

ELECTROCONDUCTIVITY AND STRUCTURAL ANALYSIS OF HYBRIDIZED PPy/rGO COMPOSITES

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ABSTRACT

Polypyrrole (PPy) was synthesized via microemulsion method from its pyrrole (Py) monomer, while reduced graphene oxide (rGO) was produced by using modified Hummer's method from graphite powder. Polypyrrole (PPy) with reduced graphene oxide (rGO) composites (PPy/rGO) has been harvested by ultrasonication method with various combination weight feeding ratio of pyrrole to the reduced graphene oxide (rGO) varied as 4:1, 3:1, 2:1, and 1:1, and the resulting composites were designated as PPy/rGO 4:1, PPy/rGO 3:1, PPy/rGO 2:1, and PPy/rGO 1:1 respectively. The prepared composites have been successfully characterized in terms of the composition, morphological and electrochemical properties. The obtained powder composite was characterized by scanning electron microscopy (SEM), Raman spectroscopy and electrical conductivity (four-point probes). The hybridized composites were synthesized using ultrasonication, filtration, drying process and dispersion before they were being dropped for fabrication onto glassy carbon electrode (GCE) for the cyclic voltammetry (CV) characterization at 100mVs^{-1} . The conductivity of PPy/rGO composites obtained from four-point probes for PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) was $1.190\Omega^{-1}\text{cm}^{-1}$, $1.522\Omega^{-1}\text{cm}^{-1}$, $1.980\Omega^{-1}\text{cm}^{-1}$ and $2.504\Omega^{-1}\text{cm}^{-1}$ respectively, where it shows good conductivity properties. The characterization results revealed that the structure of the composite is well developed and the reduced graphene oxide (rGO)

embedded with Polypyrrole (Ppy), where it forms a good network structure in the composites. The results obtained promise great applications in high conductivity modified electrode.

Keywords: Polypyrrole; Reduced graphene oxide; Electroconductivity; Structural;

INTRODUCTION

Polypyrrole (PPy) was synthesized from the pyrrole (C_4H_5N) monomer that consists of a 5-membered ring, containing a nitrogen (N) heteroatom. As other organic molecules, pyrrole polymerization occurs upon oxidation of the monomer, that were resulted through the formation of a conjugated polymer chain with overlapping π -orbitals and a positive charge along the polymer backbone. Chemical synthesizing of PPy in large quantities in solution is one of the most easiest and common ways. It involves exposing of the pyrrole monomers to a strong oxidizing agent yielding a black precipitate. In this chemical polymerization process, the propagation step is controlled by the fact that the monomer is in large excess of the radical cation and formed upon the oxidation, where then it attacks another monomer molecule generating a dimer radical cation which becomes further oxidized. Due to this and coupled with the loss of hydrogen the polymer chain grows until termination [1]. Conducting polymer is a polymer that has the conductivity properties. These conducting polymers have a unique characteristic that makes them suitable to act as a transducer that converts the biological signal to an electrical signal. It also provides an excellent platform for the immobilization of biomolecules at the electrodes. In addition to that, these conductive polymers also provide a better signal transduction in biological biosensors where it enhances the sensitivity, selectivity, durability, biocompatibility, direct electrochemical synthesis and flexibility for immobilization of biomolecules onto the solid surface [2]. The examples of conducting polymers are polynaphthalens, polyparaphenylene, polypyrrole, polyaniline, polycarbazole, polythiophene, polyazulene and few others more. However, among those entire conducting polymers, only polyaniline, polypyrrole and polythiophene were commonly used in biosensor due to their characteristic of biocompatibility which results in the minimal and reversible disturbance to the working environment and protect electrodes from fouling [2].

