pellets has been gradually increasing recently. Furthermore, pure boron is an attractive element for boronization of vacuum vessel walls during operation in the case of the deuterium (D)-tritium (T) reaction [3-4], which will expand the scope of applications of B in the field of fusion reactors.

On the other hand, pure boron is easily affected by impurity elements such as carbon or oxygen. The B Compound has poor processability and is difficult to sinter, so the pelletization was a critical issue. In the past, pellet injection experiments using materials in the LHD that are difficult to sinter have used small cylindrical capsules filled with the injection material as the pellet. However, in the case of pellet of small cylindrical capsules containing injection elements, the pellet experiments still have significant issue, namely, the small amount of injection elements and the contamination of impurities from the small cylindrical capsule as shown in Figure 1. As a solution to this critical issue, the authors proposed a process for sintering pure B without using small cylindrical capsules. In the starting study, authors speculated that impurity carbon from the high-temperature furnace would bond with the original boron particles on the particle surface, and as a result, the carbon from the high-temperature furnace would inhibit interdiffusion between the original boron particles. Considering the carbon contamination on the surface of boron particles, the authors developed a sintering method of pure boron using "tantalum (Ta) foil", which is widely known as the getter effect of impurity carbon [5]. Furthermore, the authors did not employ sintering loads for post-sintering processability. In this paper, we present a sintering process using tantalum foils without sintering loads and injection experiments using sintered boron pellets.

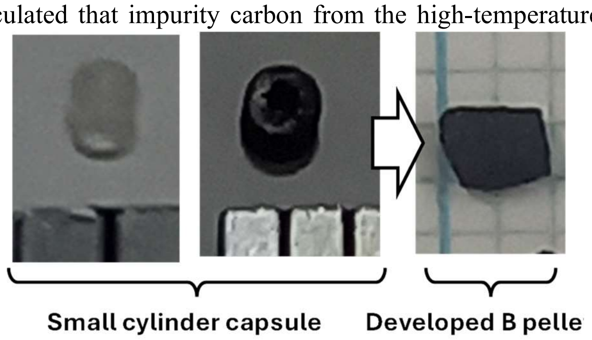

FIG. 1 previous small cylinder capsules and Developed B pellet

2. EXPERIMENTAL PROCEIDURE

Pure boron powder (purity: 99%, particle size: 40 μm) was inserted into a round Ta foil (thickness: 50 μm) and the edges of the round Ta foil containing the boron powder were sealed. The sealed Ta capsule was sintered by high temperature furnace at 2000℃ 1~10hr in 1×10^{-3}Pa without sintering load. After the heat treatment, Ta foil was removed from sintering B. The sintered boron ingot was worked for the analysis of microstructure and the plasma injection test

3. RESULTS

After removing the Ta foil, the sintered pure boron exhibited hardness sufficient to withstand pellet injection and a density of 1.162 g/cm3 (56% of the theoretical density). Sintered boron can be processed by drilling, turning on a lathe, etc., and we have succeeded in forming it into pellets (diameter 1.5 mm, length 2.0 mm) for injection experiment, as shown in Figure 2.

The microstructures before and after sintering are shown in Figure 3. Raw boron powder of 40μm diameter before sintering was shaped non-spherical particles. After 1 hour at 2000°C, the particles were spheroidized and necked between particles. Then, after 5 h at 2000 °C, the growth of grain necks was observed, and finally, after 10 h at 2000 °C, the grains were further sintered with a slightly close system (micropores).

In the injection experiment into the LHD, pure B pellets sintered at 2000℃ for 1 hour were used, and 37 injections were successful without ablation at the plasma edge. Considering the effect of sintering time on the microstructure, the pure B pellet after 2000℃-5~10hr sintering would be able to inject further density boron in the future.

