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Platinum nanoparticles ion-implanted-modified indium tin oxide electrode for electrocatalytic oxidation of formaldehyde

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ABSTRACT

A facile and low-cost method is developed to ion implant platinum nanoparticles (PtNPs) onto indium tin oxide (ITO) electrode. This modified electrode is eco-friendly without the use of any linking chemicals. The PtNPs formed on the electrode are in the zero-valent metallic state with a size distribution in the range of 5–12 nm. The modified electrode surface becomes smoother after platinum ion implantation and the PtNPs formed on the electrode. Electrochemical performances are measured by cyclic voltammetry (CV) and chronoamperometric. The PtNPs/ITO electrode shows prominent electrocatalytic activity towards the oxidation of formaldehyde with long-term stability, which could be useful in fuel cells.

Introduction

Formaldehyde (HCHO) is a risk to human health. But it has become more interesting due to its possible application in liquid fuel cells [1–3]. Most of research has focused on electrocatalytic oxidation of formaldehyde on noble metal nanoparticles. Among these materials, platinum nanoparticles have been widely concerned due to their superior electrocatalytic properties [4–6].

All kinds of approaches have been used to synthesise platinum nanoparticles (PtNPs), including the chemical reduction of platinum precursors by reducing agents, electrochemical deposition and surfactant or ligand-based colloidal methods. However, these methods are complicated with the use of stabilizers and binding reagents and the negative effects brought by these chemicals have to be considered [7–9].

Ion implantation is a kind of material surface modification technique, which provides practical and excellent electrode materials with long-term stability. This technique can implant the nanoparticles on the surface of the substrate and the size of the nanoparticles can be controlled just by the implantation condition. In addition, the process is facile, low-cost and eco-friendly without the use of any other chemicals [10–12].

In the present paper, we have applied the ion-implantation method to fabricate PtNPs-modified ITO electrodes. The

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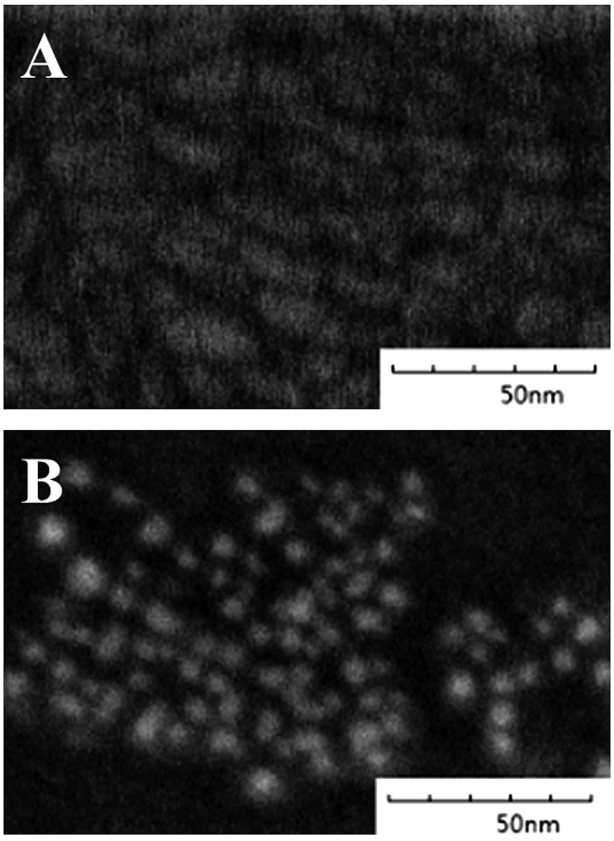

Fig. 1 – SEM images of the bare ITO electrode (A) and PtNPs/ITO (B) electrode.

modified electrode has been used for the electrocatalytic oxidation of formaldehyde, which exhibited remarkable catalytic activity and high stability.

Experimental

Preparation of PtNPs-modified ITO electrodes

ITO glass was obtained from the Beijing Tsinghua Engineering Research Center of Liquid Crystal Technology. Ion implantation was carried out using a Beijing Normal University (BNU) metal vapor vacuum arc (MEVVA) implanter. Platinum ions with 10 KeV at the fluences of 5.0×10^{16}ions/cm^2 were implanted onto the pretreated ITO surface, forming the PtNPs/ITO electrode. The ITO glass and electrode was washed with triply distilled water and ethanol for several times before used.

Apparatus

The structure and morphology of the electrode were characterized by scanning electron microscope (SEM) (Hitachi X650, Japan). X-ray photoelectron spectroscopy (XPS) measurement was performed on an AXIS Ultra spectrometer (Shimadzu, Japan). Atomic force microscope (AFM) images were recorded by using a Nanoscope Instrument (Vecco). All electrochemical measurements were carried out on a CHI650D electrochemical workstation (CH Instrument Inc, China). A conventional three-electrode system was employed with a bare or modified ITO electrode ($A = 75$ mm^2) as the working electrode, the Ag/AgCl electrode (saturated KCl) as the reference electrode, and the platinum wire electrode as the auxiliary electrode.

Results and discussion

Electrode characterization

SEM was employed to observe the surface morphologies of bare ITO and PtNPs/ITO electrodes. As show in Fig. 1, It can be clearly seen that there are much more PtNPs formed on the ITO surface (Fig. 1B). The quasi-spherical PtNPs are formed with a size distribution in the range of 5–12 nm, averaging 8 nm.

XPS shows significant Pt4f signals corresponding to the binding energy of Pt (Fig. 2A). Two strong satellite peaks at 74.7 eV (Pt $4f_{5/2}$) and 71.2 eV (Pt $4f_{7/2}$) were observed. It could be concluded that the implanted PtNPs were in the zero-valent metallic state by comparing the binding energies [13,14]. Fig. 2B shows the CV of the bare ITO (a) and the PtNPs/ITO electrode (b) in 0.1M NaOH. No peaks on the bare ITO were found while a pair of redox peaks appeared on the PtNPs/ITO. The anodic peak appeared at about 0.586 V in the forward scan is ascribed to the formation of Pt oxides, and

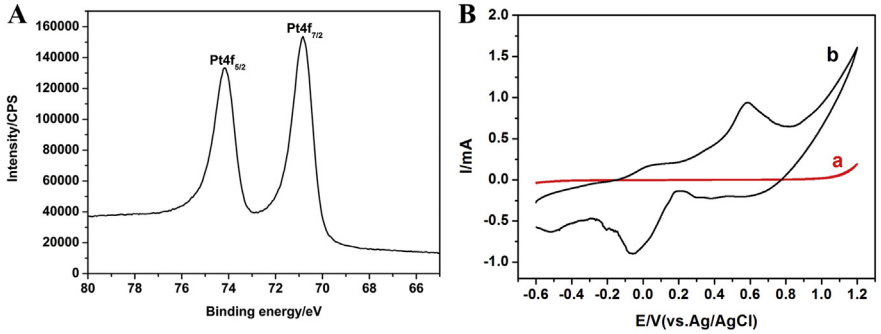

Fig. 2 – (A) XPS spectra of Pt4f on PtNPs/ITO electrode. (B) CV of the bare ITO (a) and the PtNPs/ITO electrode (b) in 0.1M NaOH. Scan rate: 100 mV s^{-1}.