§3. Production of He⁻ Ions by Surface Collisions of Metastable He Atoms

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High energy beams of ^3He and ^4He can be used to diagnose spatial and energy distributions of fusion produced alpha particles confined in next generation fusion experiment devices. An ion source system that can deliver the intense beam of negative He ion(He^-) is necessary to realize the high energy atomic He beam, and the ion source is now being developed at NIFS based on the principle of double electron capture of He^+ in an alkali metal vapor cell. The system can be scaled up to an actual diagnostic system after resolving some engineering problems.[1] However, it may consume large amount of power to deliver the beam with necessary intensity, as the efficiency to produce He^- is low, and the brightness of the produced beam is small.

We have already shown that the direct conversion of He^+ into He^- out of collisions with a low work function metal surface is an inefficient process.[2] Another way to produce He^- beam using the surface process is to start the beam with the neutral metastable states. This can be easily accomplished by passing a He^+ beam in an alkali metal vapor. The metastable states of He are known to possess some finite electron affinities, and electrons in the metal conduction band can be transferred to these levels following the probability roughly estimated by the following formula;

$$p = \frac{2}{\pi} e^{-\frac{e(\phi_w - E_a)}{av}},$$

where ϕ_w is the work function of the metal substrate, E_a is the electron affinity, v is the exit velocity of the negative ion, and a is some constant related with the distance of the range where exchange of the electron between the metal and the negative ion takes place. The value of ϕ_w-E_a for the metastable He-Cs covered metal system is about the twice the value for the hydrogen-Cs covered metal system. Provided the similar value for $a \cdot v$ is achieved, the conversion efficiency of metastable He into He^- through a surface collision can exceed several %, and a precise measurement is necessary to prove this estimation.

The negative He^- beam forming system based on surface conversion can be efficient as the beam prior to the injection into the negative ion beam forming system is transported free from the space charge. The well defined negative ion emission surface can further improve the beam optics. Thus, to study merits and demerits of He^- surface production from a matastable He beam, an experimental set up is being assembled. As shown in Fig. 1, a beam of metastable He is separated from positive ions after the production in an alkali metal vapor cell and directed to the surface of the Mo target. The incident angle of the beam can be change by rotating the Mo surface. Inside of the scattering chamber, a rotatable Wien filter selects the velocity of the scattered He^- and the beam current is measured with a Faraday cup.

The performance of the apparatus has been checked with hydrogen ion beams. An ion beam containing H^+, H_2^+, and H_3^+ produces atoms having the full, one half and one third of the acceleration energy. Part of these atoms are converted to negative ions at the surface of Mo target and are detected by the Faraday cup after the velocity selection by the Wien filter. This causes a broad spectrum measured by the system as shown in Fig. 2. The expected dependence upon the incident, and exit angles are also confirmed, and the system seems capable of measuring the negative ionization efficiency at the surface. To correlate the negative ion yield with work function, alkali metal evaporator, and the work function monitoring system will be installed to the system.

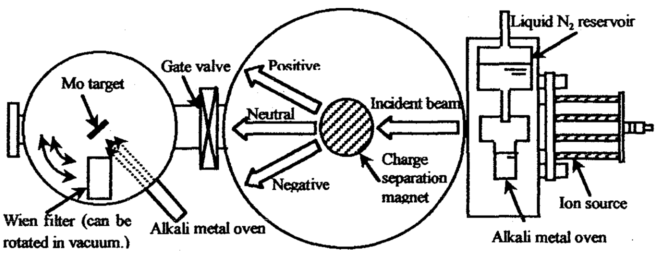

Fig. 1. Schematic illustration of the experimental set up.

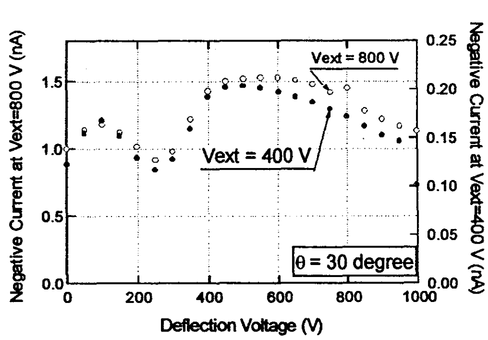

Fig. 2 Typical results measured with hydrogen beams.

References

1) M. Sasao, M. Nishiura, A. Taniike, and M. Wada, Rev. Sci. Instrum., **69**, (1998) 1063.

2) M. Sasao, M. Wada et. al, Rev. Sci. Instrum., **61**, (1990) 418.