Graphene was predicted to have extraordinary electronic properties by the scientists back to the year of 1947, but no-one had worked out on how to extract it from graphite. Since then, graphene was considered as a material that only existed in theory and being assumed not to exist as free standing material regarding to its unstable nature. This perception changed as it was isolated in 2004 by two researchers who first discovered graphene, Andre Geim and Kostya Novoselov was awarded the 2010 Nobel Prize for physics as “groundbreaking experiments regarding the two-dimensional material graphene” as recognition of remarkable ingenuity in experimental physics. Geim’s group successfully isolated thin graphite by using adhesive tape to peel off layers from graphitic crystal flakes and they gently rub those fresh layers against an oxidized silicon

surface. Then they were able to determine the thickness of that layer which was few angstroms' thick by using Atomic Force Microscopy (AFM). Their "Scotch tape" technique was very reminiscent of the use of adhesive tape to routinely peel layered crystals, held together van der Waals forces, to expose fresh surfaces [3]. Reduced graphene oxide (rGO) which is one of the members in class of carbon allotrope has increasing popularity. Its increasing popularity was due to its unique properties of superlative physical properties that can be employed in polymer composites, corrosion inhibitors, chemical and biological sensors and photovoltaic cells as a transparent conductor. Easy to be synthesized with a very economical production do contribute to its popularity. In synthesizing the rGO, it can be classified into two different broad areas which are the derivative of rGO from graphite and the other one is rGO derived from other sources such as epitaxial and chemical vapor deposition (CVD) growth methods [4].

Until nowadays, many researches have been done, in order to improve the electrical conductivity of PPy by intercalation with graphene. Where most of the preparation of PPy/rGO composites was via in-situ polymerization technique involving pyrrole monomer and graphite oxide (GO), followed by chemical reduction using hydrazine monohydrate has been demonstrated [5]. The special properties of PPy and graphene that has been well known as fast electron transport, large surface area, high electrical and thermal conductivities, good biocompatibility, excellent mechanical flexibility and has a low potential manufacturing cost did attract the scientist to work on this research [6], [7].

Hence, in this study, the yield polypyrrole (PPy) from pyrrole (Py) monomer was the polymer used in this research as the primary material, while the yielded reduced graphene oxide (rGO) from graphite powder was the secondary material. These two yield synthesized product were then intercalate via the hybridization of the PPy and rGO through dispersion, ultrasonication, filtration and drying process as to yield the PPy/rGO composites. With different weight feeding ratio of PPy/rGO composites combination, the morphology structure and electrical conductivity have been obtain, where the combination of PPy/rGO (1:1) ratio provide the highest electrical conductivity which is greatly promising for faster electron transfer for transducer.

EXPERIMENTAL

Materials

Graphite (3.0g), potassium ferrocynide ($K_2Fe_2CN_2$), potassium ferricyanide ($K_2(FeCN)_6 \cdot 3H_2O$), sodium dodecylsulfate (SDS)($(NH_4)_2S_2O_8$)(0.08M), ammonium peroxy disulfate (APS), pyrrole (C_4H_5N), 0.08M n-amyl alcohol, distilled water (DW), sodium nitrate (1.5g), potassium permanganate ($KMnO_4$), 15ml hydrogen peroxide (3%), methanol, ethanol, acetone, 1M sulfuric acid (H_2SO_4) and 1:10 hydrogen chloride (HCl). All this materials can be purchase from the Sigma Aldrich, Beijing Biodee Biotechnology Co. and also nearest market for the food samples [7], [8].

Preparation of Polypyrrole (PPy)

Microemulsion method was the method used in order to produce the polypyrrole (PPy). An aqueous solution of 0.08M SDS (sodium dodecylsulfate) was prepared and stirred vigorously for 20 minutes, 100ml of 0.08M pyrrole was added drop wise and stirred vigorously for next 30 minutes. The pyrrole was distilled by rotary evaporator (rotovap) before it was used, as to remove the impurities in the solution. Then, 100ml of 0.08M n-amyl alcohol was added in the mixture and was stirred for another 10 minutes before the 100ml of 0.08M APS (ammonium persulphate) was added into the mixture and stirred for 24hours. Those processes of mixing and stirring were held at the temperature of 4⁰C. After 24 hours, excessive methanol was added as to terminate the reaction. The precipitates were centrifuged at 10000rpm for 15-20 minutes by washing it with methanol, distilled water (DW) and finally wash with acetone. Lastly, generated PPy was filtered, dried and kept the in desicator [8].

