Application for Plasma Diagnostics with D(α,γ)^{6}Li Gamma-ray

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Introduction

The gamma ray measurement from fusion plasma is one of the important techniques to clarify fast ion properties in plasma. Some observation of the gamma-ray in JET plasma was reported. ^{12}C(d,pγ)^{13}C and ^{9}Be(α,nγ)^{12}C reactions on the JET observation are mainly recommended as the actual prospective nuclear reaction on the gamma-ray measurement [1]. However, it is thought that the gamma-ray observation by means of these reactions significantly depends on the conditioning (i.e. densities of the beryllium and carbon in plasma). Therefore, it is also important to examine the availabilities concerning the methods of gamma ray. We have tried to measure the 2.18 MeV gamma ray of D(α,γ)^{6}Li reaction and the properties of the another gamma ray emission by MeV-He^{++} beam irradiation experiment.

Irradiation experiment and gamma ray spectroscopy

We carried out the irradiation experiment to measure the gamma spectroscopy induced by He^{++} beam. Figure 1 shows the schematic view of the irradiation experiment. Tandem van de Graaff accelerator (5SDH-II) in Kobe University was used. A deuteride polystyrene (C_6D_6) thick target was implanted with He^{++} beam in the energy range of 2-4 MeV. Also thick targets of a carbon and a deuteride titanium (TiD_x) were implanted to compare with the result of the C_6D_6 target irradiation respectively. The mean of He-beam current was about 400nA. The emitted gamma ray was detected by a HpGe detector. The HpGe detector's relative efficiency was about 25% and was surrounded with the lead block assembly to intercept background gamma ray and unnecessary gamma-ray as much as possible. The energy calibration of the detector was done with the Co-60 and Cs-137 checking source. In order to monitor the production of neutron by the irradiation, we used the BF_3 counter which installed on the experimental room wall.

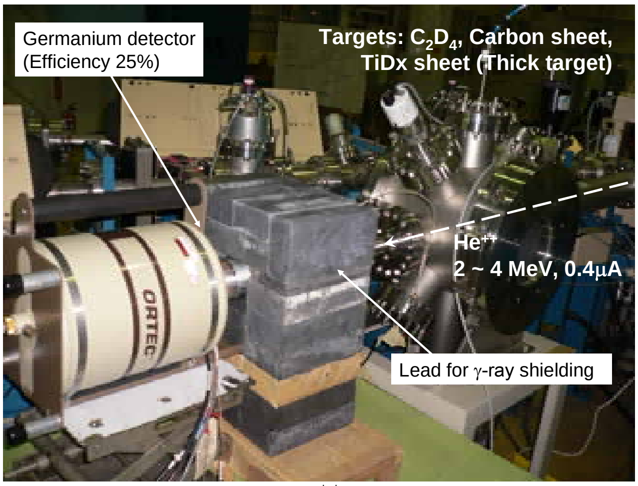

Fig.1 Schematic view of He^{++} irradiation experiment.

Result and discussion

Figure 2 shows the detected background gamma spectrum with our Ge detector. Some typical background peak (K-40, Tl-208, Bi-214 and Pb-214) was mainly observed. In order to detect gamma ray from the samples effectively, there is no shielding material between the head of detector and the target backing material. Therefore, the level of background yield was more several time than a while covered case.

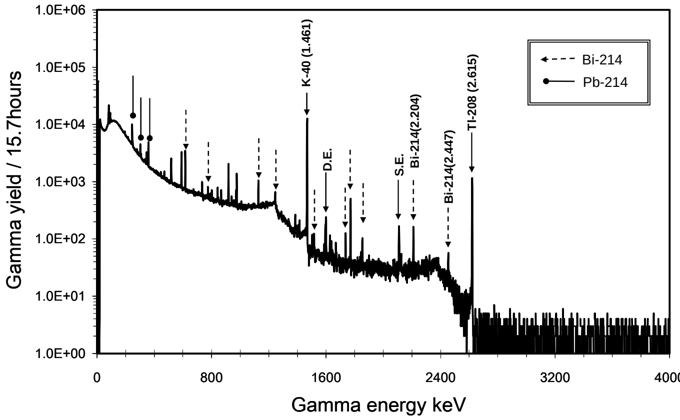

Fig.2 Measured background for 15.7 hours. Some typical photo peaks (K-40, Tl-208, Bi-214 and Pb-214) was observed.

