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Pt Decorated Functionalized Acetylene Black as Efficient Cathode Material for Li Air Battery and Fuel Cell Applications

Authors : Rajashekar Badam, Vedarajan Raman, Noriyoshi Matsumi

Abstract : Efficiency of energy converting and storage systems like fuel cells and Li-Air battery principally depended on oxygen reduction reaction (ORR) which occurs at cathode. As the kinetics of the ORR is very slow, it becomes the rate determining step. Exploring carbon substrates for enhancing the dispersion and activity of the metal catalyst and commercially viable simple preparation method is a very crucial area of research in the field of energy materials. Hence, many researchers made large number of carbon-based ORR materials today. But, there are hardly few studies on the effect of interaction between Pt-carbon and carbon-electrolyte on activity. In this work, we have prepared functionalized carbon-based Pt catalyst (Pt-FAB) with enhanced interfacial properties that lead to efficient ORR catalysis. The present work deals with a single-pot method to exfoliate and functionalized acetylene black with enhanced interaction with Pt as well as electrolyte. Acetylene black was functionalized and exfoliated using a facile single pot acid treatment method. The resulted FAB was further decorated with Pt-nano particles (Pt-np). The TEM images of Pt-FAB with uniformly decorated Pt-np of ~3 nm. Further, XPS studies of Pt 4f peak revealed that Pt0 peak was shifted by 0.4 eV in Pt-FAB compared to binding energy of typical Pt^0 found in Pt/C. The shift can be ascribed to the modulation of electronic state and strong electronic interaction of Pt with carbon. Modulated electronic structure of Pt and strong electronic interaction of Pt with FAB enhances the catalytic activity and durability respectively. To understand the electrode electrolyte interface, electrochemical impedance spectroscopy was carried out. These measurements revealed that the charge transfer resistance of electrode to electrolyte for Pt-FAB is 10 times smaller than that of conventional Pt/C. The interaction with electrolyte helps reduce the interface boundaries, which in turn affects the overall catalytic performance of the electrode. Cyclic voltammetric measurements in 0.1M $HClO_4$ aq. at a potential scan rate of 50 mVs-1 was employed to evaluate electrochemical surface area (ECSA) of Pt. ECSA of Pt-FAB was found to be as high as 67.2 m^2g^{-1}. The three-electrode system showed very high ORR catalytic activity. Mass activity at 0.9 V vs. RHE showed 460 A/g which is much higher than the DOE target values for the year 2020. Further, it showed enhanced performance by showing 723 mW/cm^2 of highest power density and 1006 mA/cm^2 of current density at 0.6 V in fuel cell single cell type configuration and 1030 $mAhg^{-1}$ of rechargeable capacity in Li air battery application. The higher catalytic activity can be ascribed to the improved interaction of FAB with Pt and electrolyte. The aforementioned results evince that Pt-FAB will be a promising cathode material for efficient ORR with significant cyclability for its application in fuel cells and Li-Air batteries. In conclusion, a disordered material was prepared from AB and was systematically characterized. The extremely high ORR activity and ease of preparation make it competent for replacing commercially available ORR materials.

Keywords : functionalized acetylene black, oxygen reduction reaction, fuel cells, Functionalized battery
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