

# Effect of Carbon Black Loading on Electrical Conductivity and Thermal Degradation of Poly (vinyl Chloride)/Poly (ethylene oxide) Conductive Films for Sensor Application

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**Abstract:** Conductive polymer films based on carbon black filled PVC/PEO (50/50 wt/wt %) was prepared by solution casting technique. The effect of carbon black loading on the electrical conductivity and thermal degradation was studied. The result shows that the electrical conductivity increased with increasing of carbon black loading. The thermal degradation of the PVC/PEO conductive blends were performed using Thermogravimetric analysis (TGA). The TGA data indicates that the addition of carbon black into the blend was improved the thermal stability of the PVC/PEO blends.

## Introduction

A wide spread attention has been growing in manufacturing polymeric materials as conductive material without compromising the enviable mechanical and processing properties [1]. Polymeric materials are naturally insulators and conductivity of the composite materials depends on the content and properties of the filler such as the size and shape of the filler particles in addition to their distribution matrix, beside the interaction between the filler surface and polymeric matrix [2]. Poly (vinyl chloride) is chosen as a polymer matrix because of its broad range of application, low cost, chemical stability, biocompatibility and sterilizability. However, PVC has low thermal stability which hinders some of its applications [3]. Poly (ethylene oxide) (PEO) also referred as polyethylene glycol (PEG) known as polyols of molecular weight below about 20,000 while PEO refers to higher molecular weight polymers. The PEO consists of epoxide ring where the two corners of the molecule consist of -CH<sub>2</sub> linkages and the third corner is oxygen [4]. Carbon black (CB) which is commonly used in industry to achieve the conductive polymer composites due to its low cost and abundant supply, exhibits the particle shape at relatively low concentration and supermolecular structures at relatively high concentration [5]. Carbon black widely used as conductive fillers in order make the insulating nature polymers in electrically conductive due to its processability and lighter than other metallic particles [6]. The most broadly used material to improve conductivity is carbon black. Carbon black is composed about 97–99% elemental carbon. The other major constituents are hydrogen and oxygen. The

hydrogen is distributed as hydrocarbon throughout the CB. These atoms are set into several organic functional groups such as -OH (hydroxyl), -COOH (carboxyl) on its surface [7].

## Experimental

**Materials.** Poly vinylchloride (PVC) with M.W  $\approx$  220 000 and poly ethylene oxide (PEO) with M.W  $\approx$  100 000 were used as a basic polymeric matrix. Carbon black (CB) with the mean particle size  $<$  177  $\mu$ m was used as conductive filler in the conductive polymer blend. Dioctylterephthalate (DOTP) with the M.W  $\approx$  390.56 was used as a plasticizer.

**Sample preparation.** The PVC and PEO conductive film were prepared using solution cast technique. The required amount of PVC and PEO were dissolve in Tetrahydrofuran (THF) by using stirrer at speed 600 rpm. The solution was prepared at room temperature. After incorporating the required amount of Dioctylterephthalate (DOTP) as plasticizer and carbon black was suspended in the PVC/PEO blends. The mixture was stirred continuously for 4 hours until get a homogeneous mixture. Then, the mixture was cast onto a glass mould and allowed to evaporate slowly inside a fume cupboard at room temperature. The same methods were repeated to produce sample with different carbon black loading.

## Results and Discussion

Figure 1 shows the relation between electrical conductivity of the PVC/PEO/CB conductive film and carbon black loading. From the Figure 1, it can be seen that the electrical conductivity of the PVC/PEO conductive films increased with increasing of carbon black loading. This is due to incorporation of carbon black loading improving the conductivity of the film. Jie Chen et al.[8] studied that the electrical resistivity of composites decreases slightly at the CB content smaller than 3.0 wt% and later decrease apparently at the CB content higher than 3.0 wt%.

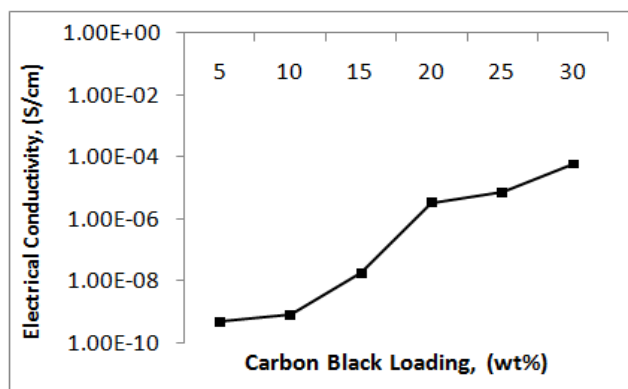


Figure 1. Electrical conductivity vs Carbon black loading of PVC/PEO with different carbon black loading.

