14-7 Material Research for Transmutation of LLFP in a Fast Reactor

–Irradiation Test of $^{11}B_4C$ as a Neutron Moderator–

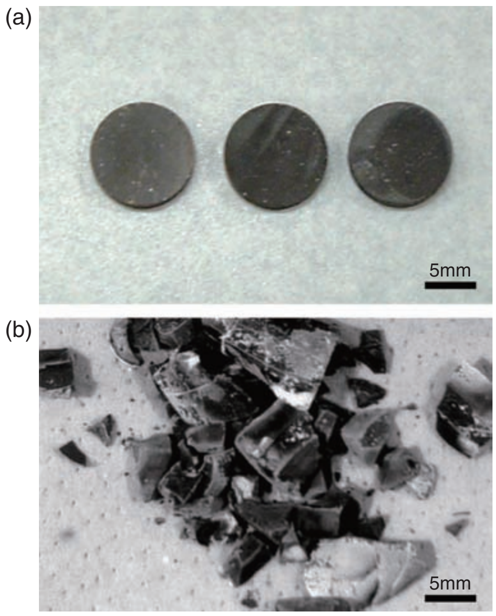

Fig.14-14 Appearance of (a) Irradiated $^{11}B_4C$ and (b) $^{10}B_4C$ at around 500°C
An irradiated $^{10}B_4C$ pellet was broken, and the $^{11}B_4C$ pellet kept the same shape as before being irradiated.

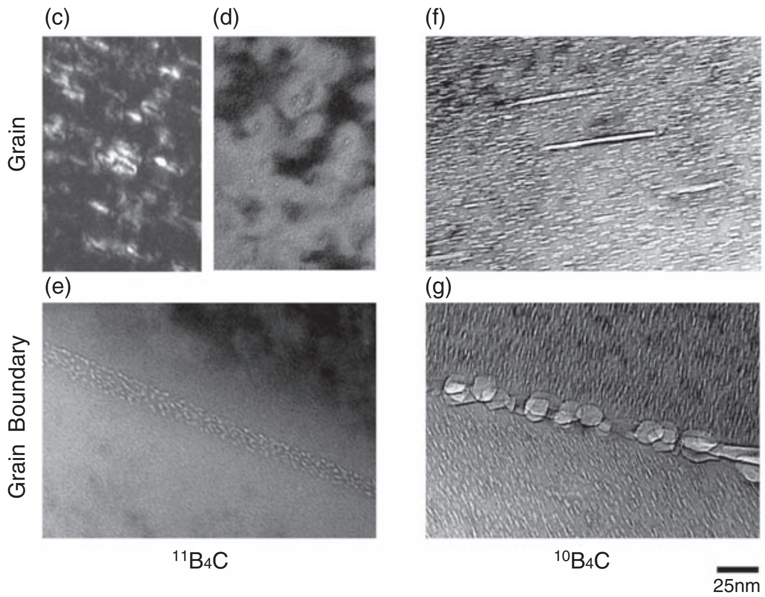

Fig.14-15 Microstructure of irradiated $^{11}B_4C$ and $^{10}B_4C$
Irradiation defects in $^{11}B_4C$ microstructures. Micro dislocation loops (c), bubbles (d). Small helium bubbles (e) were gathering in the grain boundary of $^{11}B_4C$. Helium (He) bubbles (f) were gathering in high density on the grain in $^{10}B_4C$. Large bubbles (g) grew around grain boundaries in $^{10}B_4C$.

It is difficult to store high level waste that contains long-lived fission products (LLFP). Transmutation of LLFP, which changes them into short lived or stable nuclides, is a solution. Thermal reactors are efficient for LLFP transmutation, but fast reactors also have possibilities for it by modifying a fast neutron into a thermal neutron. $^{11}B_4C$ was fabricated from concentrating ^{11}B in natural boron carbide. Both hydride and $^{11}B_4C$ are candidates to be moderators. It is possible to raise the efficiency by loading LLFP as a target with the moderator, in order to transmute LLFP in the fast reactor. The slow-down power of $^{11}B_4C$ is lower than hydride. $^{11}B_4C$ has an advantage in the thermal design, because the boron carbide has been stabilized to the melting point chemically, while the hydride dissociates the hydrogen when it reaches a high temperature.

Hydride and $^{11}B_4C$ were irradiated in Phenix, a fast reactor in France. We have many irradiation experiences with $^{10}B_4C$ as an absorber material. $^{10}B_4C$ was fabricated from concentrating ^{10}B. He was produced by a ^{10}B (n, α) ^{7}Li reaction. A B_4C pellet was sintered for irradiation. The He stored in it and changed into He bubbles. These bubbles caused the pellets to crack, which is a bad effect for materials stability. The volume of He generated in $^{11}B_4C$ was expected to be about 1/100 in comparison with that in $^{10}B_4C$.

In this study, $^{11}B_4C$ was irradiated at 530°C to 1.9×10^{26} n/m^2 (E>0.1 MeV), and $^{10}B_4C$ was irradiated at 800-900°C to 3.1×10^{26} n/m^2 (E>0.1 MeV). Afterwards, a post irradiation experiment was performed. The $^{10}B_4C$ pellet was difficult to be divided around 700-800°C. Then, the $^{11}B_4C$ was specially irradiated at 530°C. The irradiated sample became very brittle. Therefore, a test piece of irradiated $^{11}B_4C$ was prepared by ion-milling method in full detail.

In Fig.14-14, the appearance of $^{11}B_4C$ and $^{11}B_4C$ after irradiation is shown. In Fig.14-15, the microstructure of $^{11}B_4C$ and $^{10}B_4C$ after irradiation is shown. In the $^{11}B_4C$ grain, large bubbles of a high-density were observed compared to $^{10}B_4C$. In the grain boundary, additional large bubbles were observed in the grain. It was considered that in the $^{11}B_4C$, the growth of the bubble was slow, and the nucleation frequency is also low. From the observation results, it was confirmed that $^{11}B_4C$ was stable under the moderator service conditions. In the future, a more detailed microstructure observation will be performed.

Reference

Donomae, T. et al., Neutron Irradiation Effects on $^{11}B_4C$ and Recovery by Annealing, Nippon Seramikkusu Kyokai Gakujutsu Ronbunshi, vol.115, no.1345, 2007, p.551-555 (in Japanese).