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Short Communication

Synthesis and Characterization of Pt Nanowires Electrodeposited into the Cylindrical Pores of Polycarbonate Membranes

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Continuously ordered platinum (Pt) nanowire arrays were successfully prepared by electrodeposition (ED) method using ion track-etched polycarbonate nanotemplates. The pore diameter of the templates ranged from 50 nm to 80 nm. To fabricate the working electrode, a thin layer of Au (~260 nm thick) was coated on the reverse side of template to create electrical contact. A chloride-based electroplating bath at 35 °C was used for the ED process. Pt ions in the solution were guided to move through pores where they were subjected with a reduction process for one-dimensional growth of Pt atoms. X-ray diffraction analysis showed that in some cases, Pt nanowires (NWs) followed the crystallographic texture of the Au substrate. Two strong peaks related to (111) and (220) were observed as reflections corresponding to the platinum planes, which are characteristics of the face-centered cubic structure of Pt. Scanning electron microscopy indicated the morphology of NWs inside the pores. The continuous shape of the NWs was demonstrated by transmission electron microscopy. The fabricated wires were found to have spindle-shaped characteristics due to the morphology of pores in the template.

Keywords: Pt nanowires; DC electrochemical deposition; Polycarbonate template.

1. INTRODUCTION

The fabrication of arrays of pure metal nanowire (NW) has attracted much attention because of their special potential application in making ohmic contact between different parts of nanodevices, and their extraordinary optical and electronic properties [1, 2]. The electrochemical deposition/dissolution method is one of the most promising processes for the synthesis of nanostructure materials or devices, and is relatively inexpensive and simple [3-6]. Liquid phase deposition includes crystallization from the molten phase or aqueous phase can be applied for synthesis of nanoparticles based on chemical

bath deposition and electrodeposition (ED) [7, 8]. Among the different deposition techniques, ED has the advantage of being a selective method: when a conducting substrate is covered by a patterned resist layer, deposition occurs only where the substrate is exposed to solution [9, 10]. The template method has been considered the simplest technique to fabricate metal NWs because of the absence of high-cost and complicated lithographic processes to define nanoscale structures [11, 12]. The use of this method will result in metals being conducted to deposit into nanoporous materials with uniform pore diameters called templates. The template method has been investigated using a variety of membranes, such as anodized aluminum oxides [13], nano-channel alumina [14], and polycarbonate membranes (PC) [15-17], among others. However, ED of metals using the PC membranes has been proven to be a high-yield technique in the production of large arrays of wires [18].

The one-dimensional arrays of platinum have been intensively investigated for their use as actuators [19] and biosensors [20]. However, there are fewer reports that focus on the ionic mass transfer that accompanies ED in nanosized pores of PC membranes. This technique can fabricate unique NW arrays by controlling the electric charge passing through the pores. This work aims to test the possibility of obtaining new Pt nanostructures through the ED method into the cylindrical pores of PC membrane at 35 °C. The face-centered cubic (fcc) structure has been found to be the major crystallographic pattern for all the fabricated NWs.

2. EXPERIMENT

Polycarbonate Track Etched (PCTE) filters 6 μm thick and a pore density of $4\times10^{4} cm^{-2}$ were purchased from GE Osmonics (USA), and were used as templates for the fabrication of Pt NW arrays. To create the electrical contact, the reverse sides of the PCTE templates were coated with a metal thin film ~260 nm thick through the evaporation of pure Au in a vacuum chamber at a pressure of 3.8×10^{-5} mbar. The four-point probe measurements demonstrated good conductivity of the gold thin film with surface resistivity of ~60 $\mu\Omega\cdot cm$. X-ray diffraction (XRD) of Au-coated membranes implied that the gold substrate has a strong (111) texture. As-prepared PC templates were masked and contacted to a thin copper wafer to construct a working electrode (WE) with defined exposure areas.

In the electrochemical cell, a calomel electrode, which was used as reference electrode (RE), controlled the potential difference between WE and the solution. The chronocoulometry method was applied by an ER466 integrated potentiostat system (eDAQ Pty Ltd, Australia) computer-controlled by the Chart software (eDAQ Pty Ltd) to control the transferred electric charge, which is proportional to the thickness of the coated metal and the length of the NWs [9]. An electrochemical bath containing pure hexachloroplatinic acid H_2PtCl_6 $(H_2O)_6$, potassium chloride (KCl), and sulfuric acid (H_2SO_4) was used for the chemical deposition of Pt NWs at 35 °C. A fixed voltage of –0.25 V was applied by the potentiostat between the WE and RE. Thus, the template pores filled with Pt atoms fabricate arrays of Pt NWs. A schematic illustration of the electrochemical bath is shown in Fig. 1.

