Heat durability test of molybdenum foil for the new CRIB cryogenic gas target

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A cryogenic gas target was developed and used for over 10 years[1)] for high-intensity low-energy secondary beam productions at CRIB (Center for Nuclear Study RI Beam separator.[2)]) The basic design comprises a stainless-steel gas cell with a 80-mm-long vs. ϕ20-mm cylindrical aperture, where the target gas is confined by 2.5-μm-thick Havar foil windows at the beam entrance and exit sides. The gas supply duct and gas cell are cryogenically cooled by liquid nitrogen. A forced gas flow system is employed through the entire gas line to avoid density reduction under high heat deposition caused by beam irradiation. The maximum intensity of the primary beam irradiation is limited by the heat durability of the Havar foil, which is known to be 2 W. Therefore, the gas target is always operated at a sufficiently low heat deposition of the primary beam onto the Havar foil windows to avoid damage.

Currently, we are developing a ^{26}Si RI beam with an intensity of 5×10^4 pps or higher for future measurements of the α-resonant scattering and ^{26}Si(α, p) reaction at CRIB (Exp. No. NP1812-AVF55). The highest beam intensity of ^{26}Si achieved at CRIB is 1.2×10^4 pps[3)] with a ^{24}Mg primary beam at 7.5 MeV/nucleon and 0.2 particle μA (pμA), which is limited by the 2-W heat deposition on the Havar windows. The above goal is possible once we achieve the maximum heat deposition of 8 W or higher. To this end, we consider the following design changes: (1) Using a foil material with a higher heat conductivity and/or higher melting point than those of Havar foil; (2) Redesigning the gas cell with a higher cooling performance.

In the previous test experiment (Exp. No. NP1812-AVF55-01), we confirmed the advantages of molybdenum (Mo) and titanium (Ti) over Havar foil. The former has better high-temperature property due to its higher melting point and heat conductivity, and the latter has lower heat deposition because the minimum required vacuum-tight thickness offers smaller energy loss of the beam passing through it. Next, we tested the heat durability of 2- and 3-μm-thick Mo foil mounted on the currently used gas target cell in the Detector Develop Beam Time (Exp. No. DD20-01). The target cell was filled with ^{4}He gas up to 400 Torr, cooled by liquid nitrogen with forced circulation. An ^{16}O beam at 6.8 MeV/nucleon was injected into the gas target with the maximum beam intensity of 1.4 pμA. The time course of the maximum temperature monitored by the thermography is shown in Fig. 1 for different

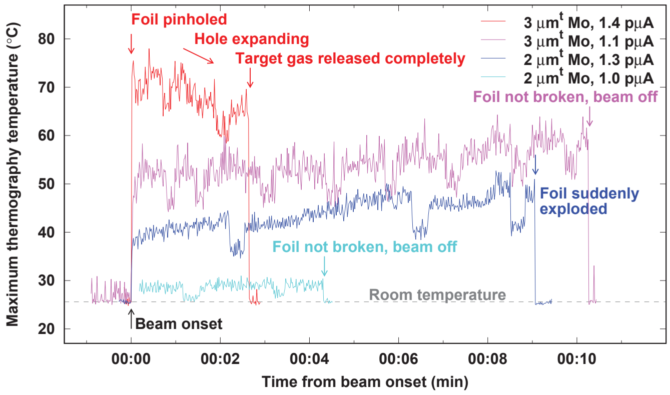

Fig. 1. Time course of maximum temperatures.

foil thicknesses and beam intensities. Note that the read temperature tends to be considerably lower than the expected value because of the limited spatial resolution of the thermography for the beam spot size. For an overall trend, the thicker foil is more easily heated up because of the larger energy loss of the beam particle than the thinner one. We believe that the process of each foil above 1.3 pμA was different; the temperature of the thinner one (blue line) increased gradually and the foil suddenly exploded at some point. In contrast, the thicker one (red line) showed a pinhole created right after the beam injection started, and the read temperature was decreasing as the hole expanded to loose the gas completely at the end. Despite such different trends, the breaking intensity was found to be similar (1.3–1.4 pμA), which can be attributed to the mechanical strength of the thinner foil becoming too weak to hold the gas even at a lower temperature where the thicker foil is still stable (even with a pinhole). We conclude that both the 2- and 3-μm-thick Mo foils can resist a beam intensity of 1.0–1.1 pμA or a heat deposition of 6–7 W at least; thicker foils are preferred for stable operation.

The remaining issue is the more efficient heat release from the Mo foil to the cryogenic gas cell body; this can be achieved by a design change (2). This is important to achieve further heat duration (>8 W) and for a more stable long-duration operation. This will be tested by another Detector Development Beam Time (Exp. No. DD20-02).

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References
1) H. Yamaguchi *et al.*, Nucl. Instrum. Methods Phys. Res. A **589**, 150 (2008).
2) Y. Yanagisawa *et al.*, Nucl. Instrum. Methods Phys. Res. A **539**, 74 (2005).
3) H. S. Jung *et al.*, Phys. Rev. C **85**, 045802 (2012).