Figure 3 shows the measured gamma-ray from used C_6D_6, carbon and TiD_x under 3.5-MeV He^{++} irradiation. each yield was normalized with incident coulomb of He^{++} ion. Below 1MeV, it is thought that the count of gamma ray was dominant at gamma-ray by ${}^{nat}Ge(n,n\gamma)$ inelastic reaction and $Al(n,x\gamma)$ reaction. Especially, the profile of spectra in the range of 0.5 and near 1 MeV corresponds with the past results [2]. It could be considered that the the neutron emission was due to the ${}^{13}C(\alpha,n){}^{16}O$ reaction and D-D reaction between the recoil deuteron by He^{++}

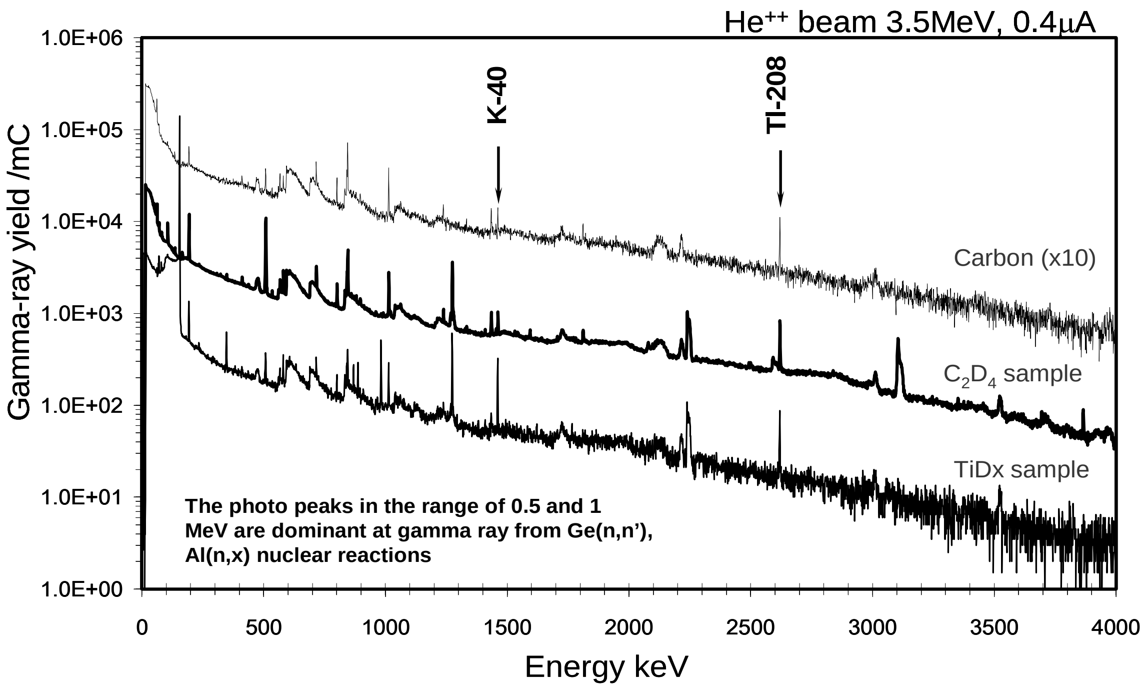

Fig. 3 shows the measured gamma-ray from used C_6D_6, carbon and TiD_x under 3.5-MeV He^{++} irradiation.

and deuterium in the sample. From the monitoring of the BF_3 detector, the neutron counting rate on the irradiation of the C_6D_6 and the carbon samples increased more than TiD_x case. Therefore, it is due to the neutron from $^{13}C(\alpha,n)^{16}O$ reaction. In the energy range between 2.1MeV and 2.2 MeV, that is, near 2.18 MeV gamma-ray from $D(\alpha,\gamma)^6Li$ reaction, we observed some shape and broad peak.

