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Preparation of Electrochromic Material Using Carbon Nanotubes (CNTs)

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Abstract: Electrochromic materials can change their optical properties reversibly for an applied potential due to electrochemical oxidation and reduction. Electrochromic polymer like polyaniline (PANI) is one of the most promising materials where its colour can be controlled electrically. However, the electrochromically deposited polyaniline exhibit substantial resistivity, which is attributed to the lack of conducting pathways at the nanoscale associated with random deposition morphology. This study describes developing electrochromic material using carbon nanotubes (CNTs) as the filler. Preparation of electrochromic material involved electrochemical deposition of PANI film on ITO glass slide. PANI electrode was then tested in the electrochemical setup with platinum electrode by applying 0.2 to 1.4 V. The PANI electrode was found to change colour from light green at 0.2 V to purple at 1.2 V. When PANI/CNT electrode was tested, dark colour of CNT film is observed. This implies that high intensity colour can be achieved if the amount of CNTs incorporated into the electrode is reduced and well dispersed.

Key words: Electrochromic devices, carbon nanotubes, polyaniline

INTRODUCTION

Electrochromic devices attract much interest due to their potential use in applications such as smart windows, display panels, optical filter, mirror, glazing, temperature indicator and electronic paper (Mecerreyes *et al.*, 2004). Electrochromism is the phenomenon displayed by some materials of reversibly changing colour when amount of charge is applied. Electrochromic devices change light transmission properties in response to voltage and thus allow controlling the amount of light and heat passing through. Various types of materials and structures can be used to construct electrochromic devices, depending on the specific applications.

One good example of an electrochromic material is polyaniline which can be formed either by the electrochemical or chemical oxidation of aniline. Polyaniline has emerged as the one of the most promising class of active materials for electrochromic devices, due to its high capacitive characteristics, easy processing, low cost and environmental friendliness (Gupta and Miura, 2006). It has four redox states with distinct colours, which are leucoemeraldine base (yellow), emeraldine salt (green), emeraldine base (blue) and pernigraniline base (purple) (Zhao *et al.*, 2009). One drawback of polyaniline film is that it shows low conductivity where it can affect its electrochromic behaviour.

A research work has been carried out to investigate a suitable material as conductive filler in the PANI structure that would exhibit high conductivity, nanosize, high surface area and good capacitive characteristics. Recently discovered CNTs was found to be suitable as they possess properties such as excellent electrical conductivity, high surface area and good interconnectivity because of their nanosize (Gupta and Miura, 2006). It has been proven experimentally that the introduction of CNTs into a polymer matrix improves the electric conductivity and also the mechanical properties of the original polymer matrix (Li *et al.*, 2003; Zhou *et al.*, 2004).

CNTs were discovered by Iijima (1991) and has been presented as very promising materials in both electronic and mechanical properties. These CNTs have novel properties that make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science. They exhibit extraordinary strength, low resistivity, high stability, and are efficient conductors of heat. There are two major types of carbon nanotubes; single walled (SWCNTs) and multiwalled (MWCNTs).

MATERIALS AND METHODS

PANI deposition: In this part, the polymer is deposited from a monomer solution (1 M H₂SO₄ + 0.1 M aniline) onto

