

# The Effect of Poly (ethylene glycol) Diglycidyl Ether as Surface Modifier on Conductivity and Morphology of Carbon Black-Filled Poly (vinyl chloride)/Poly (ethylene oxide) Conductive Polymer Films

M. D. Siti Hajar<sup>\*,1,a</sup>, A. G. Supri<sup>2,b</sup> and A. J. Jalilah<sup>3,c</sup>

<sup>1,3</sup>School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Kompleks Taman Muhibah, Jejawi 2, Perlis, Malaysia

<sup>2</sup> Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Pauh Putra, Arau, Perlis

<sup>\*,a</sup>sitihajarmohddin@gmail.com, <sup>b</sup>supri@unimap.edu.my, <sup>c</sup>jalilahjalil@unimap.edu.my

**Abstract** – Blends of poly (vinyl chloride) and poly (ethylene oxide) with the addition of carbon black as filler was prepared via solution casting technique to fabricate a conductive polymer film. Besides, poly (ethylene glycol diglycidyl ether) (PEGDE) was added into the formulation in order to improve its properties. The surface morphology of the conductive polymer film was characterized via scanning electron microscope (SEM). The results showed that the conductivity of the film was greatly enhanced by incorporating the PEGDE as the surface modifier in the PVC/PEO conductive polymer film. **Copyright © 2015 Penerbit Akademia Baru - All rights reserved.**

**Keywords:** Poly (vinyl chloride), Poly (ethylene oxide), Poly (ethylene glycol) Diglycidyl Ether, Electrical conductivity

## 1.0 INTRODUCTION

Polymer blending is one of the most important methods for the development of new materials with a variety of properties and superior than the individual component polymer. It is one of the efficient ways to reduce the crystalline content, as well as to improve the amorphous content. Generally, the polymer materials are insulators and they blend with conductive filler to improve its conductivity properties. The conductivity of the composite materials depends on the size and the shape of the filler particles, in addition to their distribution within the polymer matrix [1]. The conductivity of the polymer increases if the added filler forms a continuous conductive network in the matrix. Some examples of conductive fillers, in order to form a conductive network, are natural and synthetic graphite, copper, carbon black, and carbon nanotubes [2].

Polyvinyl chloride had been chosen as the polymer matrix because of its broad range of application, low in cost, chemical stability, biocompatibility, and sterilizability. Besides, it has

been broadly used in the industry for many years. However, PVC has low thermal stability and brittleness, which hinders certain applications. Therefore, it is important to blend PVC with other polymer materials to achieve good properties in order to yield high added values [3]. Polyethylene oxide (PEO) is a semi-crystalline polymer, owning both crystalline and amorphous phases at room temperature. It is the most interesting base material because of its high thermal property and chemical stability [1, 4]. On top of that, PEO is a weak proton acceptor polymer, and therefore, it is compatible with PVC because PVC can be considered as a proton donor that contributes acidic hydrogen. In recent years, PVC has been commonly used in polymer blending due to its miscibility with other polymer materials.

On the other hand, carbon black (CB), which is commonly used in the industry to achieve conductive polymer composites due to its cost advantage over many other types of fillers and abundant supply, exhibits the particle shape at relatively low concentration, as well as supermolecular structures at relatively high concentration [5]. Besides, CB has been widely used as conductive filler in order to transform the insulating nature of polymers to electrically conductive due to its easy process ability and light weight compared to other metallic particles [6]. Meanwhile, poly (ethylene glycol diglycidylether) (PEGDE) is also commonly used in the chemical industry for surface modifying and crosslinking. It has widely acted as an additive for crosslinking polymers bearing amine, hydroxyl, and carboxyl groups, besides possessing good solubility in water [7]. In polymer electrolyte application, PEGDE is usually incorporated as a plasticizer and stabilizer. It does not only improve the conductivity, but also the high chemical stability of the solid polymer electrolyte. Recently, Jing Fu et al. reported that the measured conductivity of the alkaline solid polymer electrolyte membrane from PVA ranged from  $2.75$  to  $4.73 \times 10^{-4} \text{ Scm}^{-1}$  at room temperature increased up to  $1.5 \times 10^{-3} \text{ Scm}^{-1}$  with addition of PEGDE. This was due to the high chemical stability of the membranes that was achieved by high densely chemical crosslinking modification, as well as the formed interpenetrating network of the membrane [8].

In addition, the important objective of the research was to study the effect of PEGDE and the loading of the conductive filler on the properties of PVC/PEO films. Therefore, this research reports an investigation on electrical conductivity properties, as well as morphology of PVC/PEO-filled CB conductive film by varying CB loading and adding PEGDE in the conductive polymer film.