Figure 4 shows the detail spectrum in the range of 2.04 -2.24 MeV on 2.25-, 3.0- and 3.5-MeV H^{++} irradiations to the C_6D_6 sample respectively. On the case of 3.5 MeV irradiation, we observed 2.24-MeV sharp peak and satellite peak, a somewhat broad peak near the 2.22 MeV and a broad peak with some structure near 2.06-2.16 MeV. However 2.18 MeV peak which agree with $D(\alpha,\gamma)^6Li$ reaction could not be found. The dash horizontal line in Fig.4 means the yield level estimated with the past cross section data [3]. As our preliminary view, it was thought that the sharp peak on 2.24 MeV is due to $H(n,\gamma)D$ and 2.22-MeV peak is Bi-214 (2.204MeV). Furthermore, it is considered that the broad peak in 2.06-2.16 MeV is constructed from the single escape peak of Tl-208 and some gamma-ray from $^{nat}Ge(n,n\gamma)$. As above mentioned, we need to improve our measurement system to observe the 2.18 MeV gamma-ray from $D(\alpha,\gamma)^6Li$ reaction. Especially, the shielding of the background gamma ray precisely should be improved.

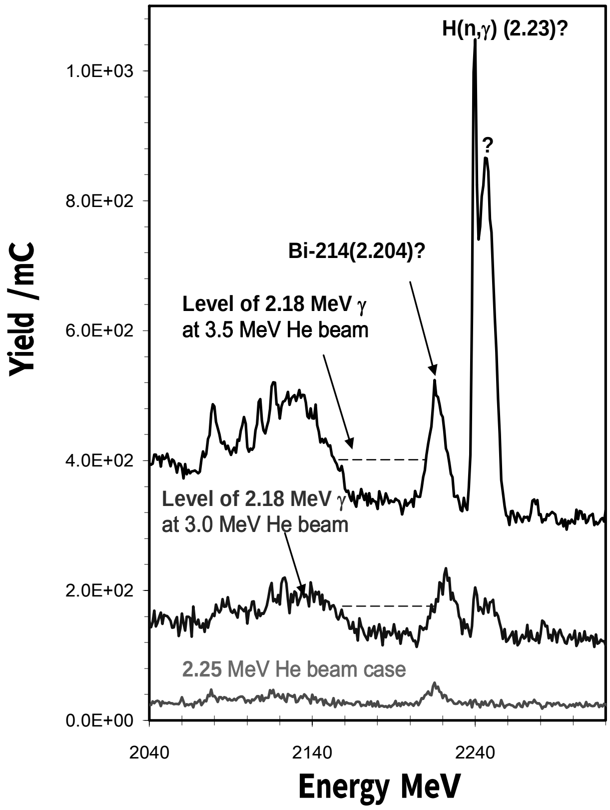

Fig.4 The detail spectrum in the range of 2.04 -2.24 MeV on 2.25-, 3.0- and 3.5-MeV H^{++} irradiations to the C_6D_6 sample.

On the other hand, 3.09, 3.68 and 3.85-MeV peak was obviously observed on the He^{++} beam irradiation. Also the 3.09- MeV peaks have the distortion of the profile. Figure 5 shows the measured gamma profile. The three peaks is significantly thought that the 3.09-MeV peak was induced by $^{12}C(d,p\gamma)^{13}C$ reaction. For the reason of the observation, we suggest that elastic recoil deuteron with He^{++} bombardment induced the sequential $^{12}C(d,p\gamma)^{13}C$ reaction (see Fig.5). Also it is suggested that the distortion of the 3.09-MeV peak profile was due to the Doppler effect. The half life time ($T_{1/2}$) of 3.09 MeV gamma from the $^{12}C(d,p\gamma)^{13}C$ reaction is estimated about 1 fsec [4]. Also the maximum kinematics energy of the residual ^{13}C nucleus can estimate about 0.2 MeV. Considering the range of 0.2-MeV ^{13}C nucleus in the sample (C_6D_6), the stopping time is in order of 1 nsec and corresponds with the

