



# A layered hollow sphere architecture of iridium-decorated carbon electrode for oxygen evolution catalysis



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## ABSTRACT

Here, we introduce a layered hollow sphere (LHS) architecture of iridium-decorated carbon electrode. The electrode was prepared by coating of a solution composed of graphene oxide (GO),  $\text{IrCl}_3$ , and polystyrene bead followed by subsequent pyrolysis. The morphology of the electrode was investigated according to the composition of solution, and the electrocatalytic properties were characterized. The usage of GO highly enhanced the electrochemical surface area of the electrode (by ~6 times). The LHS electrode also showed outstanding electrocatalytic properties: a current density of  $89.99 \text{ mA/cm}^2$  could be obtained at a potential of 1.6 V.

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## 1. Introduction

Hydrogen is a promising candidate for chemical energy storage, which can be sustainably produced by water electrolysis using photovoltaics, hydroelectric power, or wind power [1–3]. However, the oxygen evolution reaction (OER) under acidic conditions deteriorates the overall efficiency of the water electrolysis [4,5]. Due to their outstanding activity and stability, iridium (Ir) based materials represent the best compromise for OER catalysts, but the poor abundance and high cost of Ir are barriers to widespread utilization [6–8]. To reduce the amount of precious Ir materials used in the electrode, alloy formation with cheap transition metals has been attempted, but resulted in decreased activity [9–11]. An alternative approach is to fabricate porous Ir structure to increase its specific surface area.

Because of the extremely large specific surface area of porous structure, it offers numerous benefits for charge and mass transport in electrochemistry [12–14]. Porous structure has shown performance enhancements for catalyst, battery, sensor, supercapacitor and electrochromic device [15–19]. For example, Jiang et al. prepared macroporous Ir oxide films featuring pores of about 500 nm diameter derived from polystyrene (PS) microsphere, which

showed excellent electrochromic properties compared to non-porous structure [20]. Hu et al. prepared three-dimensionally ordered macroporous  $\text{IrO}_2$  using silica colloidal template, which showed the overpotential of 0.22 V as a catalyst for OER [21]. Recently, Ortel et al. prepared mesoporous  $\text{IrO}_2$  using poly(ethylene oxide)-polybutadiene-poly(ethylene oxide) triblock copolymer as a template, which exhibited the overpotential of 0.21 V as a catalyst for OER [22].

The most popular approach for the preparation of porous structure is to use polymeric or inorganic beads as a template, such as PS, poly(methyl methacrylate) or silica spheres [20,21,23]. A few layers of beads are firstly stacked, and then precursor solution is filled the voids between beads and converted to metal. Finally, the template was removed by selective dissolution in an appropriate solvent, or by calcination at elevated temperatures [23,24]. The morphology of remained metal is determined by the size of bead and the volume of voids (Fig. 1). In the void filling process, the modification of void structure is still necessary in order to optimize the electrochemical properties.

Here, we introduced a layered hollow sphere architecture (LHS) by using graphene oxide (GO) and Ir precursor. PS microbead is used as a template on which GO is successfully covered and Ir cations were adsorbed on the GO, resulting in a LHS. The thin layer of GO is easy to cover PS bead due to the electrostatic interaction, and functional group of GO can easily anchor metal ions, thus LHS

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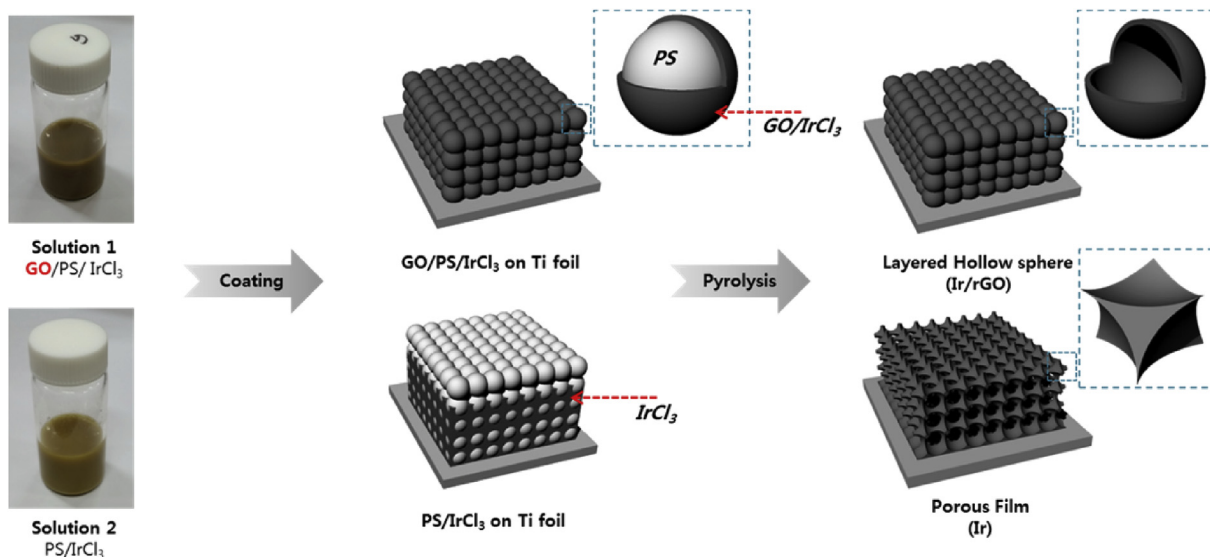


Fig. 1. Scheme for preparation of (a) a layered hollow sphere electrode, and (b) a porous film electrode. (A colour version of this figure can be viewed online.)

of carbon decorated with Ir could be constructed. We expected that various shapes of hollow structures could be constructed with this method.

