Testing of a prototype lost α-particle diagnostic utilizing an imaging bolometer

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A lost alphas diagnostic is one of the high priority tasks for ITER which still has no satisfactory solution. The multi-foil thermal detector (MFTD) with moderate energy resolution was tested earlier in a single-channel prototype version [1,2] which is not compatible to ITER requirements. A multi-channel version of the MFTD prototype had been developed and tested at the FNL ion accelerator in Tohoku University, which uses an imaging bolometer [3] as a thermal sensor and 2-dimensional set of different foils with thicknesses as an energy discriminator for alphas. A number of different materials (aluminum, platinum, gold) and thicknesses (0.8 to 5.3 μm), and their combinations were tested for the energy discrimination. The 0.6 μm thick platinum foil blackened with a graphite layer was used as a stopping/re-radiating foil in the imaging bolometer, which was also heated up to 220°C for the better sensitivity by 4 small-size vacuum compatible heaters. Phoenix IR camera from FLIR Systems had been used for monitoring of the temperature profile variations under the ion beam irradiation. In order to minimize the effect of beam power and profile variations, the beam was swept by the electric magnets it in the 2 directions, thus providing relatively uniform irradiation of the foils. The following alpha particle energies were tested: 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.5, 1.7 and 1.9 MeV. All tested filtering foils have shown adequate performance related their stopping power calculated by TRIM. However, very strong beam profile dependence versus the ion energy had been discovered at the FNL which results to quite remarkable difficulties for the quantitative analysis of the data obtained.

Also, the remarkable difficulties resulted from the uncertainty of the re-radiation foil temperature profile, since it was locally heated up to 220°C at the periphery, but the central areas were much colder due to radiative cooling. The heated foil was proved to provide much higher sensitivity and reduced thermal diffusion effects, but it requires to perform a complicated procedure of temperature profile calibration, or an application of special efforts to minimize temperature non-uniformity.

Nevertheless, the results obtained showed that the tested foils are applicable for the MFTD design. The IR imaging bolometer proved to be an efficient tool for monitoring of energetic light ion fluxes with 200-300 keV energy resolution. But an absolute accuracy of the beam power measurements was poor due to a number of uncertainties related to the beam power profile and instability, thermal diffusion and the temperature profile of the re-radiating foil. Further device modernization and new experiments are planed to improve the accuracy.

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