Preparation of Reduced Graphene Oxide (rGO)

Reduced graphene oxide was synthesized by using the improved Hummer's method by Marcano et.al, (2010). Mixture of 6g graphite powder and 36g of KMnO₄ was mixed together and stirred in 1 liter beaker. Meanwhile 720mL of H₂SO₄ and 40mL of H₃PO₄ was mixed in 500ml beaker before it was poured into 1 liter beaker that contain graphite powder and KMnO₄. These 4 elements that include the powder s and solutions were stirred for 12 hours at 50⁰C. The mixture was cooled down to the room temperature after 12 hours of stirring before ice from 400mL of distilled water was poured into the mixture beaker and further stirred until the ice melt. Then, in between 9ml to 24ml of H₂O₂ was added into the mixture until color of the mixture turn from dark brown into bright yellow. The mixture was then poured into a large container and was filled up with distilled water until $\frac{3}{4}$ of the container for washing step. The mixture was let to settle down for a few days, so the suspension and unsuspended solution was observed, the unsuspended was removed and distilled water was refilled. The washing step was repeated for 5 times and the remaining suspension was transferred onto petri dish as to allow it to dry. The resulting dried film was peeled and grind into powder. The powder was then washed with 10% HCl for 3 times, continued washing with distilled water for 3 times and washed with ethanol once respectively, as to remove the remaining metal. Where the washing steps was conducted by filtering the graphite oxide by using a vacuum filter. Resulting graphite oxide was dried in the oven at 60⁰C. As to convert the graphite oxide to graphene oxide, 200mg of dried graphite oxide were mixed with 200ml of distilled water and was ultrasonicated at 600W for 30 min as it produced the graphene oxide. Then, 200ml of graphene oxide were add with 3.2g of glucose and ultrasonicated at 600W for 30 minutes. Later, it were continued with centrifugation (10000 rpm) for 15 minutes, rinsed with excessive of distilled water and filtered by vacuum filter. Lastly, collected reduced graphene oxide were placed into a petri dish and dried in the oven at 60⁰C for 5 hours.

Synthesis Of PPy/rGO Composites

Four different ratio combinations of PPy/rGO composites was synthesized by disperse 4mg/ml suspension rGO in 5.1ml of 50:1 mixture of water and EtOH and then mixed with 4mg of PPy as 1:1 ratio, 2.64mg/ml suspension rGO in 5.1ml of 50:1 mixture of water and EtOH and then mixed with 5.3mg of PPy as 2:1 ratio, 2mg/ml suspension rGO in 5.1ml of 50:1 mixture of distilled water and EtOH were then, being mixed with 6mg of PPy as 3:1 ratio. Lastly 1.6mg/ml suspension rGO in 5.1ml of 50:1 mixture of water and EtOH, were then mixed with 6.4mg of PPy as 4:1 ratio. The mixtures were then being ultra-sonicated for 1 hour. PPy/rGO hybrid material was obtained via filtration, purified using water, and dried in vacuum oven at 25°C for 24 hours [9].

Fabrication Of rGO, PPy, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) And PPy/rGO (1:1) Onto Glassy Carbon Electrode (GCE)

This procedure has been conducted as to fabricate the rGO, PPy, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) onto the GCE. At each time before usage of the GCE, it must be clean by using ethanol and distilled water (DW) and being sonicated for 2 minutes. Then, an aliquot of 15 μ l (5 μ l $\times$ 3times) from 0.1ml of the ethanol solution containing 0.1-wt% rGO, PPy, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) was dropped onto the GCE and let the hybrid materials dried onto the electrode before it was continued with the Cyclic Voltammetry (CV) characterization [9].

RESULTS AND DISCUSSIONS

Scanning Electron Microscopy (SEM)

The morphology of the PPy, rGO, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) was observed by SEM, with the image shown in Figure 1. The synthesized PPy, shown up as large sharp rocky shape and typical of the rough surface of PPy as depicted in Figure 1 (a) [10]. While the morphology of reduced graphene oxide (rGO) can be clearly seen in Figure 1 (b) where it showed flake-like shape with a wrinkled surface [11]. Images appeared for PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) composites shown a clearly reduced graphene oxide features the layer structure with dense stacking of PPy and the flake-like look of reduced graphene oxide (rGO) still could be observed. The ultrasonication of PPy and reduced graphene oxide (rGO) into 5.1ml of 50:1 mixture of distilled water and EtOH for 1 hour had form fully exfoliated PPy/rGO solution. From the images obtained, it revealed that PPy were grown on the surface of the reduced graphene oxide (rGO) and a little agglomerate of PPy is found, which usually occurred during the synthesis process. This agglomeration indicate the polymerization of pyrrole occurred on the surface of reduced graphene oxide (rGO) owing to the π - π interaction and hydrogen bond between pyrrole and reduced graphene oxide (rGO) [12]. Incorporation of PPy onto reduced graphene oxide (rGO) enlarges the surface area, which improve the adsorption performance of PPy/rGO. Reduced graphene oxide has a large π -electron system and forms π - π