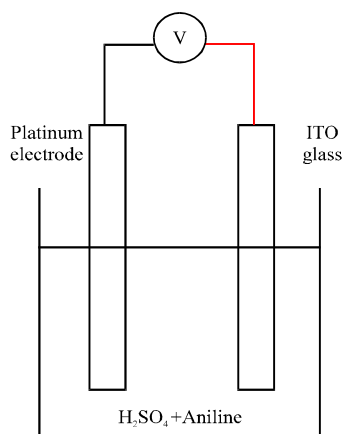


Fig. 1: Polymer deposition

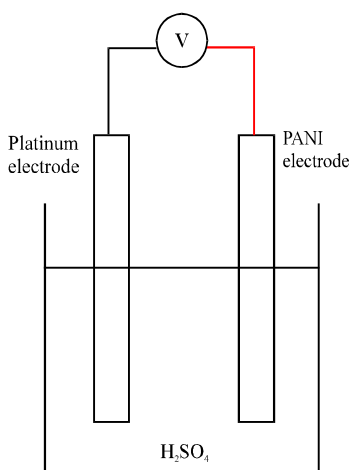


Fig. 2: PANI testing

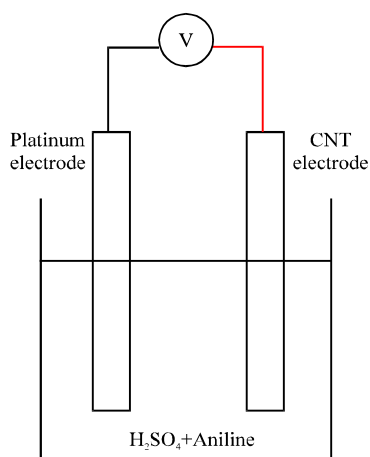


Fig. 3: Polymer deposition

ITO glass (Woodward, 2007; Aoki and Tano, 2005) as described in Fig. 1. There are; two electrodes, one is

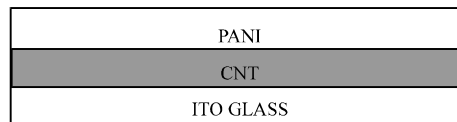


Fig. 4: PANI/CNT Electrode

platinum electrode and the other is ITO glass. Both electrodes were placed into the deposition solution with a separation of 10 mm. The power supply of 1.5 V was applied in order to deposit aniline onto the electrode.

PANI testing: Afterwards, both electrodes were transferred into the testing solution which contains 0.1 M H_2SO_4 (Hu *et al.*, 2007). The power supply on the potential is altered from -0.2 to 1.4 V in order to observe the colour changing. The setup for polymer testing is shown in Fig. 2.

Deposition of CNT and PANI: Bulk CNTs used is a commercial product of ILJIN, Korea. It is of multiwalled type and was synthesized by arc discharge technique. CNTs were mixed with PVDF binder and applied on the ITO glass. The electrode was dried at 80°C for 3 h to remove the solvent. Then the CNT electrode was multiwalled deposited with PANI using electrochemical process as shown in Fig. 3. This resulted in the deposition of aniline onto CNT electrode as shown in Fig. 4. CNT electrode and PANI/CNT electrode were then characterized structurally by using scanning electron microscopy (SEM) and Raman Spectroscopy (Gupta and Miura, 2006).

RESULTS AND DISCUSSION

PANI film was deposited on ITO glass by electrochemical process at 1.5 V and all samples were characterized by FESEM. Figure 5a-c shows the deposition of PANI with duration of 3 min and Fig. 5d-f shows the deposition of PANI with duration of 5 min. Clearly, surface of PANI can be obtained with two different deposition time.

It is observed that the morphology of PANI films deposited in 5 min is smoother with fewer crevices. This uniform structure is believed to have better conductivity as a result of continuous structure with less trapping centers in the form of voids. Thus the parameter with deposition time of 5 min was chosen for deposition of PANI film onto CNT electrode.

CNTs used are of multiwalled type as shown in Fig. 6 with typical diameter of 35 nm. SEM image of PANI/CNT film is shown in Fig. 7. The crystallinity of

