Experimental Studies on the Neutron Emission Spectra and Activation Cross-section in IFMIF Accelerator Structural Elements

III. 1. Experimental Studies on the Neutron Emission Spectra and Activation Cross-section in IFMIF Accelerator Structural Elements

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The International Fusion Materials Irradiation Facility (IFMIF) project has been proposed to establish an accelerator-based D-Li neutron source designed to produce an intense fast neutron field for high fluence test irradiations of the fusion reactor candidate materials[1].

To establish the database required for the design of IFMIF, we have been conducting systematic experiments on the neutron emission spectrum and radioactivity accumulation in IFMIF structural elements from 2001[2-5]. In the previous reports (2001, 2002), the results on lithium target for 25, 40 MeV deuterons were reported. The experiments are carried out at the No.5 target room in CYRIC using the AVF cyclotron (K=110 MeV), a beam swinger system and the TOF method, and stack target method.

In the last year, we have carried out new experiments for 40 MeV deuterons with extended techniques and obtained new results for

1) neutron emission spectrum from a thick C, Al target and

2) activation cross-sections of the $^{nat}C(d,x)^{7}Be$, $^{27}Al(d,x)^{7}Be$, ^{22}Na, ^{24}Na reactions using a stacked target technique[6].

The experimental method was almost the same with these in previous experiments[5]. Thirty thin targets of carbon and aluminum with natural composition (200 μm thicknesses) were prepared and stacked to stop the incident beam in the targets to measure not only neutron spectra from a thick C, Al target but also excitation functions of the $^{nat}C(d,x)^{7}Be$, $^{27}Al(d,x)^{7}Be$, ^{22}Na, ^{24}Na reactions concurrently.

The neutron spectra were measured for almost entire range (1-50 MeV) of secondary neutrons at ten laboratory angles between 0- and 110-deg with the two-gain time-of-flight (TOF) method[7] using a beam swinger system. The results are shown in Fig.1 and Fig.2.

The main peaks due to deuteron break-up reaction are observed around 15 MeV having strong angular dependence similar with previous results of Li(d,xn) reactions[2-5]. This yield of the main peak is decreasing with increasing of the mass of target. Such data are very few and will be useful for the model development of the neutron emission.

The number of radioactive nuclides accumulated in the stacked targets was measured by counting the γ-rays from the nuclides of ^{24}Na, ^{22}Na and ^{7}Be using a pure Ge detector. The induced activities were determined with corrections for γ-ray detection efficiency, energy determination and deuteron attenuation using EGS 4[8], TRIM code[9] and Shen's formula[10] respectively. In Figs.3-6, the results of the activation cross-sections are shown, together with other experiments[11], recommended data by the IAEA group and PHITS calculation[13]. No other data are available for carbon but the present values for aluminum are consistent with other data and about two-times as large as the PHITS calculation. To estimate radioactivity induced by deuterons with PHITS, therefore, improvements will be required for cross-section calculation models. Present experimental results will be used as the basic data to check the accuracy of the Monte Carlo simulation and for the shielding design of a medium energy accelerator facility such as IFMIF.

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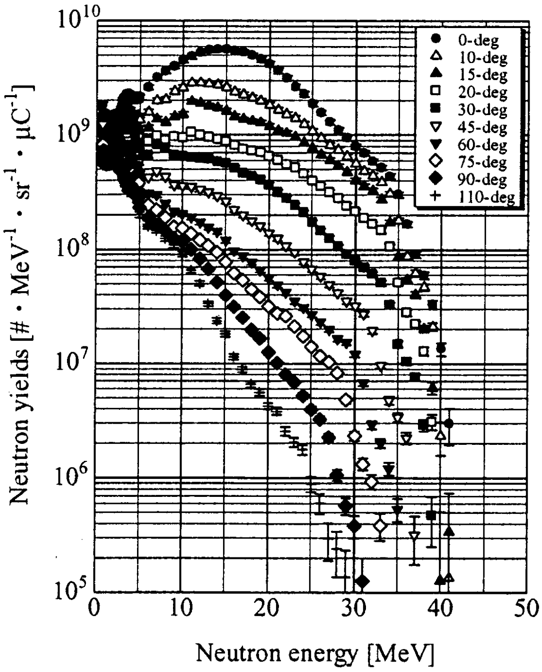

Fig. 1. The neutron spectra from thick carbon target for incident deuteron energy of 40 MeV.

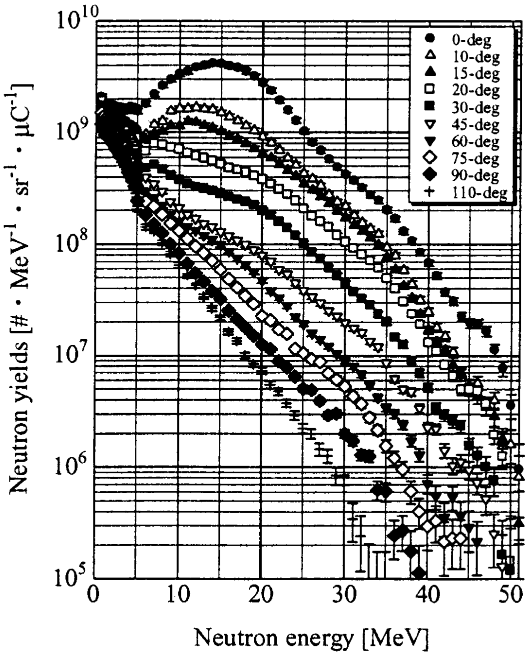

Fig. 2. The neutron spectra from thick aluminum target for incident deuteron energy of 40 MeV.

