§3. Activation Analysis of NIFS-HEATs with 14 MeV Neutrons

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Low activation under neutron irradiation is one of the essential properties of the V-4Cr-4Ti alloy proposed as structural material for future fusion reactors. For absence of elements producing long-lived nuclides, the vanadium alloy intrinsically has the potential to facilitate reactor maintenance and reduce the radioactive wastes by material recycling. However, in the actual use, small amount of impurities in the alloy may eliminate the advantage by induction of long-lived radioactive nuclides. In the Fusion Engineering Research Center, high purity large ingots of vanadium alloy (NIFS-HEATs) have been fabricated to establish industrial process for reactor construction. The purpose of the present study is to analyze impurities in the NIFS-HEATs by activation method and examine the levels of induced activation and decay heat with 14 MeV neutrons. The results of impurity analysis obtained in 2001 were briefly described below.

The neutron irradiation was performed at FNS (Fusion Neutronics Source) of Japan Atomic Energy Research Institute. In the facility, 14 MeV neutrons were produced by bombardment of 350 keV deuteron beam on a tritium target. Plate specimens of NIFS-HEAT-1, whose typical dimensions were 20 mm x 15 mm x 1 mm, were placed in front of the tritium target during irradiation. After adequate cooling time, gamma-ray spectra of the specimens were measured with a high-purity Ge detector. For the analysis of impurities producing long-lived nuclides, the total neutron fluence was amounted to 1.5 x 10^{15} n/cm^2 by one-month operation. The gamma-ray spectra were measured after the cooling time of 100 days and 300 days. For the analysis by short-lived radioactive nuclides, the irradiation time and the fluence were 2 hours and 1.0 x 10^{10} n/cm^2, respectively. The cooling time was 3 hours. For comparison, irradiations of the similar conditions were also performed on US#832864 specimens fabricated by the US-DOE.

Fig. 1 shows the example of the gamma-ray spectra measured 300 days after the one-month operation. The plot for the US specimen is shifted vertically by one order. At each of peaks in the spectrum, neutron induced radioactive nuclides are labeled with the considered source elements, i.e. impurities in the ingot. Peaks corresponding to Fe and Ni were clearly observed. Their concentrations calculated from the height of the peaks were 80 ppm and 11 ppm for the NIFS-HEAT-1 and 220 ppm and 10 ppm for the US#832864, respectively. Although the peaks were obscure, other detected impurities were Na of 2 ppm and Nb of 30 ppm in the both specimens. From results of the 2 hours irradiation, Al impurity was detected by the ^{27}Al (n,α) ^{24}Na reaction. The concentrations were 93 ppm in the NIFS-HEAT-1 and 170 ppm in the US#832864. Table 1 lists the detected impurity elements and their concentrations mentioned above. The values of concentrations except Na and Nb were almost consistent with those by chemical analysis.

In the five impurity elements detected by the present irradiations, Al and Nb were considered to be harmful for the low activation property. The level of Al concentration allowed for remote handling of the vanadium alloy in reactors was estimated to be 200 ppm. It was confirmed from the results that the Al concentration in the NIFS-HEAT-1 satisfied the criterion. However, as to Nb impurity, the concentration obtained from the obscure peak exceeded the criterion level of 10 ppm. More irradiation experiments focusing on Nb and other harmful impurities such as Ag and Mo are required for precise examination of the activation property.

At present, similar impurity analysis by activation method and measurement of decay heat are performed for NIFS-HEAT-1, NIFS-HEAT-2, some domestically fabricated alloys and round robin specimens from the United States and China.

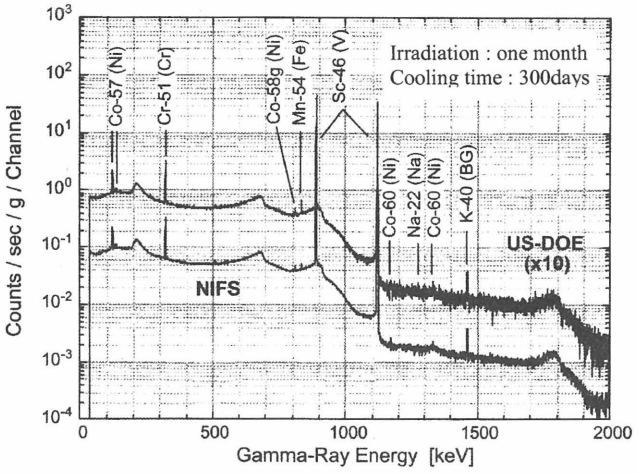

Fig. 1. Example of gamma-ray spectra of vanadium alloy specimens measured 300 days after one-month irradiation.

Table 1. Impurity concentrations measured by present activation analysis with 14 MeV neutrons.

Impurity element	Concentration (ppm)	
	NIFS-HEAT-1	US#832864
Fe	80	220
Ni	11	10
Na	2	2
Nb	30	30
Al	93	170