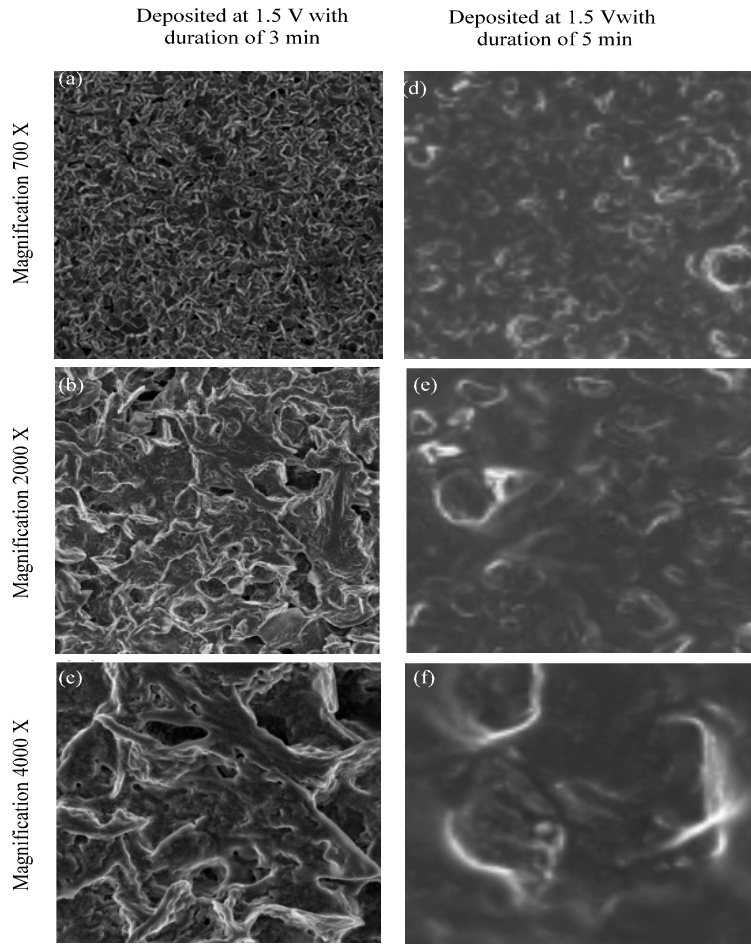


Fig. 5: SEM image of PANI film

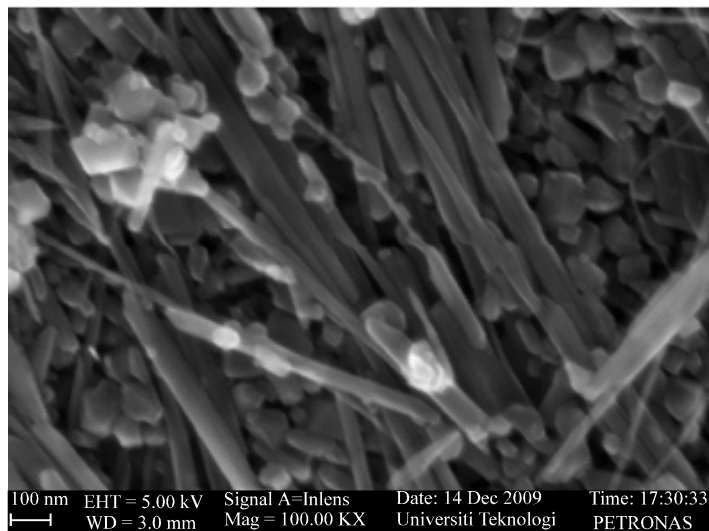


Fig. 6: SEM image of bulk CNTs

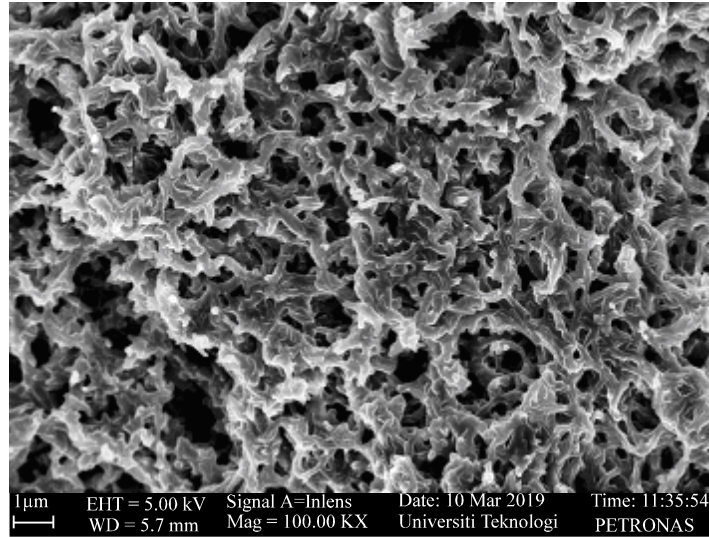


Fig. 7: SEM image of PANI/CNT

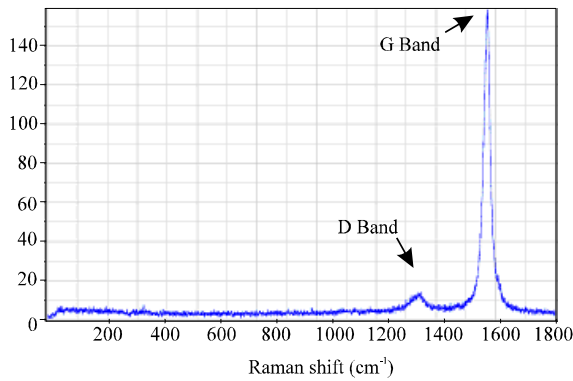


Fig. 8: Raman spectrum of MWCNTs

MWCNTs is very good as evidence from the Raman spectrum (Fig. 8) that describes a high graphitic peak (G band) and a very low disordered peak (D band). During the electrochromic testing, voltage was applied through the cell from 0.2 to 1.2 V. The device exhibited light green colour at 0.2 V, green at 0.4 V, dark green at 0.6 V, green/blue at 0.8 V, dark blue at 1.0 V and blue/purple at 1.2 V as shown in Fig. 9.

When PANI/CNT electrode was tested by applying voltage of 0.2 to 1.2 V, similar changing of colour was observed. However, very dark colour patches were prominent indicating the area of CNT film. This implies that there is a possibility of achieving high intensity colour by having CNT film. It is believed that uniform display intense colour can be obtained if the amount of CNTs incorporated is reduced. Further improvement can be achieved if CNTs are well dispersed in the film.

