

## Electronic states analysis of Li metal surfaces scraped in ultra-high vacuum by photoelectron spectroscopy

Ryo Ihara and Masaru Takizawa

Department of Physical Sciences, Faculty of Science and Engineering, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga 525-8577, Japan

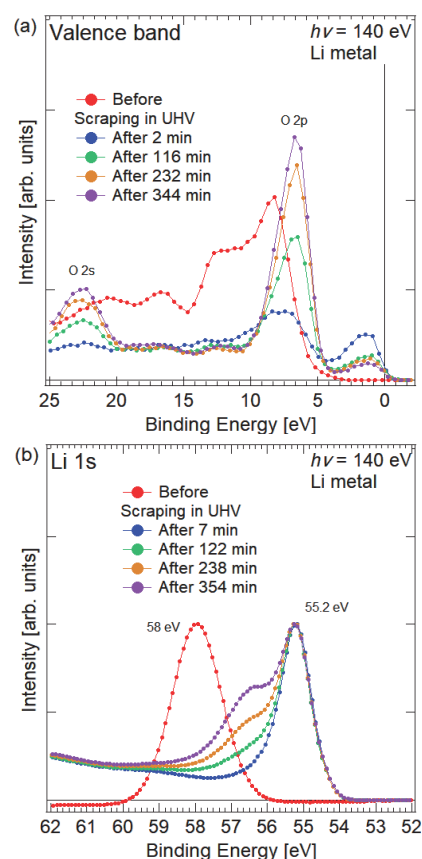
A Li-air battery is able to have higher energy and higher capacity than a Li-ion battery does (1). Due to the reaction of Li metal with some gases, however, it is difficult to control and understand the Li metal surfaces. Extensive measurements have revealed a chemical property of Li compounds during charge-discharge process (2). In addition, it is reported that some lithium oxide appeared (3). But it is possible to change from Li metal to the Li compounds until measurement result was obtained. Because of high activity of Li metal, its surface reacts with residual gases in a vacuum chamber. Therefore, it is important to confirm the changes from Li metal to other Li compounds in ultra-high vacuum (UHV). Keeping in UHV, we tried to measure the electronic state of modified Li metal by photoelectron spectroscopy (PES).

The PES measurement was carried out at the linearly polarized soft x-ray beamline BL-7 of SR center, Ritsumeikan University, using a hemispherical electron energy analyzer, SCIENTA SES2002. The measurements were performed at room temperature under the UHV of  $\sim 5 \times 10^{-8}$  Pa. Using an Al K $\alpha$  source ( $h\nu = 1486.6$  eV), we also performed X-ray PES (XPS) measurements to see contamination peaks. Lithium metal plates from HONJO METAL CO. were transferred to the UHV chamber without being exposed in the air. The sample surfaces were scraped *in situ* with a diamond file to obtain clean surfaces.

The series of PES results after scraping the surfaces in UHV are shown in Fig. 1. After scraping in UHV, the contamination peaks around the binding energies from 10 to 25 eV disappeared and the clear Fermi edge appeared [Fig. 1(a)]. The scraping *in situ* could clearly remove contaminations. After keeping in UHV for a long time, however, the structures around the binding energy of 6 eV and 23 eV increased. These peaks would be assigned to O  $2p$  and O  $2s$  peaks, respectively. As for the Li  $1s$  core-level spectra, it became shifted and sharpened after scraping in UHV [Fig. 1(b)]. This peak is assigned to intrinsic Li metal because the binding energy of this peak is the lowest among those of other Li compounds. After keeping in UHV for a long time, however, another peak appeared and increased. This peak is assigned to Li oxide, not Li carbonate, because the intensity of C  $1s$  peak was little in the XPS

spectra. Therefore, the surface of Li metal is highly active to a residual gas in the UHV chamber.

We have tried to measure the intrinsic electronic state of Li metal by scraping its surface in UHV. The clear Fermi edge and the sharp Li  $1s$  peak appeared. However, the electronic states changed even after keeping in UHV. In this measurement condition, Li metal changed to Li oxide.



**Fig. 1** Valence band spectra (a) and Li  $1s$  core-level spectra (b) of Li metal before and after scraping in UHV.

### References

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