Topics: TECH

Development of pure boron pellet for fusion reactor

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Boron (B) is an attractive element for proton-boron (p-B11) fusion reactions. However, the pellet injections experiments using small cylindrical capsules rest some critical issues of a low amount of injecting element and a contamination of impurity from miniature cylinder capsule. As the solution of the critical issue, author(s) 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.

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 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.

Experimental Procedure

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.

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 molding, as shown in Figure 1. The microstructures before and after sintering are shown in Figure 2. After 1 hour at 2000°C, the particles are spheroidized and necking between particles is observed. 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).

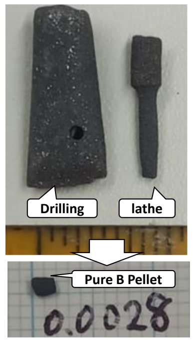

Fig. 1. worked pure B and the pellet

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℃10hr sintering would be able to inject further density boron in the future.

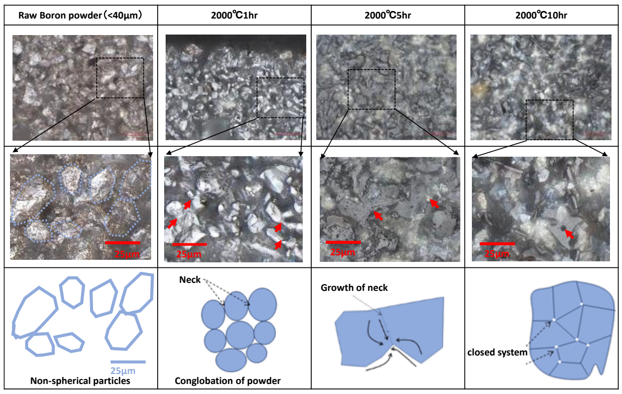

Fig. 2. Effect of sintering time on the microstructure

Discussions

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.

Conclusion

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.

References

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