noncovalent interactions as the predominant force between the adsorbent and the adsorbate. Thus a reduced graphene oxide (rGO) adsorbent shows a high binding capacity for aromatic molecules and the interactions of electrostatics and induction also contribute to the further stabilization of the π - π interaction between reduced graphene oxide (rGO) and aromatic molecules. While the long chains, mesoporous surface and delocalized π -electron system in PPy also undergo attractive interactions with analyte molecules through enhanced van der Waals and dipole-induced dipole interactions. Therefore, the PPy/rGO could achieve high absorption [13].

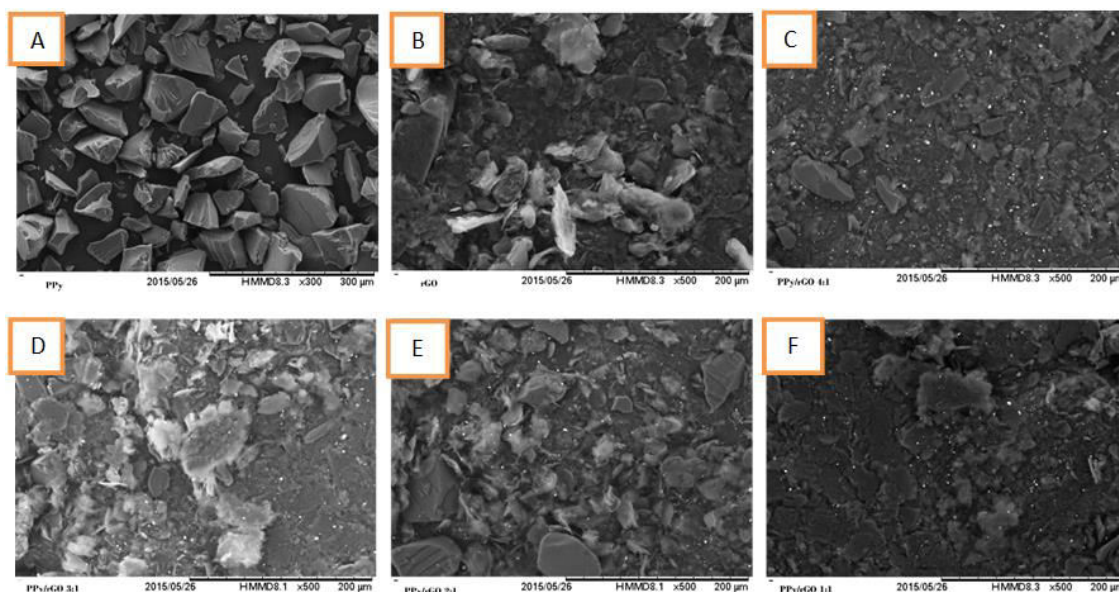


Figure 1: a) SEM of Polypyrrole (PPy) at 300 X magnification b) SEM of reduced graphene oxide (rGO) at 500 X magnification, c) SEM of Polypyrrole/reduced graphene oxide ratio (4;1), PPy/rGO (4:1) at 500 X magnification, d) SEM of Polypyrrole/reduced graphene oxide ratio (3;1), PPy/rGO (3:1) at 500 X magnification e) SEM of Polypyrrole/reduced graphene oxide ratio (2;1), PPy/rGO (2:1) at 500 X magnification f) SEM of Polypyrrole/reduced graphene oxide ratio (1;1), PPy/rGO (1:1) at 500 X magnification

