N-doped graphene as an efficient catalyst for oxygen reduction reaction in alkaline medium: effects of heat-treatment temperature and catalyst loading

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The oxygen reduction reaction (ORR) is an active area of research due to its important role in electrochemical energy conversion/storage devices such as fuel cells and metal-air batteries.1-3 The development of highly efficient non-platinum catalysts for ORR is one of the most attractive challenges in this field.4-6 Here, we will demonstrate that a novel N-doped graphene catalyst prepared from pyrolyzing cyanamide, graphene oxide and a small amount of transitional metal salts show very promising catalytic activity for the ORR.

The N-doped graphene was characterized by transmission electron microscopy (TEM), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). The effects of heat-treatment temperature and catalyst loading on N-doped graphene towards ORR were investigated in alkaline electrolyte. The electrocatalytic activity and kinetics on the ORR were examined using rotating disk electrode (RDE) and rotating ring-disk electrode (RRDE) techniques.

Figure 1 shows the TEM image of N-doped graphene heat-treated at 900°C. It shows clean multi-layer graphene with lots of wrinkles, which is commonly observed for graphene-based materials. The semi-transparent nature of NG-900 indicates a very small thickness. Figure 2 displays the ORR polarization curves for N-doped graphene heat-treated at various temperatures from 700 to 1000°C in O2-saturated 0.1 M KOH solution. It can be clearly seen that the highest ORR activity was obtained from NG-900. ORR activity decreased in the following order: NG-900 > NG-1000 > NG-800 > NG-700. Further from the RDE and RRDE techniques, the ORR on NG-900 catalyst was demonstrated to follow the four-electron transfer pathway. With sufficiently high loading, the half-wave potential of this catalyst was close to that of Pt/C catalysts (loading: 40 µg Pt cm-2). These results suggest that N-doped graphene using cyanamide as N-precursor is promising substitute for platinum-based catalysts in alkaline medium.

References