## 2.0 METHODOLOGY

### 2.1 Materials

Poly vinyl chloride (PVC) with  $M.W \approx 220\,000$  and poly ethylene oxide (PEO) with  $M.W \approx 100\,000$  were used as the basic polymeric matrix. Carbon black (CB) with the mean particle sized  $< 177 \mu\text{m}$  was used as conductive filler in the conductive polymer blend. Besides, dioctylterephthalate (DOTP) with  $M.W \approx 390.56$  was used as a plasticizer.

### 2.2 Sample Preparation

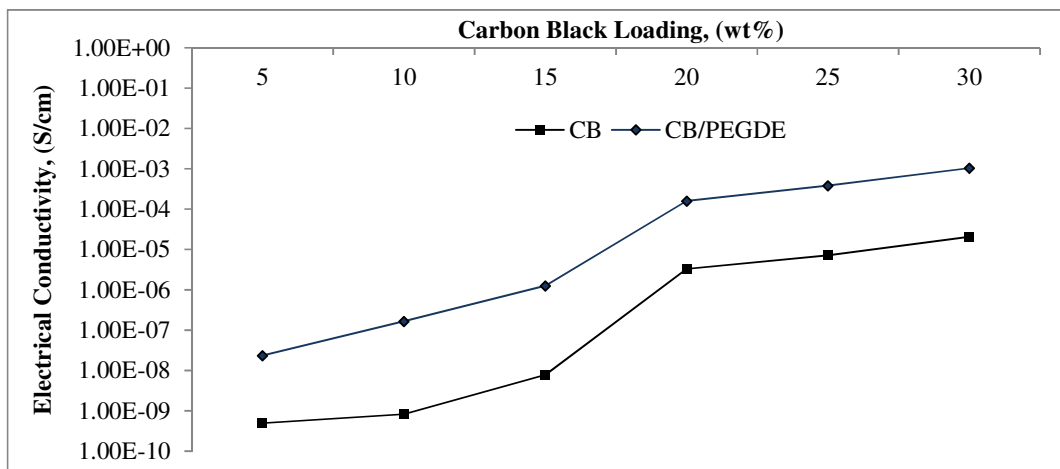
The PVC and the PEO conductive films were prepared by using the solution cast technique. The required amounts of PVC and PEO were dissolved in Tetrahydrofuran (THF) with a stirrer at a speed of 600 rpm. The solution was prepared at room temperature. After incorporating the required amount of Dioctylterephthalate (DOTP) as plasticizer, PEGDE as surface modifier, and CB was suspended in the PVC/PEO blends. The mixture was stirred continuously for 4 hours

until a homogeneous mixture was obtained. Then, the mixture was cast onto a glass mould and was allowed to evaporate slowly inside a fume cupboard at room temperature. The same methods were repeated to produce samples with different CB loading.

### 3.0 RESULTS AND DISCUSSION

Figure 1 shows the relationship of the electrical conductivity as a function of the conductive filler content for PVC/PEO/CB films and PVC/PEO/CB/PEGDE films. From Fig. 1, the electrical conductivity of the PVC/PEO conductive film increased with the increase of CB loading. The increment of electrical conductivity was due to the increase of surface interaction between CB particles in PVC/PEO/CB films. However, the PVC/PEO/CB/PEGDE films showed higher electrical conductivity compared to PVC/PEO/CB films. This was because the addition of PEGDE enhanced good distribution of CB on the surface of the PVC/PEO/CB films. The presence of PEGDE also promoted proton conduction and increased the conductivity value. Meanwhile, Jin et al. studied the effect of PEGDE content as plasticizers on the ionic conductivity of (PEO-PMA)-based polymeric gel. The results showed that the ionic conductivity increased with the increase in the content of PEGDE [9].

Meanwhile, the percolation threshold value was about 20wt% for both PVC/PEO/CB films and PVC/PEO/CB/PEGDE films. A percolation threshold in conductivity is present when the volume fraction of the filler is enough to provide continuous electrical paths through the polymer matrix. Besides, the percolation threshold is varied with shapes and agglomeration of the filler, as well as the type of polymer used [10].