The PPy/rGO composite was synthesised by ultrasonication procedures. When the mass ratio of PPy to reduced graphene oxide decreasing from 4:1 to 3:1 to 2:1 and 1:1, the physical appearances of individual material change when they were hybridized into a composite and the lesser the amount of PPy in the composite, the flatter surface of the image observed. This is due to the PPy tend to grow on the reduced graphene oxide (rGO) to form thick-layer structure and the density packed of PPy are still visible that could be observed in Figure 1 (c), Figure 1 (d), and Figure 1 (e), that represent the PPy/rGO (4:1), PPy/rGO (3:1) and PPy/rGO (2:1) accordingly. However, when the mass ratio of PPy to reduced graphene oxide is (1:1) in Figure 1 (f), the reduced graphene oxide (rGO) is completely covered by PPy thus it forms a well designed

PPy/rGO structure with great network of bonding which does not tend to form a thick-layer structure and prevent the restacking of both reduced graphene oxide and PPy [14].

Raman Spectroscopy

Raman spectroscopy is widely used to obtain the structural information about carbon-based materials [14]. The Raman spectra of PPy, GO, rGO PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) are depicted in Figure 2. From these results, all samples shown almost the same peak of spectra at D band, G band and 2D band but their intensity were different from one to another.

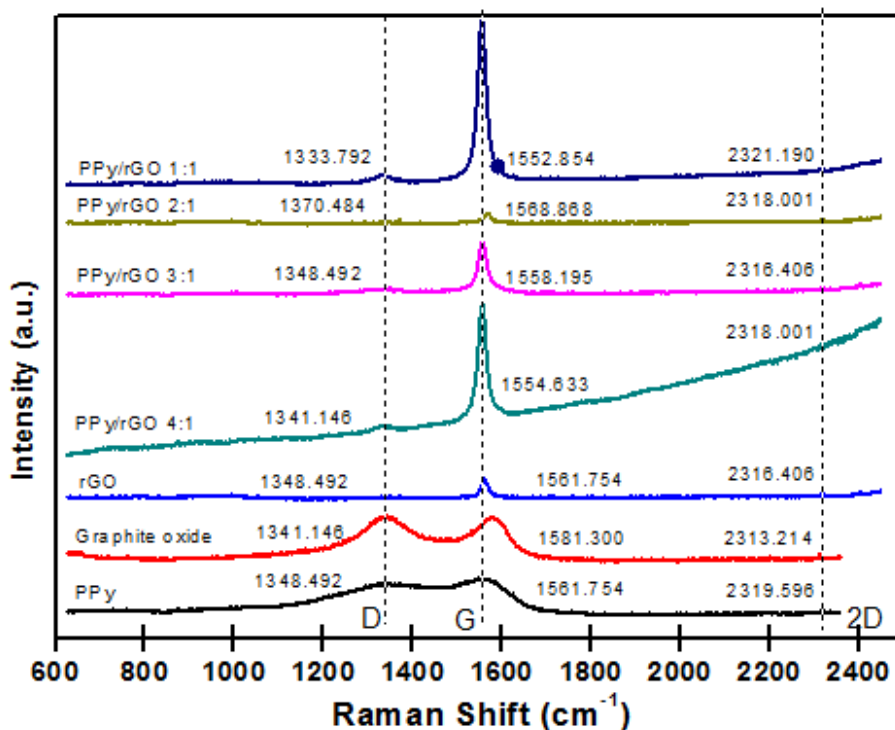


Figure 2: Raman Spectroscopy of Polypyrrole (PPy), Graphite Oxide (GO), reduced Graphene Oxide (rGO), Polypyrrole/reduced graphene oxide ratio (4;1) PPy/rGO (4:1), Polypyrrole/reduced graphene oxide ratio (3;1) PPy/rGO (3:1), Polypyrrole/reduced graphene oxide ratio (2;1) PPy/rGO (2:1) and Polypyrrole/reduced graphene oxide ratio (1;1) PPy/rGO (1:1)

By looking at Figure 2, Figure Raman spectrum of PPy, GO, rGO PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1), the D band were shown up at around $\sim 1333\text{cm}^{-1}$ to $\sim 1370\text{cm}^{-1}$, the G band around $\sim 1552\text{cm}^{-1}$ to $\sim 1581\text{cm}^{-1}$ and the 2D band around $\sim 2313\text{cm}^{-1}$ to $\sim 2321\text{cm}^{-1}$. The D band is attributed to the vibration K-point phonons of A_{1g} symmetry, arises from the breathing vibration of aromatic rings, which are related to the edges, structural defects that correspond to the conversion of sp^2 -hybridized carbon to a sp^3 -hybridized carbon and the G band originates from the zone center E_{2g} mode, which corresponding to ordered sp^2 -bonded carbon atoms [15].