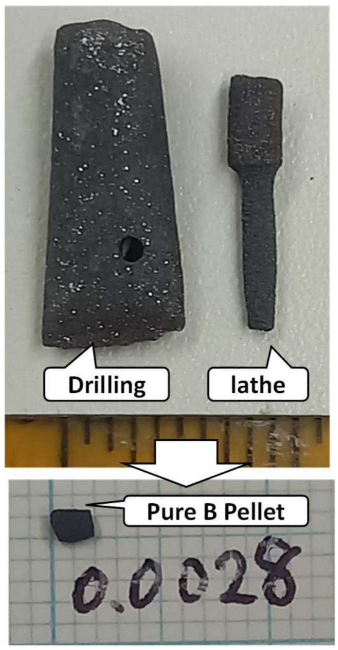

FIG. 2 worked pure B and the pellet

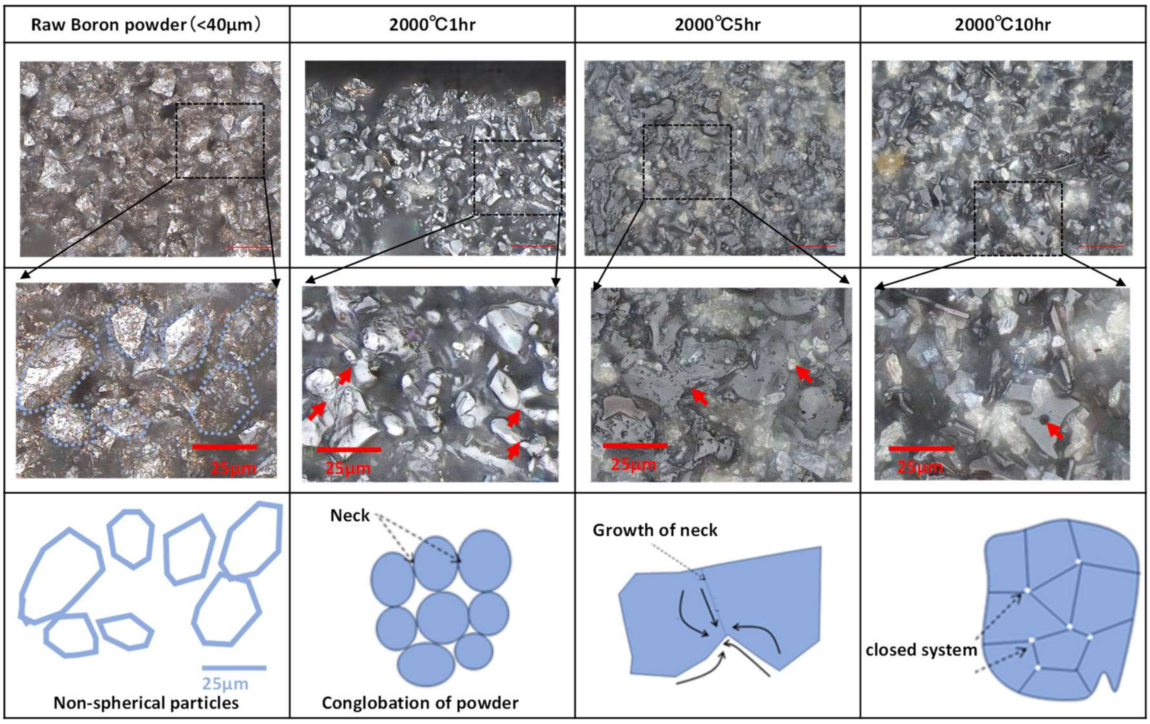

FIG. 3 Effect of sintering time on the microstructure

4. DISCCUSSIONS

Similar injection experiments using "11B" are planned for the next LHD experimental campaign, and our group hopes to be able to carry out the next experiment using this process. Pure boron is also expected to be used to boronize the walls of operating vacuum vessels, and its use is expected to expand to nuclear fusion experiments around the world.

5. CONCLUSIONS

Boron is considered a promising element in proton-boron (p-B11) fusion reactions. Therefore, the fabrication process from raw powder to injection pellet was required. In this starting study, we proposed the fabrication process of simple pure boron pellets without previous small cylinder capsule and powder drop equipment. In this paper, the effect of sintering time on the microstructure was investigated. The main results are as follows:

1.Pure boron has been successfully sintered without applying sintering loads. The sintered boron exhibited the advantage of processability and the strength to withstand pellet injections. Pellets fabricated from pure boron have survived injection for plasma experiments.

2. Considering the effect of sintering time on the microstructure, the growth of necks and slightly close systems (micropores) between boron particles were observed with increasing time to sinter, suggesting the possibility of developing even denser pellets.

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