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Enhanced Oxygen Evolution in Lithium-Oxygen Battery using RuO_2 Nanoparticles and its Mechanism

Eda Yilmaz, Hye Ryung Byon

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

Rechargeable non-aqueous lithium-oxygen ($Li-O_2$) battery providing theoretically high specific-energy-density calculated as ~3 kWh kg^{-1}_{cell} is a promising future energy storage system. However, the energy loss, indicated by an over-potential, during $Li-O_2$ electrochemical process ($2Li^+ + O_2(g) + 2e^- \leftrightarrow Li_2O_2(s)$, $E_{rev} = 2.96$ 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_2O_2 during the oxygen evolution reaction (OER, $Li_2O_2(s) \rightarrow 2Li^+ + O_2(g) + 2e^-$) on recharge.[2] In addition, byproducts, e.g., lithium carbonate (Li_2CO_3) and lithium acetate formed due to degradation of non-aqueous electrolyte have required further energy to be decomposed.[3]

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,[4] a promoter enhancing the movement of Li_2O_2 species,[5] a decomposer degrading electrolyte greatly[6] and a stabilizer improving cyclic stability[5].

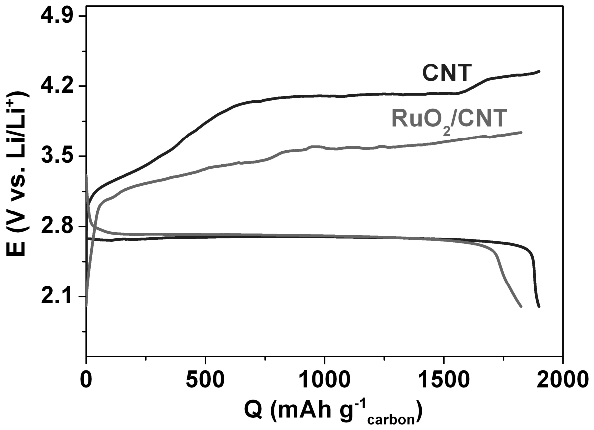

Fig.1 First cycle discharge/charge curves with RuO_2/CNT and CNT cathodes using 0.5 M of LiTFSI in tetraglyme electrolyte at 0.05 mA/cm^2 current rate.

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_2O_2 in the presence of RuO_2 NPs. In addition, shapeless Li_2O_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

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