Typically peak of PPy appeared at 1348.492cm^{-1} and 1561.7542cm^{-1} which were due to the C=C backbone stretching and the ring-stretching mode, respectively [14]. When PPy intercalating the reduced graphene oxide (rGO) as to form PPy/rGO composites present all characteristic peaks of PPy and reduced graphene oxide (rGO), however the G and D bands of reduced graphene oxide (rGO) were significantly broadened and their intensity increased with introduction of PPy. G band is directly proportional to the graphitic in-plane crystallite size, thus it showed increasing of G band intensity revealed that the polymer thickness increased after covering the reduced graphene oxide (rGO) by PPy [15], [16].

Electrical Conductivity Measurements

The electrical conductivity measurements were performed on PPy, rGO PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) by using 4-point probes direct current (DC) measurements. The results of electrical conductivity were calculated and represented in Table 1.

Table 1: Conductivity Measurements (4-point probes)

Sample	Thickness (<i>t</i> , cm)	Resistance (Ohm, Ω)	Resistivity (ρ , $\Omega \cdot \text{cm}$)	Conductivity (σ , $\Omega^{-1}\text{cm}^{-1}$)
rGO	0.005	365.439	1.827	0.547
PPy	0.004	233.179	0.933	1.072
PPy/rGO (4:1)	0.007	120.011	0.840	1.190
Ppy/rGO (3:1)	0.006	109.492	0.657	1.522
Ppy/rGO (2:1)	0.009	56.124	0.505	1.980
Ppy/rGO (1:1)	0.010	39.934	0.399	2.504

By varying the feeding weight ratios of pyrrole to reduced graphene oxide (rGO), the PPy/rGO composites with different content of PPy can be obtained to observe the conductivity and electrochemical properties. The electrical conductivity of PPy/rGO composites is strongly dependent upon the feeding weight ratio of PPy and reduced graphene oxide (rGO). The conductivity of PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) composites harvest improved the conductivity compared to the pure PPy and pure reduced graphene oxide (rGO) [16]. Electrical conductivity of samples characterizes from 4-point probes DC measurements were calculated by using the equation (Eq. 1), (Eq. 2) and (Eq. 3).

The electrical resistance, resistivity and conductivity of the composites materials were obtained using Four-point probe system coupled. This was used to measure sheet Resistance R_s and by employing set of equations, the value of the electrical conductivity can be calculated. Thus,

$$\text{Resistance sheet } (\Omega, \text{ Ohm}), R_s = \frac{\rho}{t} = \left(\frac{\pi t}{\ln 2} \right) \left(\frac{V}{I} \right) \\ = 4.35 \left(\frac{V}{I} \right) \text{ Ohm} \quad \text{-Centimeter for } s \gg t \quad (1)$$

The electrical resistivity ρ ($\Omega \cdot \text{cm}$) was determined using the formula,
 Resistivity, $\rho = R_s \times t$ (2)

and hence,

The electrical conductivity σ ($\Omega^{-1} \text{cm}^{-1}$) was obtained by using the equation,
 Conductivity, $\sigma = \frac{1}{\rho}$ (3)

Where, t is the thickness of the sample, V is the measured voltage and I is the current [17]

