Electrochemical characterization of polymeric sensor of poly-acrylonitrile self-modified with carbon nanotubes (CNT)

1. Introduction

Some advanced techniques in conductive polymers were presented using nanoparticles within to produce different applications in the electrochemical field [1-5], such as working electrode of cyclic voltammetry with high electro-conductivity [6].

It was observed that in mixed nanomaterials, high damping can be achieved by using friction between the nanotubes and the polymeric material. The aim of this research is to study the damping properties in the structures of the mixed material supported by nanotubes of various rubber ratios. The damping properties of samples for pipe ratios between 0-0.6% were studied and tested in practice. By comparing the raw material of the base and the base with the additive, it was observed that the damping was improved by adding nanotubes to the mixture. Practical results showed that the maximum damping ratio (damping factor) was 0.4% of carbon nanotubes [7].

The effect of carbon nanotubes on the electrical properties of polyvinyl chloride has been studied. Examples of polyvinyl chloride composites and carbon nanotubes prepared using thermal pressing technology. Weight ratios of carbon nanotubes are (0, 5, 10 and 20) wt.%. The results show that the continuous electrical conductivity increases with increasing weight ratios of carbon nanotubes. Continuous electrical conductivity also changes with increasing temperature for different concentrations of carbon nanotubes. The activation power of the continuous electrical conductivity decreases with increasing the concentration of carbon nanotubes [8].

Carbon nanotubes were used to strengthen the epoxy mixture with polysulfide and assessed the tensile and wear characteristics. In order to achieve a better evaluation of properties, several ratios of nanomaterials were used and mixed with epoxy resin. Poly sulfide was then added to the mixture. Nanocarbon coefficient has increased from 245-273 MPa and the tensile strength of 30.5-38.9 MPa and fracture stress from 12.4% to 14.2%. Electronic elements [9].

Carbon nanotubes were employed using covalent recruitment and in two phases. The employed carbon nanotubes were coated with copper metal using (Electroless coating process). Three groups of superposed copper nanoparticles were prepared using powder technology with different weight ratios of carbon nanotubes. The first group contained carbon nanotubes as they were, the second group contained the employed carbon nanotubes, while the third group contained coated carbon nanotubes. The comparison of these samples showed that the coating process significantly improved the hardness and wear resistance of the superposed nanomaterial. The improvement...
in properties can be attributed to increased adhesion to the ground and dispersion of carbon nanotubes. SEM, XRD, and FTIR were used to characterize the coating process as well as to characterize metal-based nanomaterials [10].

2. Experimental

2.1 Apparatus

Cyclic voltammetry (CV) was performed with an EZstat apparatus (NuVant Systems, USA) consisting of an electrochemical cell connected to a computer [11]. Reference silver chloride electrodes were placed in 3mol potassium chloride. A 1mm platinum wire used as counter control electrodes [12]. A glassy carbon electrode (GCE) was polished with alumina solution and ultrasonic waterpath 10 min to maintain performance and remove impurities [13-15].

2.2 Materials

Poly-acrylonitrile was received from SCRC, (China), carbon nanotubes (purity 99%) were supplied by Fluka company (Germany), Potassium ferrous cyanide K₄Fe(CN)₆ (Merck Sante SAS, Germany), KCl, KClO₄, K₂SO₄, K₂HPO₄, and KNO₃ (Technicon chemicals, Tournai, Belgique). Deionized water and added 0.1 mM of K₄Fe(CN)₆ solution in a cyclic voltammetric cell with the GCE, reference and counter electrodes immersed in the fluid as shown in Fig. 1.

2.2.1 Manufacture of poly-acrylonitrile modified with carbon nanotubes (CNT)

Poly-acrylonitrile was modified with carbon nanotubes were manufactured using the thermal method [16].

2 g of poly-acrylonitrile was mixed with 1 mg of carbon nanotubes using 50 mL of chloroform as a solvent and heated at 50 °C with continuous mixing using a magnetic bar (magnetic bar) for 72 hours for use in diagnostic analyzes and electrode fabrication.

2.2.2 Fabrication of self-modified polymer with carbon nanotubes

The working electrode is made of self-modified polymer with carbon nanotubes by taking a piece of it in a circular diameter of 5 mm and a thickness of 2 mm. The other is connected with a copper wire and all the parts are covered with a glass tube and fixed with epoxy adhesive as shown in Fig. 2.

2.3 Characterization studies of the new modified polymer

2.3.1 FTIR infrared spectra

The infrared spectra of the poly-acrylonitrile alone is shown in Fig. 3 and its comparison with the polymer modified carbon nanotubes in Fig. 4.

3.2.2 X-ray study of the new modified polymer

The study of X-ray spectra of the polymer material (poly-acrylonitrile) emergeded of two peaks as shown in Fig. 5 comparing with the modified polymer material with carbon nanotubes which showed the emergence of a new third summit in the polymer composition of the nanomaterial as shown in Fig. 6.

