Lithium ion production for laser ion source†

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The use of laser ion source (LIS) is an effective and simple method for creating a wide variety of ions. However, this method has not yet been extensively tested on alkali metal targets owing to their high reactivity. In this report, we investigated the Li plasma properties in laser ablation for the future application of alkali metal beam acceleration because Li ion beams can be used for neutron beam creation[1)].

Li oxidizes rapidly when exposed to the atmosphere. To limit the exposure of the targets, special precautions were taken when producing the targets. The metals were polished, rolled to an appropriate thickness using a rolling mill, and immediately stored in a portable vacuum chamber. When the targets were installed, argon gas flow was employed to reduce the exposure to oxygen. Then, the target chamber was immediately pumped down to vacuum. The attempted target thickness was 1.0 mm, although it was not easy to achieve good accuracy. The targets were irradiated with a neodymium-doped yttrium aluminum garnet (Nd:YAG) laser operating at 1.4 J, with a wavelength of 1064 nm and a pulse length of 6 ns. The laser was focused on the target with a plano-convex focusing lens with a focal length of 100 mm. The distance of the lens from the target was adjustable from outside of the target vacuum chamber, thus allowing the beam to be focused and defocused. The incident angle between the laser path and the beam line was 20°. The target chamber and subsequent beam line were held below 1.8×10^{-4} Pa for the duration of the experiment. A Faraday cup (FC) with a $\varphi = 10$ mm aperture was placed 2.4 m away from the targets to measure the beam current. The suppressor voltage of the FC was set to −3.5 kV. The positively charged particles in the plasma were analyzed using an electrostatic ion analyzer (EIA). The selected ions were detected by a secondary electron multiplier (SEM). The total distance between the detector and target was 3.7 m. The ion species and charge states were determined by the time of flight information in the SEM signal and the applied voltage to the EIA.

In the experiment, we detected H, Li, and O ions. Unfortunately, the apparatus cannot distinguish ions of different species but which have the same mass to charge ratio. Therefore, some detected signals may be contributed by different species. The entire view of the experimental setup was explained in our previous publication[2)].

A focused laser beam with power density of the order of 10^{12} W/cm^2 was used to create high-charge-state Li beams. A fresh laser spot was always supplied in the motorized stage for every laser shot. The analysis showed oxygen charge states ranging from O^{1+} to O^{8+} as well as $^{7}\mathrm{Li}^{3+}$, $^{7}\mathrm{Li}^{2+}$, $^{7}\mathrm{Li}^{1+}$, and $^{6}\mathrm{Li}^{3+}$. The beam composition data can be seen in Fig. 1.

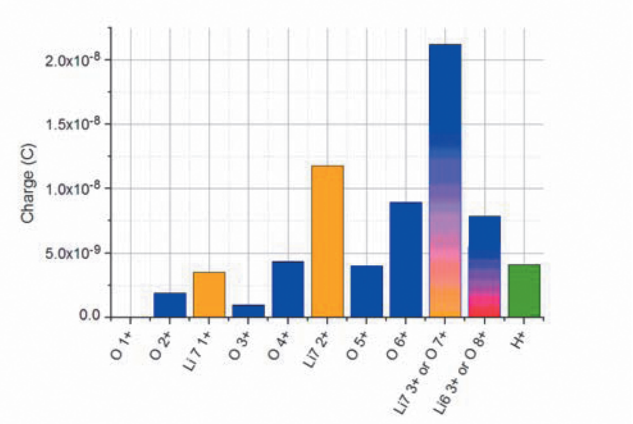

Fig. 1. Species and charge state distribution in the plasma from the Li target. The charges were counted at 1.0 m from the target with a 1.0 cm^2 sensing area.

The LIS could create high-charge-state ions from the Li target. There was an apparent oxygen contamination in the beams. We also found that the Li target was clearly oxidized in the vacuum chamber held below 1.8 x 10^{-4} Pa. To adopt a laser ion source with a Li target for industrial applications, oxidization and the time-consuming target preparation need to be overcome.

References

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2) S. Ikeda et al., Rev. Sci. Instrum. **85**, 02B913 (2014).

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