Development Study of Fast Reactor Core with Hydride Neutron Absorber

We are now developing hafnium hydride control rods6,7 for Fast Breeder Reactor (FBR) in order to drastically prolong its in-core life accounting its superb characteristics of helium and swelling free features.A new hydride neutron absorber of nuclear reactor has proposed based on the results of irradiation experiments in Japan Materials Testing Reactor (JMTR) of Japan Atomic Energy Agency (JAEA). A metal-hydride has very high hydrogen atom density, which is equivalent to that of liquid water. Fast neutrons in nuclear reactors are efficiently moderated and are absorbed in the metal-hydride. The Hafnium hydride and Gd hydride are considered as neutron absorber in FBR.

Fast breeder reactor is considered as the major nuclear power source for the future. The B_4C has been mainly used for control and shut down material in FBRs. But the life of B_4C control rods is restricted by Pellet-Cladding Mechanical Interaction (PCMI) failure due to the He gas swelling of B_4C pellet which is caused by the following nuclear reaction,

$$B^{10}\ (n, \alpha)\ Li^{7}. \qquad (1)$$

The concept how to prolong control rod life of FBR by using HfHx is illustrated in Fig. 1. In order to prolong the control rod life–time we propose to use HfHx as absorber material for FBR by the reasons that He gas is not generated in nuclear reaction of HfHx, and that HfHx can be expected to absorb neutron for more than 40 years owing to the fact that Hf^{178} and Hf^{179} which are generated by neutron captures of Hf^{177} and Hf^{178} respectively, also have large neutron capture cross sections which are expressed by the following reaction,.

$$Hf^{177}\ (n, \gamma)\ Hf^{178}\ (n, \gamma)\ Hf^{179}\ (n, \gamma)\ Hf^{180}. \qquad (2)$$

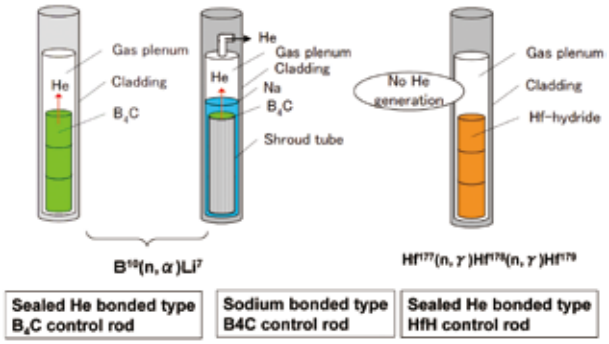

Fig. 1 Schematic of HfHx application concept to FBR control rod.

The control rod assembly, which contains Hf-hydride, is considered to enhance neutron absorption in fast reactors. In general, a metal-hydride has very high hydrogen atom density, which is equivalent to that of liquid water. Fast neutrons in nuclear reactors are efficiently moderated and are absorbed in the metal-hydride. As the ratio of H to Hf increases, the Hf-control rod can more efficiently absorb neutrons in fast reactor core. For example, the worth of $HfH_{1.0}$ is larger than that of B^{10} 40% enriched B_4C.

One of the most important R&D items to establish the idea of Hf-hydride control rod is the development of Hf-hydride pellet, which can be safely irradiated for long time. The idea has proposed based on the results of irradiation experiments in JMTR of JAEA. Fig. 2 shows the structure of capsule for irradiation experiments, where the actinide hydride pellet were loaded. After irradiations, non-destructive examinations (X-ray photograph, gamma scanning and so on) and destructive examinations (electron microprobe analysis, physical property measurements and so on) were performed and the integrity of the hydride pellet during irradiation was assured.

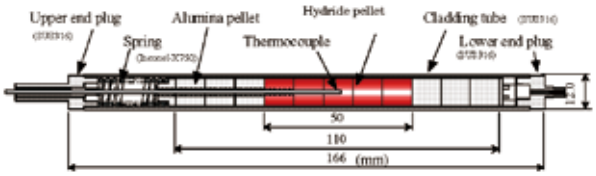

Fig. 2 Schematic of HfHx application concept to FBR control rod.

The development program of hydride neutron absorber has been started, which is accepted as an innovative nuclear research and development program of Ministry of Education, Culture, Sports, Science and Technology of Japan.

References

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