We prepared the electrode by a facile process: coating the solution of GO, PS and Ir precursor on Ti foil, followed by pyrolysis.

During the pyrolysis, Ir deposition, decomposition of the template, and reduction of GO occurred simultaneously. We studied the morphology of the electrodes as a function of the composition of the solution, and investigated the electrocatalytic performance of these materials for the OER.

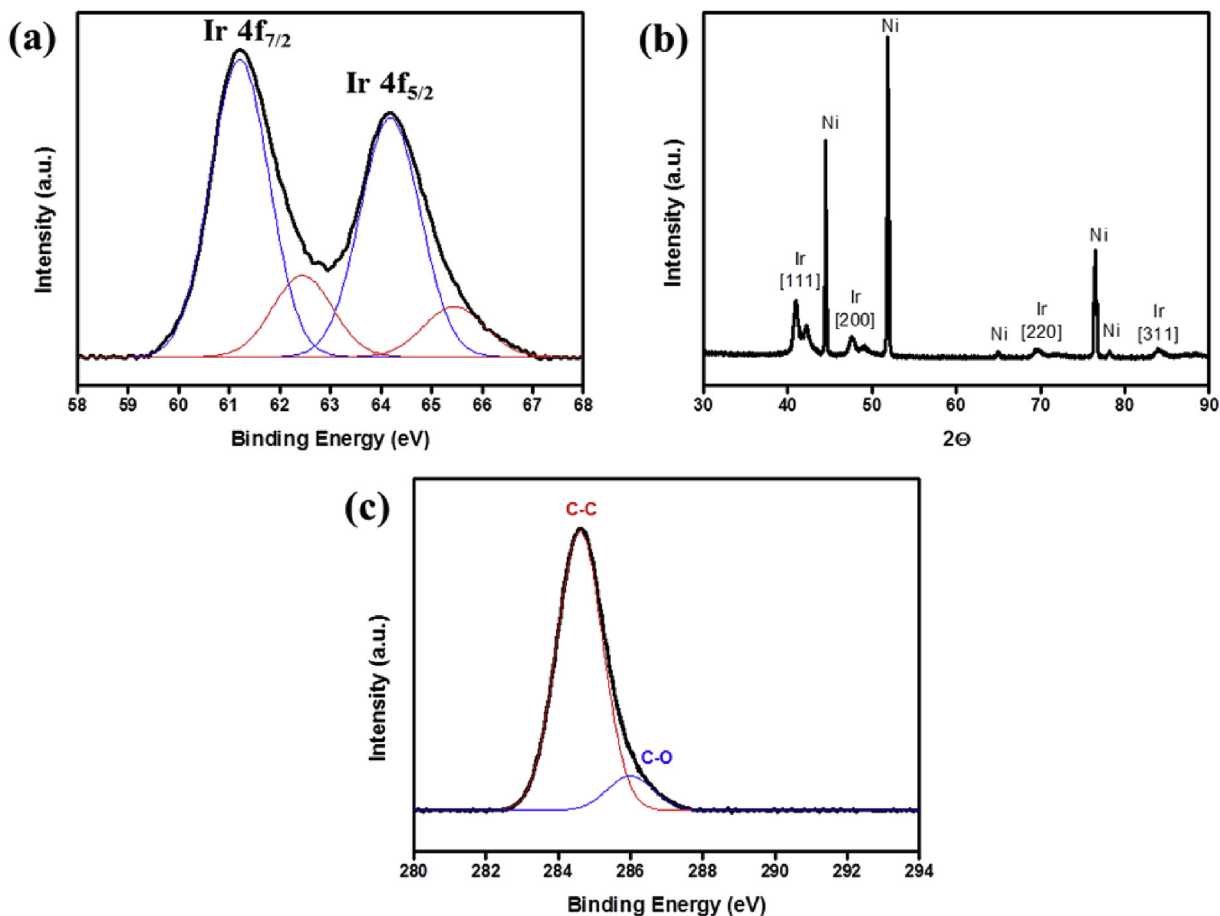


Fig. 2. XPS spectra of (a) Ir 4f and (c) C 1s orbitals, and (b) XRD spectrum of the LHS electrode. Ni foil was used only for XRD analysis, instead of Ti foil. (A colour version of this figure can be viewed online.)

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