§ 4. Gas Nuclear Transmutation Effects in Aluminum Nitride (AlN)

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Gas transmutation effects were studied by the isotope tailoring method in aluminum nitride (AlN). The aluminum nitride is a good electrical-insulator, has high thermal conductivity and is a candidate for substrates of electrical circuits to be used in a high nuclear heating environments in fusion devices such as International Thermonuclear Experimental Reactor (ITER). Also, as one of refractory insulating nitride, aluminum nitride has good compatibility with liquid lithium, and it is one of candidates for MHD-coatings on vanadium structural materials in burning fusion devices.

Fine powders of aluminum nitride (AlN) were prepared by nitriding highly pure aluminum powder (99.98mass% manufactured by Toyo aluminum Co.) with highly pure nitrogen-15 isotope gas. ($^{15}N/^{14}N$ = 99.7at%/0.3at%, impurity concentrations of O_2, CH_4, and CO_2 were less than 20/volppm, manufactured by Nihon Sanso Co.) Also, conventional pure $Al^{14}N$ powders were prepared with nitrigen-14 gas. Obtained AlN fine powders were then sintered at 2100K Small amount of Y_2O_3 fine powders were added as a sintering agent. Sintering was carried out in an argon environment. Except for a density and an open porosity, $Al^{14}N$ and $Al^{15}N$ have about the same property-parameters as shown in Table 1. The final N-15 enrichment ratio was 99.2at%. A small amount of N-15 was replaced by N-14 in the process of sintering in an argon gas environment.

Table 1. Properties of sintered $Al^{15}N$ and $Al^{14}N$

	$Al^{15}N$	$Al^{14}N$
Density (% TD)	97.3	93.5
Open Porosity (%)	0.8	6.8
Composition (mass%)		
C	0.17	0.23
O	1.14	1.13
Y	1.20	0.62
Fe	<0.001	<0.001
Si	0.042	0.068
Ca	0.002	0.002

The prepared specimens were irradiated in two fission reactors which have different neutron spectra: JOYO, a sodium cooled fast reactor, in Oarai Engineering Center of Institute of Japan Nuclear Fuel Cycle Development (JNC), has a hard neutron spectrum and, HFIR, a water-cooled high-flux isotope reactor of Oak Ridge National Laboratory, has a typical mixed neutron spectrum. The HFIR irradiation was carried out under the Japan/USA collaboration called JUPITER-II program. The present results shown in Fig. 1, in comparison with accumulated data obtained in JOYO and in JMTR (Japan Materials Testing Reactor in Oarai Research Establishment in Japan Atomic Energy Research Institute), are clearly demonstrating that there will be definite gas nuclear transmutation effects in the aluminum nitride. The high hydrogen gas formation rate in the HFIR is enhancing the linear expansion about twice, namely the swelling rate will be six times larger than that in the irradiation environments not associated with gas production.

This is rather unexpected since the irradiation temperature is high enough for hydrogen atoms to make long-distant diffusion. Also, it was unexpected that the linear expansion rate showed good linear dependence on the fast neutron fluence, irrespective of reactors used and irradiated temperatures. Detailed examinations of microstructures of irradiated Aluminum nitride specimens are planned. Also, isotope tailored Aluminum oxide (Al_2O_3) specimens, irradiated in HFIR, will reveal effects of transmuted helium. These will reveal effects of transmuting gasses on evolution of radiation induced microstructures and performance of aluminum nitride (AlN) near burning fusion plasma in fusion reactors.

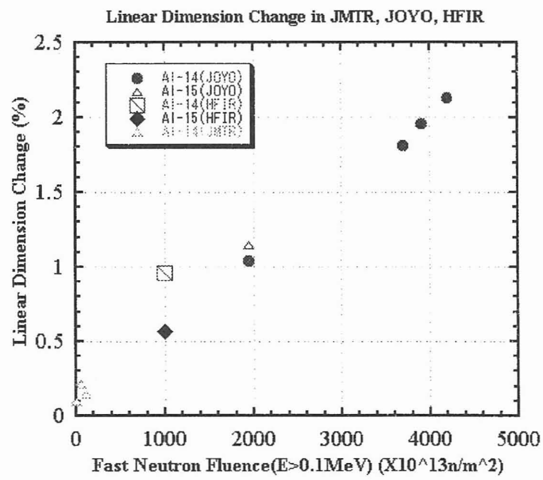

Figure 1 Linear dimension change in three different reactors tabulated in Table 2, as a function of fast neutron fluence.