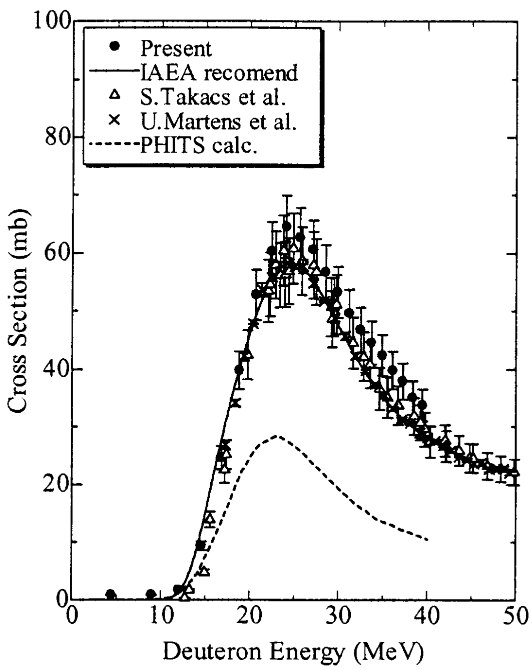

Fig. 3. Al(d,x)^{24}Na cross-sections.

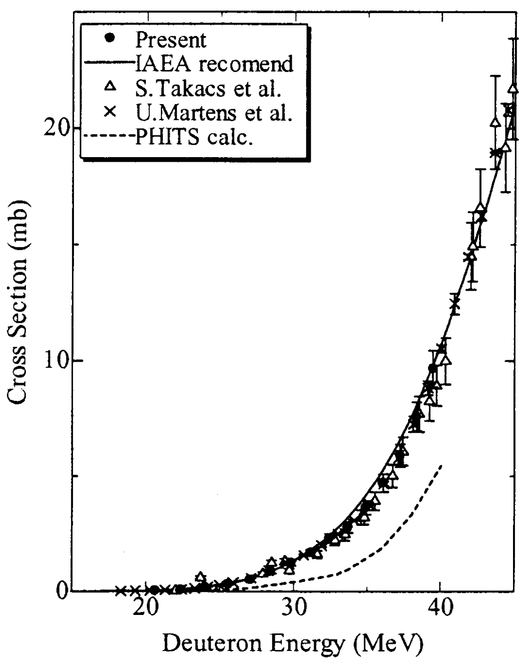

Fig. 4. Al(d,x)^{22}Na cross-sections.

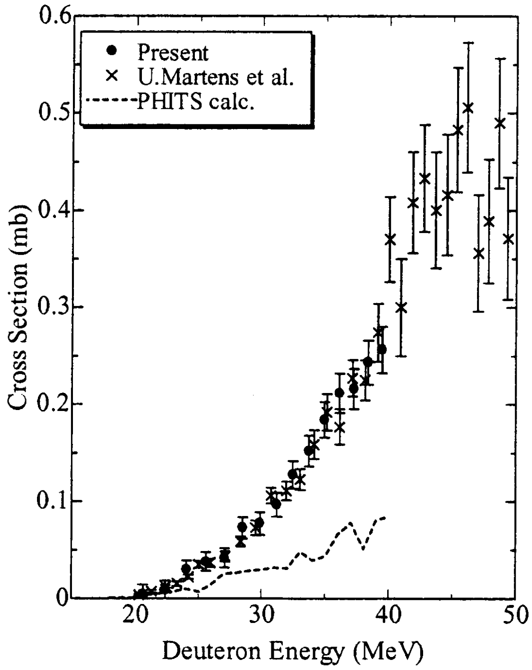

Fig. 5. Al(d,x)^{7}Be cross-sections

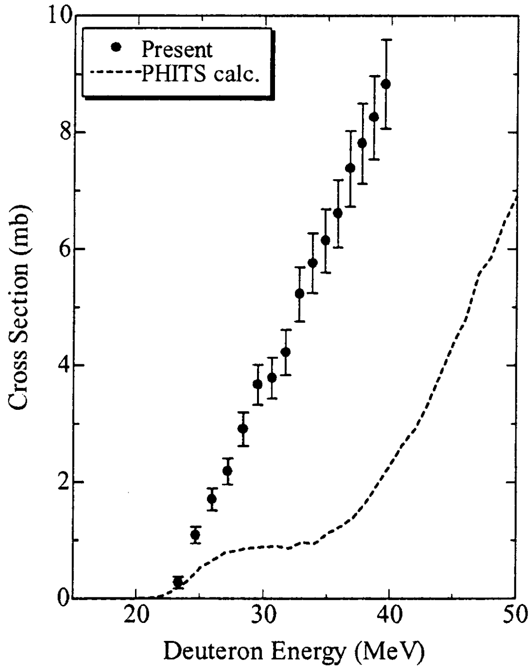

Fig. 6. C(d,x)^{7}Be cross-sections