Enhanced Oxygen Evolution in Lithium-Oxygen Battery using RuO$_2$ Nanoparticles and its Mechanism

Eda Yılmaz, Hye Ryung Byon
Byon Initiative Research Unit, RIKEN
2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan

Rechargeable non-aqueous lithium-oxygen (Li$_2$O$_2$) battery providing theoretically high specific-energy-density calculated as ~3 kWh kg$^{-1}$cell in a promising future energy storage system. However, the energy loss, indicated by an over-potential, during Li$_2$O$_2$ electrochemical process (2Li$^+$ + O$_2$(g) + 2e$^-$ $\leftrightarrow$ Li$_2$O$_2$(s), $E_{rev}$ = 2.96 V vs. Li$^+$/Li) is considerably severe, which is one of the great challenges for implementation of practical battery systems. The over-potential is prominently caused by the difficulty of decomposition of insulating Li$_2$O$_2$ during the oxygen evolution reaction (OER, Li$_2$O$_2$(s) $\rightarrow$ 2Li$^+$ + O$_2$(g) + 2e$^-$) on recharge. In addition, byproducts, e.g., lithium carbonate (Li$_2$CO$_3$) and lithium acetate formed due to degradation of non-aqueous electrolyte have required further energy to be decomposed.

Many efforts for suppression of the over-potentials during discharge and recharge have been devoted by incorporation of metal and metal oxide structures to the carbon cathodes. However, there has been still a lack of deep understanding for the role of these metal and metal oxide structures. The functions of these structures have been interpreted diversely such as an electrocatalyst, a promoter enhancing the movement of Li$_2$O$_2$ species, a decomposer degrading electrolyte greatly and a stabilizer improving cyclic stability.

Here, we present improved OER performance of Li–O$_2$ cells using ruthenium oxide (RuO$_2$) nanoparticles (NPs) dispersed on multi-walled carbon nanotube (CNT) (RuO$_2$/CNT) and suggest the role of RuO$_2$ NPs. When RuO$_2$ NPs are used in the CNT cathode the over-potential during recharge is decreased to ~0.50 V as shown in Fig.1. The electrical efficiency of RuO$_2$/CNT cathode is 74%, much higher than that of CNT cathode only, which is 58%. X-ray absorption near edge structure (XANES) spectroscopy, X-ray diffraction (XRD) and transmission electron microscopy (TEM) analyses of the discharge product reveal formation of poorly crystalline Li$_2$O$_2$ in the presence of RuO$_2$ NPs. In addition, shapeless Li$_2$O$_2$ layer structure having a large contact area with CNT electrode is observed on the RuO$_2$/CNT electrode, which can be completely decomposed at low OER potential. This study reveals the role of RuO$_2$ NPs in the non-aqueous Li–O$_2$ electrochemical reaction and offers a guide to improvement of the electrical efficiency in the Li–O$_2$ battery.

References


Fig.1 First cycle discharge/charge curves with RuO$_2$/CNT and CNT cathodes using 0.5 M of LiTFSI in tetraglyme electrolyte at 0.05 mA cm$^{-2}$ current rate.