3.2.3 Study of polymer modification with nanomaterials

One of the three methods indicated by Manas, 2006 and Zinco, 2010 was used to modify the polymers either by the free radicals of the gamma rays, the ionic method or the thermal method. The thermal method was adopted in the preparation of the modified polymeric material with nanomaterials. The composition of the nanomaterial entry through the poly-acrylonitrile was proposed as per the scheme proposed in Fig. 7 [17].
3. Results and discussion

3.1 Effect of potential area

The potential area of the polymeric electrode (polymer modified with carbon nanoparticle) was compared with commercial working electrode such as glassy carbon electrode (GCE) in KCl 1 molar solution. It was noted that the area of potential of the polymer electrode is greater than the potential area of the glassy carbon electrode. The polymer electrode covers an area of -1.8 to +2.0 volts, while the commercial electrode (GCE) covers an area of less than -1.5 to +1.8 volts.

3.2 Effect of different electrodes

The standard 0.1 molar compound of $K_4[Fe(CN)_{6}]$ was used to calibrate the cyclic voltameter in aqueous solutions. Oxidation - reduction peaks of the iron were observed in Fe (III) / Fe (II) as shown in Fig. 8 of the both working electrodes, modified polymer electrode and glassy carbon electrode (GCE). It was observed that the potential difference between the oxidation and reduction peaks is $E_{pa-c} = 100$ mV and the ratio of the current value of the cathode-to-anode peaks ($I_{pa} / I_{pc}$) is equal to 1, which represents the standard value of the reversible electrodes.

3.3 Effect of scan rates on self-modified polymer electrode

At the different scan rates (0.01 - 0.1 V/s) of 0.1 mM $K_4[Fe(CN)_{6}]$ in 0.1 M KCl solution the CV were studied using polymer electrode modified with CNT manufactured in the laboratory. It has been observed that the electric current of the oxidation and reduction peaks of Fe(III)/Fe(II) increases with increasing scanning rate, which indicated that the phenomenon of heterogeneous kinetics is shown in Fig. 9. When plotting oxidation and reduction (Ipa and Ipc) versus scan rate, a straight line was shown as in Fig. 9 and 10 respectively, and the sensitivity values were high because the graphical line matched the device results [18].

3.4 Measurement of Fe(II)/Fe(III) in different concentration

The new electrode is a highly sensitive electrode in detecting low concentrations of aqueous solutions and, as evidenced by the use of the standard solution $K_4[Fe(CN)_{6}]$ in a 0.1 M KCl solution.
3.5 Study the polymer self-modified with CNT in different pH

The CV technique demonstrated the high sensitivity of the synthesized electrode in different pH levels (for both acidic and alkaline medium) on the oxidation and reduction peaks of 1 mM $\text{K}_4[\text{Fe(CN)}_6]$ in 0.1 M KCl as an electrolytic solution on the self-modified polymer with carbon nanotubes where shows in Fig. 13, a significant sensitivity in various acidic and basic solutions. Fig. 14 shows the relationship between the pH medium against to oxidation current peak of the iron ions.

3.6 Effect of different electrolytes

The different electrolytic solutions have a clear effect on the oxidation and reduction peaks of 1 mM $\text{K}_4[\text{Fe(CN)}_6]$ in terms of the current as well as voltage when using the polymer electrode. It was found that the highest degrees of the electric current was increased the oxidation and reduction peaks according to the following sequence:

- Anodic current: $\text{KCl}>\text{KClO}_4>\text{K}_2\text{SO}_4>\text{K}_2\text{HPO}_4>\text{KNO}_3$
- Cathodic current: $\text{KCl}>\text{KClO}_4>\text{KNO}_3>\text{K}_2\text{SO}_4>\text{K}_2\text{HPO}_4$

On this basis, the best electrolyte solution supported in the study of the modified polymer with carbon nanotubes is KCl.

3.7 Scanning Electron Microscopy (SEM) for polymer modified with CNT

The scanning electron microscopy of the polymer modified with carbon nanotubes have been studied as shown in Fig. 15.
It was noted that the figure shows the surface of the electrode was overlapped, impermeable, compact and punctuated by strings represented by carbon nanotubes.

3.8 Study Atomic Force Microscopy (AFM) of polymer modified with CNT

Fig. 16 shows the atomic force microscopy of the surface of the synthetic electrode in the regular image of the polymer, which overlaps with carbon nanotubes and highly homogeneity and regulation was the high proportion of the measurement of carbon nanotubes of 20-100 nanometers as shown in Fig. 17.

4. Conclusions

The new polymeric working electrode was manufactured because of its importance in the analysis of electrochemistry, especially in the cyclic voltmeter can be used in several aspects:
1. Used as an alternative to commercial solid electrodes used in the cyclic voltmeter because it is better than electrochemical analysis (in terms of electrical conductivity).
2. It can be used as an alternative to electrodes used in acidity measurement (pH meter).
3. The electrode can be used as a self-modified carbon nanotube in the rotary electrode technique which can be used with high efficiency by electrolysis since the oxidation and reduction current at high value.
References


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