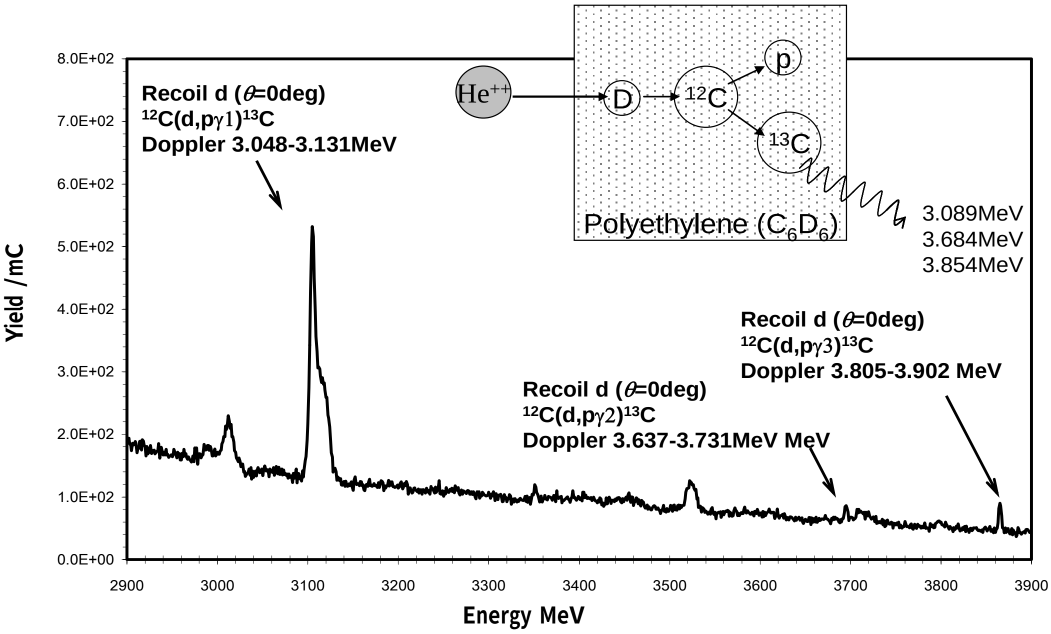

Fig.5 The gamma-peak from sequential $^{12}C(d,p\gamma)^{13}C$ reaction induced elastic recoil deuteron.

$T_{1/2}$ of 3.09 MeV gamma from the $^{12}C(d,p\gamma)^{13}C$ reaction. Therefore, it is considered that the edge shoulder of 3.09-MeV peak is the gamma-ray emitted from ^{13}C particle running in the sample.

Summary

In order to observe the γ-ray induced with high energetic α particles, we carried out the irradiation experiment with He^{++} beam. Especially, we tried to measure 2.18-MeV γ ray by $D(\alpha,\gamma)^{6}Li$ reaction and examined the propriety of the availability to plasma diagnostics.

Some broad peak in the range between 2.1 and 2.3 MeV was observed. However, it was difficult to identify 2.18-MeV γ ray from $D(\alpha,\gamma)^{6}Li$ reaction because of the background gamma-ray (Bi-214 (2.204MeV) and single escape peak from the Tl-208) and 2.2-MeV photo peak from H(n,γ)D reaction.

3.09- and 3.85-MeV peak was obviously observed and the peaks the sequential $^{12}C(d,p)^{13}C^{*}$ due to the elastic recoil deuteron with α particle bombardment (knock-on deuteron). Also It is suggested that the distortion of the 3.09-MeV peak profile is due to the Doppler effect. By the influence of the Doppler effect, it is thought that high energy α particle flux is able to measure.

Acknowledgement

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