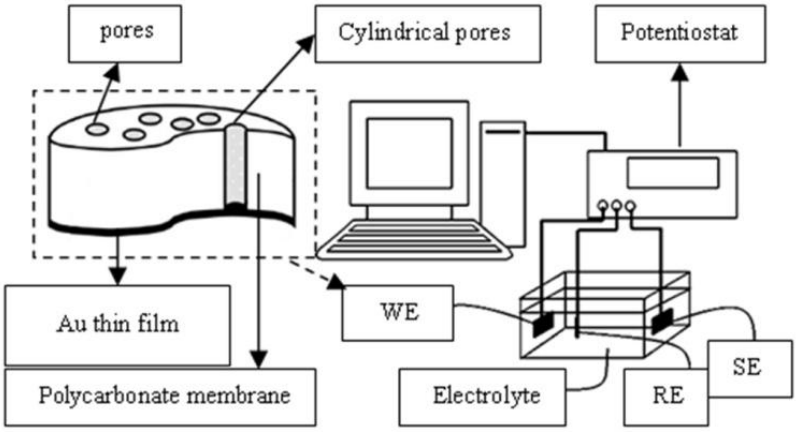

Figure 1. Schematic diagram of the electrolytic cell; Cross-sectional image of polycarbonate template is shown in the inset.

After applying sufficient charge calculated from Faraday's law [21], the PC template was removed from the cell and dipped in chloroform solution ($CHCl_3$). Polycarbonate templates were easily dissolved in dichloromethane solutions without any damage to NWs, and caused Pt NWs to be released from the membrane.

A JEOL (JSM-6460 LV) scanning electron microscope (SEM) and a JEOL (JEM-2010) transmission electron microscope (TEM) were used for the morphology studies. The crystallographic analysis was performed by a high-resolution X-ray diffractometer system (X'Pert PW3040).

3. RESULTS AND DISCUSSION

The morphology of PCTE templates after ED was studied through planar scanning electron microscopy. Fig. 2 shows the SEM micrograph in a top view of the PC membrane after Pt deposition. The tips of the NWs can be seen in the electron micrograph from the surface of Pt-filled templates.

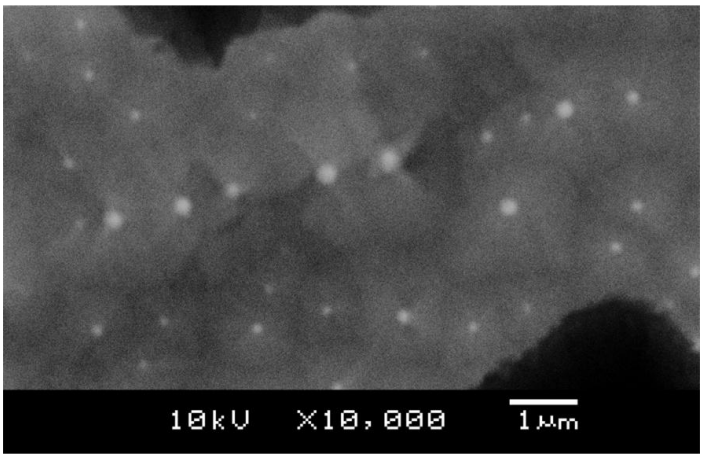

Figure 2. SEM image of polycarbonate track-etched (PCTE) template after electrodeposition of platinum

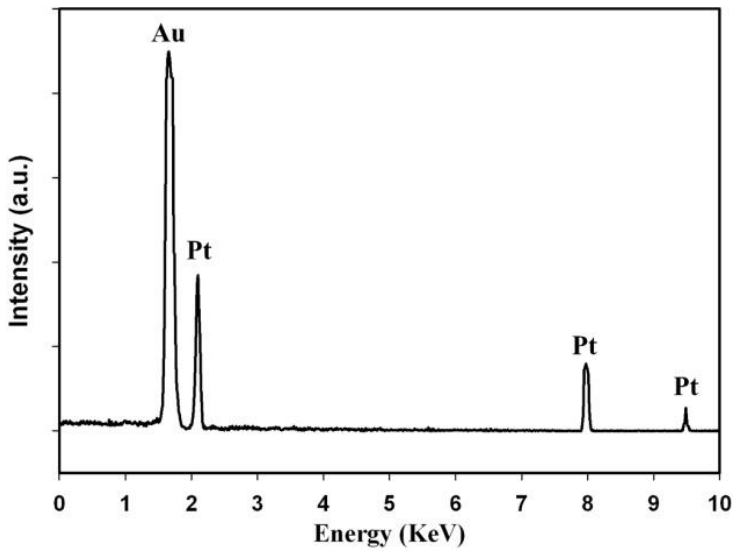

Figure 3. A typical energy dispersive X-ray (EDX) spectrum of platinum nanowires inside the cylindrical pores of an Au-coated polycarbonate membrane

The energy dispersive X-ray (EDX) spectrum, taken from the white spots on the surface, indicated the presence of Au and Pt (Fig. 3). Platinum NWs have therefore been created through the pores of the PCTE templates on the Au substrate.