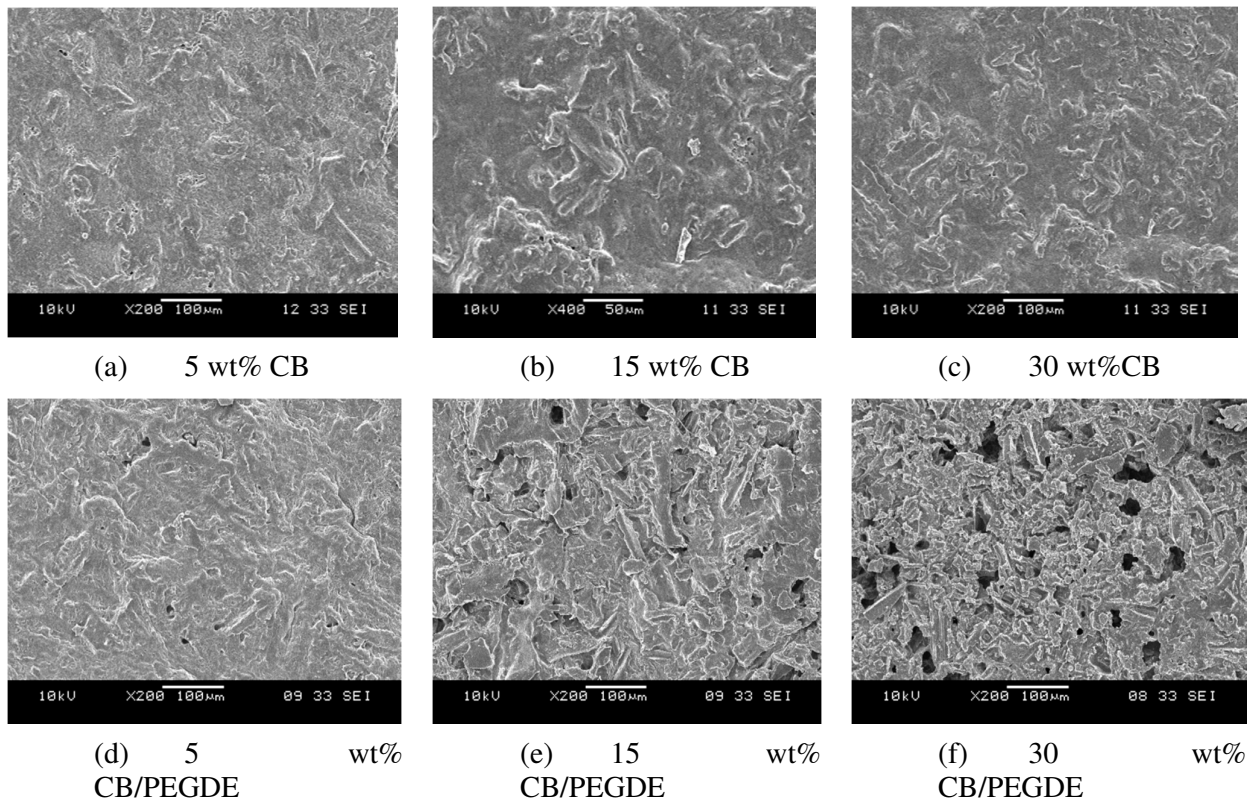


**Figure 1:** Electrical conductivity of PVC/PEO/CB films and PVC/PEO/CB/PEGDE films with different CB loading.

Figure 2(a-c) show SEM micrographs of extracted surface for PVC/PEO blended with CB loading. From the micrograph, at 5 wt% of CB loading, there was a good distribution of CB in the PVC/PEO blends, indicating a good interaction between CB and PVC/PEO phases. Nevertheless, when the content of CB was increased to 30 wt% (see Fig. 1(c)), the CB particles in the PVC/PEO blends formed an agglomeration on the surface of the film. The

agglomerations of CB particles that were formed on the surface paved the connection of the conductive path on PVC/PEO/CB conductive films that contributed to higher conductivity value when compared to 5 wt% of CB loading.

In addition, Figure 2 (d-f) show images of SEM micrographs for extracted surface of PVC/PEO blends with different CB loading and the addition of PEGDE as surface modifier in the conductive polymer films. However, the PVC/PEO/CB/PEGDE films showed many holes on the extracted surface compared to PVC/PEO/CB films. Furthermore, the surface was found rougher when the CB content was increased by 5 wt% to 30 wt%. This was due to the extraction of PEGDE during the immersion of the films in toluene for 24 hours.



**Figure 2:** SEM micrographs of extracted surface of PVC/PEO/CB and PVC/PEO/CB/PEGDE conductive polymer films.

#### 4.0 CONCLUSION

The PVC/PEO/CB conductive polymer films were produced by using solution casting method. In fact, some improvements were made by incorporating PEGDE as the surface modifier. Besides, the electrical conductivity of the PVC/PEO polymer films increased with the addition of PEGDE as surface modifier into the PVC/PEO/CB films.

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