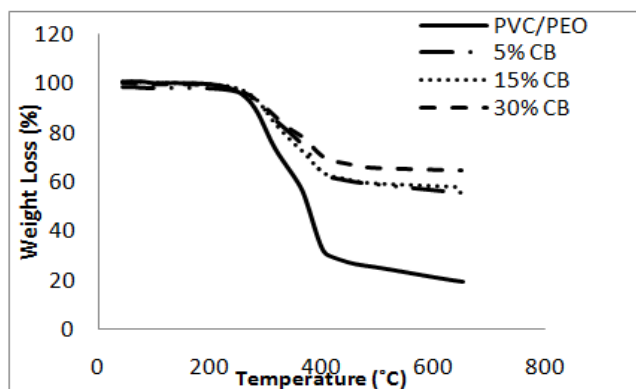


Figure 2. TGA thermogram of PVC/PEO/CB blends with different filler loading

Figure 2 shows TGA thermograms as a function of temperature in the range from 30°C to 650°C for PVC/PEO blend with different composition of carbon black. As shown in figure 2, all samples have three decomposition steps. The first steps occurring between temperatures of 200°C-280°C involve the melting point of PEO due to the splitting of small molecule and evaporation of moisture [9]. The

second decomposition stage involves the decomposition of PVC. The latter processes in the graph shows the main decomposition step because show the most significant weight loss. From the Table 1, Temperature at 5% weigh loss ( $T_{-5}$  wt %), final decomposition temperature, and residual mass of PVC/PEO/CB blend are increased with an increase in filler loading. The result show that higher filler loading gave the PVC/PEO/CB blends more thermal stability than the lower filler loading. Xin Wen et al.[10] have reported that the thermal decomposition temperature for PP/CB nanocomposites shifted significantly to a higher temperature range than for neat PP which indicate an improvement of thermal stability. Both  $T_{5\text{ wt}\%}$  and  $T_{10\text{wt}\%}$  increased with increasing CB content. This was due to formation of three dimensional filler network structure by CB in PP which responsible for the improvement in thermal stability.

Table 1. Data for  $T_{-5}$  wt%, final decomposition temperature, and residual mass of PVC/PEO/CB at different carbon black loading.

Blend composition	$T_{-5}$ wt% (°C)	Final decomposition temperature, FDT (°C)	Residual mass (%)
PVC/PEO	260.36	551.95	22.74
PVC/PEO/5% CB	267.64	565.65	57.54
PVC/PEO/15% CB	268.32	591.17	58.37
PVC/PEO/30% CB	269.78	604.84	64.82

The importance of infrared spectroscopy analysis was to determine the chemical functional groups in the PVC/PEO/CB conductive polymer blend. Different functional group absorbs characteristic frequencies of infrared. From the result in Figure 3, the wavenumber was observed presented spectrum absorption intensity peaks at  $3423\text{ cm}^{-1}$  corresponding to the N-H groups. Besides that, the Figure shows the strong absorption peak at  $3182\text{ cm}^{-1}$  represent the O-H (hydroxyl) groups. The peak at  $2995\text{ cm}^{-1}$  and  $2637\text{ cm}^{-1}$  are corresponding to the  $-\text{CH}_2$  bending from PVC and PEO structure, the vibration of CN group at  $2362\text{ cm}^{-1}$  from the plasticizer, the peak at  $1710\text{ cm}^{-1}$  signify the C=O stretching of DOTP structure and peak  $1520\text{ cm}^{-1}$  is vibration from N-H. The peak at  $627\text{ cm}^{-1}$  and  $616\text{ cm}^{-1}$  shows the C-Cl stretching of polyvinyl chloride.

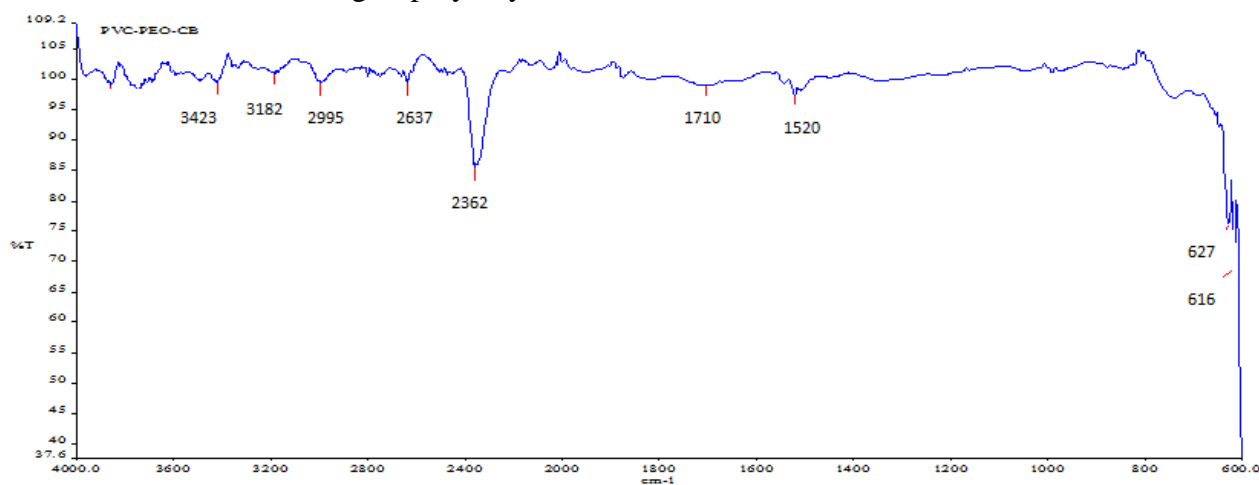


Figure 3. FTIR Spectrum of PVC/PEO/CB conductive polymer film

## Conclusion

The electrical conductivity of the PVC/PEO/CB conductive polymer blend increased with increasing of carbon black loading. The addition of high carbon black loading improves the thermal stability of PVC/PEO/CB conductive polymer blends.

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