Production of a $^7$Be implanted target


The beam system for reaction of isotope of long-life with light-ions applying normal kinematics and implanted target (BRILLIANT) is a project to realize light-ion reaction with implanted targets. The first application is for $^7$Be to measure the $^7$Be($d$, $p$) reaction for studying the primordial $^7$Li production in Big-Bang nucleosynthesis (BBN).

The overestimation of primordial $^7$Li abundance in the standard BBN model is one of the known and unresolved problems in nuclear astrophysics. The latest theoretical BBN model prediction of the primordial $^7$Li abundance is still 3 times higher than the recent precise observation.1 A key to solve the discrepancy is the destruction of $^7$Be, for which the $^7$Be($d$, $p$)$^8$Be and $^7$Be($n$, $a$)$^4$He reactions are two promising processes. It is suggested that the contribution from $^7$Be($d$, $p$)$^8$Be is larger than that from $^7$Be($n$, $a$)$^4$He.2,3 We focus on the $^7$Be($d$, $p$)$^8$Be reaction. Present available data are insufficient in terms of the accuracy or energy range.4,5 We develop an unstable $^7$Be target for a high-resolution measurement of the $^7$Be($d$, $p$)$^8$Be reaction in normal kinematics, which is a great technical challenge. We call the technique “implantation method.” The $^7$Be particles are implanted in a host material. Our goal is to implant $1 \times 10^{12}$ $^7$Be/mm$^2$ in 29 h.6,7

We performed an experiment in June 2016 to create the $^7$Be target at CRIB. The primary beam was $^7$Li$^{2+}$, and the secondary beam was produced by the $^1$H($^7$Li, $^7$Be) reaction. The $^7$Be beam energy was 4.0 MeV/nucleon. We used a 10-μm-thick Au foil as the host material after a 15-μm-thick Au foil as an energy degrader and a 2-mm$^2$ collimator (Fig. 1).

We checked the beam focus and position with the F2 PPAC detector when the beam intensity was about $10^4$ pps at F2. The beam diameter at F2 was 10 mm. We implanted $^7$Be for 19 h after increasing the beam intensity to 1.1 eμA. The amount of implanted $^7$Be was measured by detecting the 477-keV γ-rays from the electron-capture decay of $^7$Be using a LaBr$_3$ detector. Thus, we could achieve the implantation of $4 \times 10^{10}$ $^7$Be/mm$^2$ in the first experiment.

The number is still smaller than the goal. We suspect that the beam-spot size and the beam position at F2 were not fully optimized for the high-intensity beam and not maintained well during the long irradiation time. As a next step, we plan to have a development beam time to satisfy those conditions for producing a high-intensity $^7$Be beam at CRIB.

Fig. 1. Set up in the CRIB F2 chamber.

Fig. 2. Comparison between the γ-ray measurement of the implanted target and the background. An obvious 477-keV peak appeared after the irradiation.

References