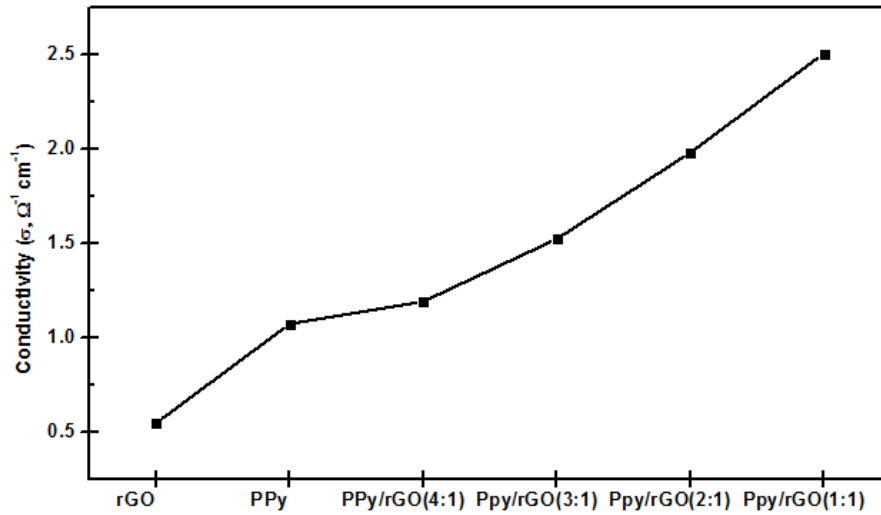


Figure 3: The conductivity of reduced Graphene Oxide (rGO), Polypyrrole (PPy), Polypyrrole/reduced graphene oxide ratio (4;1) PPy/rGO (4:1), Polypyrrole/reduced graphene oxide ratio (3;1) PPy/rGO (3:1), Polypyrrole/reduced graphene oxide ratio (2;1) PPy/rGO (2:1) and Polypyrrole/reduced graphene oxide ratio (1;1) PPy/rGO (1:1)

Figure 3 showed the graph of electrical conductivity constructed upon the samples tested which were rGO, PPy, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1). The conductivity of pure rGO is $0.547 \Omega^{-1} \text{cm}^{-1}$ and pure PPy has the electrical conductivity of $1.072 \Omega^{-1} \text{cm}^{-1}$ [16]. However, the PPy/rGO composite with different feeding weight ratios of PPy and reduced graphene oxide (rGO) produced a better electrical conductivity compared to the pure PPy and pure reduced graphene oxide (rGO). This situation occurred maybe because of the synergetic effect between reduced graphene oxide (rGO) and PPy in forming interpenetrating conductive networks. Where, as the increasing of the weight of reduced graphene oxide with lesser weight of PPy, the electrical conductivity produced was higher. It could be simplified by saying the conductivity of PPy/rGO composites increase with the increment of content of reduced graphene oxide (rGO) in the composites [16]. The electrical conductivity for PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) are

$1.190\Omega^{-1}\text{cm}^{-1}$, $1.522\Omega^{-1}\text{cm}^{-1}$, $1.980\Omega^{-1}\text{cm}^{-1}$ and $2.504\Omega^{-1}\text{cm}^{-1}$ respectively. Increasing in magnitude of conductivity as compared to the pure PPy and pure reduced graphene oxide (rGO) may be attributed to the π - π stacking between the reduced graphene oxide (rGO) and PPy [5].

Cyclic Voltammetry (CV)

