§29. An Application of Electrically Cooled Si-detector to Fast Neutral Measurement on CHS

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A new Fast Neutral Analyzer (FNA) has been developed, by using an electrically cooled Silicon Detector (Si-FNA).

The Si-FNA is suitable for a spatial measurement of energy spectra for high energetic particles, which are produced by NBI and/or ICRF heating. It has following advantages; 1) wide energy range 2) compact size 3) inexpensiveness compared to the conventional FNA.

On the other hand, it is not suitable for a low energy measurement and its energy resolution is rather bad, since the leak current affects both the energy resolution and the lower side of energy spectra. This problem can be solved by cooling the detector and FET of the preamplifier. The visible lights from plasma also affect the low energy measurement of the Si-FNA. To avoid them, we put an evaporated aluminum layer of 1000Å on the front window of the detector, which will reduce the intensity of lights by the order of 4.

This aluminum layer and Silicon-dead layer of the detector cause the energy straggling to the particles injected to the detector. Figure 1 shows a calculated energy broadening due to a Silicon-dead layer and a Silicon-dead layer plus an Aluminum layer. For 40keV hydrogen atoms, which are typical injection energy of CHS-NBI, the energy broadenings (represented by FWHM) in these layers are about 4-keV and 2.5-keV, respectively. This means the necessary improvement of the energy resolution is for the range of 4-keV. This energy resolution is achievable by cooling the detector below 10 degrees centigrade [1]. To achieve this temperature, we adopted a Peltier element to cool the detector, instead of Liquid Nitrogen.

The proto-type of the Si-FNA was constructed and the Peltier-cooling was tested on this proto-type. We have achieved −1.6 degrees centigrade by a Peltier-element. With the improvement of the detector thermal insulation, the lower temperature could be achievable. In the case shown here, only the detector was cooled but FET of preamplifier was not. Figure 2 shows the spectra measured by using the radiation source of ^{241}Am X- and γ-(59.5-keV) ray by Si-FNA. In the spectra obtained by the cooled detector, the leak current spectra appear only below 15keV, while those obtained by the non-cooled detector do up to 25-keV. The spectra due to ^{241}Am X-ray was also observed with the detector cooling. The energy resolution, which is estimated from 59.5-keV γ-ray peak width, is improved from 9-keV to 5-keV by cooling the detector.

The energy spectra of fast neutral hydrogen are also measured by the Si-FNA on CHS. Figure 3 shows the diagnostic neutral beam (DNB) spectra measured by the detector without an evaporated aluminum layer. In this shot, 38-keV DNB was injected without target plasma. The energy slowing down time of the beam is almost infinite compared to the charge exchange loss time. Therefore, a delta-function like spectrum is expected. The peak of the first-component of DNB appeared at 32-keV. This peak shift of 6-keV can be explained by the energy loss of hydrogen ion at the dead layer. The energy resolution obtained is 10-keV, which is broader than our expectation of 5-keV. The cause of this energy broadening is now under investigation.

The further enhancement in detector performance, i.e. the energy resolution and the measurable lower energy limit, is possible by cooling FET of preamplifier and improving thermal insulation of the detector.

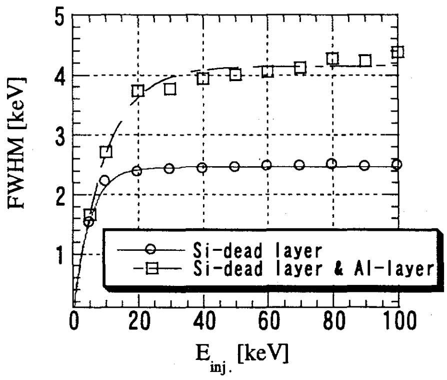

Fig.1 Calculated energy broadening of the hydrogen atoms, transmitting the dead layer (of which thickness is 500Å) and the evaporated aluminum layer (of which thickness is 0 and 1000Å) by using TRIM code.

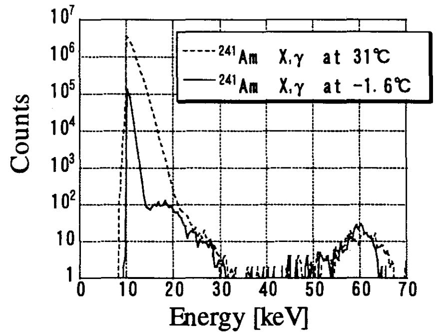

Fig.2 Energy Resolution measured by using the radiation source of ^{241}Am γ-ray (59.5keV) with and without Peltier cooling (solid and dashed line respectively).

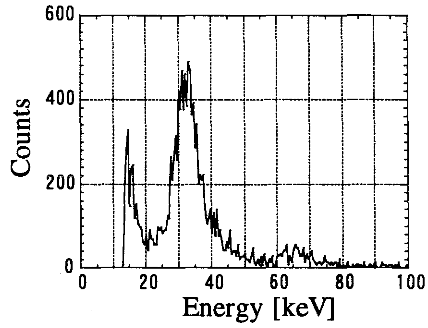

Fig.3 Spectrum measured the 38keV neutral hydrogen atoms by the Si-FNA without an evaporated aluminum layer on CHS.

Reference

[1] J.A.Ray and C.F.Barnett, IEEE.Nucl.Sci.,NS-16, (1969)