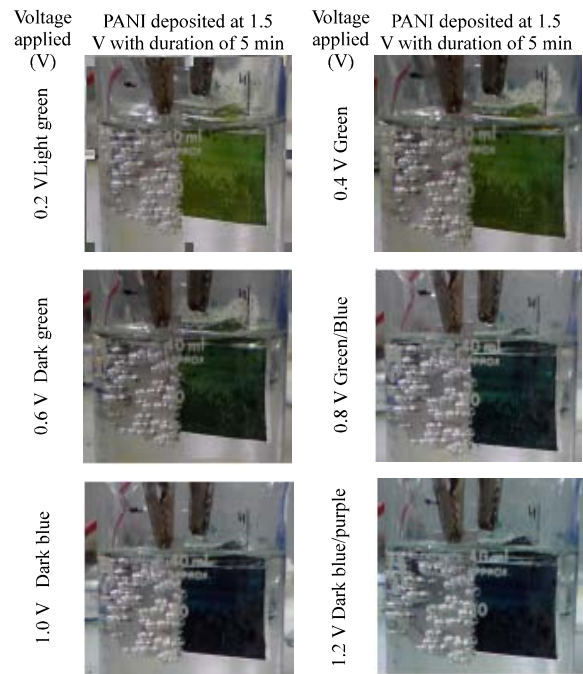


Fig. 9: Colour changing of PANI with various applied voltage

CONCLUSION

It was found that longer deposition time of PANI film, 5 min is capable of producing smoother film with less voids providing more conducting paths for electrochromic colour display. Applying the voltage of 0.2 to 1.4 V to PANI electrode changes its colour from light green to

purple. Similar changing of colour can be observed with PANI/CNT electrode but with very dark patches believed to be CNTs film obscuring the actual colour displayed. It is believed that the improvement in the luminosity of colour can be obtained by optimizing the fabrication process of producing PANI/CNT film. Thus further studies are required to investigate the weight percentage of CNTs incorporated into PANI/CNTs film with the use of the effective dispersion technique in order to achieve uniform distribution of CNTs within the film.

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