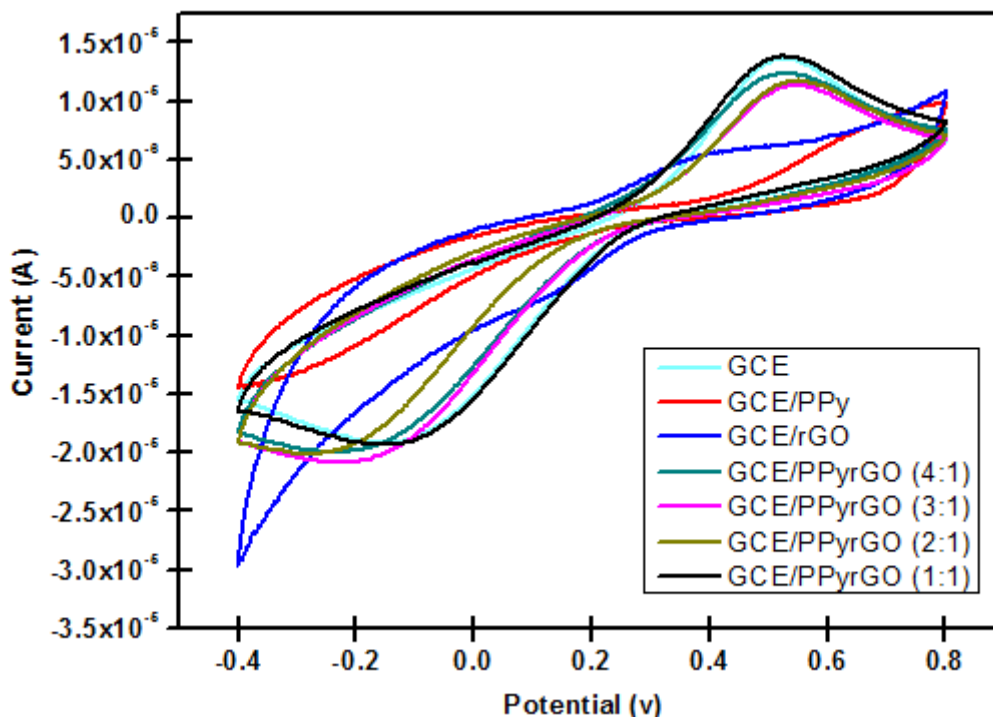


Figure 4: Cyclic Voltammetry curves of PPy, rGO, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) composites fabricated onto the glassy carbon electrode (GCE) at the scan rate of 100mVs^{-1} in the combination of 0.1M potassium chloride (KCl) and 5mM potassium ferricyanide $[\text{Fe}(\text{CN})_6]^{3-/4-}$ as a redox probe

Figure 4 depicted a comparative study of cyclic voltammograms (CVs) for PPy, rGO, PPy/rGO (4:1), PPy/rGO (3:1), PPy/rGO (2:1) and PPy/rGO (1:1) composites fabricated onto glassy carbon electrode (GCE) as working electrodes in a three-electrode system which include Ag/AgCl electrode as reference electrode and platinum electrode act as counter electrode. This CV procedure was constructed in the presence of the combination of 0.1M potassium chloride (KCl) and 5mM potassium ferricyanide $[\text{Fe}(\text{CN})_6]^{3-/4-}$ as a redox probe, at the scan rate of 100mVs^{-1} in the potential range from -0.4V to 0.8V. All CV curves demonstrating that all samples have an ideal capacitive nature with ion response, where it illustrates symmetric current-potential characteristics, indicative of good conductivity and high reversibility of the electrode materials. Obviously, the PPy/rGO (1:1) composites has a higher C_s than the PPy, reduced graphene oxide (rGO) and other PPy/rGO composites at the same scan rate, which due

to its larger enclosed area in the CV curve. PPy/rGO(1:1) composites exhibits better electrochemical capacitive characteristic, high degree of electroactivity, faster ion diffusion rate and superior reversible redox reaction than PPy due to the contribution of both layer and the pseudo-capacitance [14]. Meanwhile, by comparing the PPy/rGO (1:1) composites with the reduced graphene oxide (rGO) showed the CV curve is leveled current separation between leveled anodic and cathodic current for reduced graphene oxide (rGO) is much smaller due to the poor supercapacitive activity of stacking of the samples [12], [14], [16], [18].

CONCLUSION

In this work, the PPy/rGO composites were successfully prepared via hybridization of yielded reduced graphene oxide (rGO) and polypyrrole (PPy). It is proved that hybridization interaction between reduced graphene oxide and polypyrrole form homogeneous composites, where PPy/rGO 1:1 showed the best SEM visual image of fully interaction between PPy and rGO due to π - π stacking interaction. While result from Raman spectroscopy showed that PPy/rGO 1:1 had the highest intensity at G band that indicate the interaction between the C=C of PPy and sp^2 -bonded carbon atoms (C-C bond) of rGO. The electrical conductivity is increasing as the increment weight of reduced graphene oxide (rGO) in the Ppy/rGO 1:1 with the value of $2.504 \Omega^{-1}cm^{-1}$. PPy/rGO 1:1 composites shows remarkable higher electrical conductivity and reversibility due to the faster electron transfer observed from the redox reaction as the composites were fabricated on glassy carbon electrode (GCE) as the GCE/PPy/rGO transducer that been constructed and tested in cyclic voltammetry (CV), thus it does illustrated the Ppy/rGO 1:1 composite has a great binding network structure compared to other Ppy/rGO composites ratio, PPy and reduced graphene oxide (rGO) respectively. Therefore, it can be concluded that PPy/rGO 1:1 composite could be a great potential candidate for better conductivity performance for application usage such as supercapacitors and transducers.

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