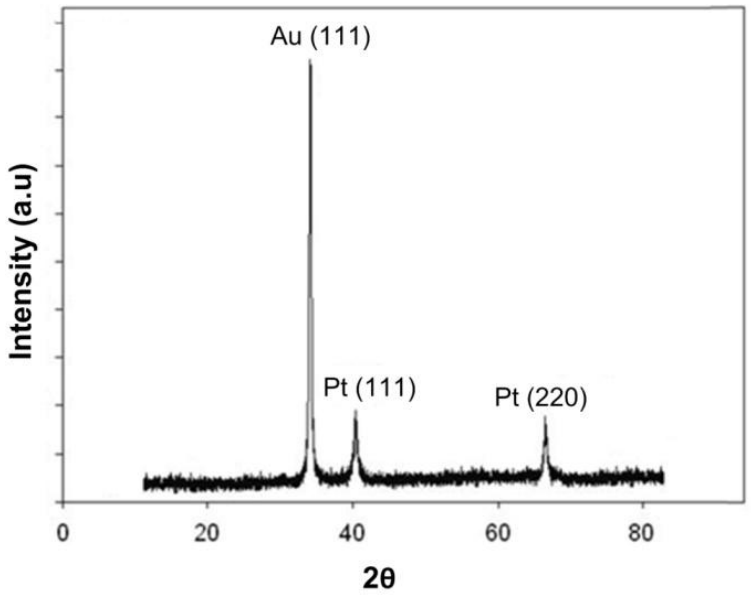

Figure 4. X-ray diffractometry of Pt nanowires in polycarbonate membrane with Au back contact

The XRD spectrum of the Pt NWs was used for the crystallographic studies of the fabricated NWs (Fig. 4). The most intensive peak belongs to the (111) plane of Au, which was evaporated at the reverse of the membrane. Two remaining peaks at 2-theta values of 41.10° and 65.90° are reflections corresponding to the platinum planes of (111) and (220), respectively, and are characteristic of the fcc

structure of Pt. From XRD investigations, we conclude that in some cases, Pt NWs followed the crystallographic texture of the Au substrate, and that the NWs are of single crystalline nature as proven by the X-ray spectrum.

The NW shape was further studied using the imaging mode of transmission electron microscopy (TEM). Fig. 5 presents a TEM image of a typical Pt NW. The NW diameter (~66 nm) remained constant over the entire length, except for the lower part, due to the spindle shape of the PC template [22]. The morphology of the NWs illustrated that one-dimensional arrays have been continuously created and that the chloroform solution did not harm the wires during release from the template.

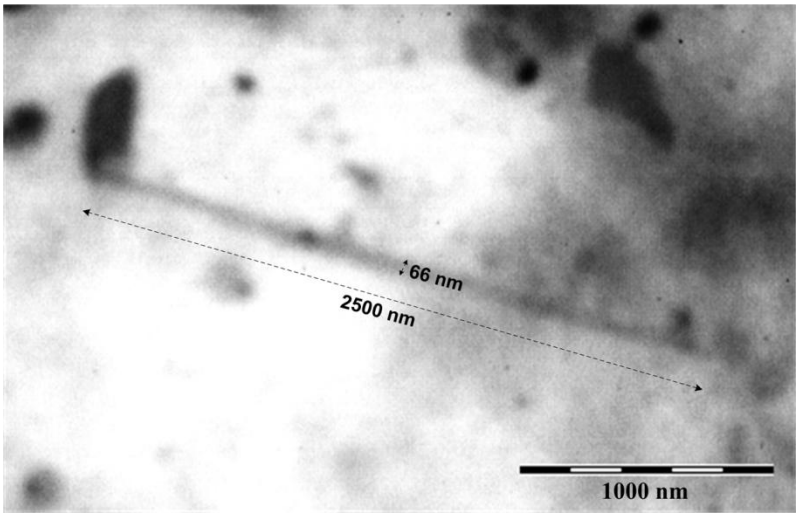

Figure 5. TEM image of a Pt nanowire (diameter ~66 nm, length ~2.5μm) fabricated by electrochemical deposition method

4. CONCLUSIONS

A thin layer of Au was evaporated on the reverse side of the PCTE templates for electrical contact to use PCTE membrane as a WE in the ED cell. Pt NW arrays were fabricated into the cylindrical pores of the PC membrane. The planar view of SEM micrographs from filled pores of the PC template showed that the NWs have been created successfully. The EDX spectrum confirmed that the white spots in the SEM micrographs belonged to Pt wires, which were created on the Au substrate. After dissolving the template in chloroform, the morphology of NWs was observed using TEM. The results showed that the NW arrays are continuous along their respective lengths. The crystallography of Pt NWs was studied using the XRD spectrum, which indicated that the NWs were single crystalline with fcc structure.

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