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Exploring Functionalized Graphene Nanocomposites for Nanoscale Switching

Pooja Shukla^{1*}, Amutha Subramani² and Arijit Sen^{1,2}**¹Dept of Physics and Nanotechnology, SRM University, Kattankulathur, India****²SRM Research Institute, SRM University, Kattankulathur, India**

Abstract : The switching of electronic devices plays a pivotal role when it comes to tailor new materials especially for spintronic applications. Graphene being a unique form of carbon often offers a wide range of flexibility in realizing nanodevices of such kind. Its good transparency towards substrate makes it suitable for integrating easily in systems like touch screens, smart windows and e-papers. Here we report some functionalized nanocomposites synthesized out of pure graphene upon mixing with PVDF polymer. The as-grown graphene/PVDF film is characterized by various techniques such as XRD and FTIR to extract the structural as well as chemical information of the graphene/PVDF film. Other physical properties like lattice strain and charge transport are also studied to explore its possible applications in device technology.

Keywords: nanodevices, nanocomposites, synthesize, polymer.

Introduction

We have seen in recent years that polymeric materials could play a vital role in the field of electronic applications¹. Enhanced electrical performance coupled with appreciable mechanical strength makes the polymer based nanocomposites better candidates in comparison to these of conventional polymeric materials such as insulators. The scaling down of the electronic technology is paying more attention to increase the density without physical scaling¹

Graphene has very good electrical conductivity as well as mobility and hence it is suitable for top-down processing^{1,2}. The flexibility of graphene with polymers is reflected in the graphene-based polymer composites. The polymer matrix we used here were filled by the carbonaceous fillers like CNT, graphene, functionalized graphene, carbon fillers, etc, having better conductivity and physical performance. Although numerous challenges remain in developing graphene-based polymer composites, these materials have been explored for a range of applications in different fields such as electronic devices, energy storage, sensors, ESD and EMI shielding and biomedical applications³.

Among several approaches, a hybridization of graphene with other functional materials has been suggested as a way to detour the technical limits of graphene^{4,6}. Graphene based polymer nanocomposites shows many interesting transport properties, such as the quantum Hall effect and quantum tunneling effect. PVDF/functionalized graphene sheet (FGS) nanocomposite provides higher thermal and electric stability than

PVDF/expanded graphite nanocomposite^{3, 7}. Lead zirconiumtitanate (PZT), zinc oxide (ZnO) and PVDF are representative piezoelectric materials used in microelectromechanical system (MEMS) piezoelectric transducers⁸. Thus, graphene is considered to be an ideal nanofiller for enhancing the mechanical, electrical and thermal properties of polymers^{9,10}.

In this paper, graphene/PVDF nanocomposites are analyzed in terms of film characteristics and enhancement mechanism. The study of the switching capability of PVDF and its composites are also discussed.

Experiment

Pure graphene, polyvinylidene fluoride (PVDF) and N, N dimethylformamide (DMF) are purchased commercially from the market.

The graphene/PVDF film is synthesized by the slightly modified wet-chemical method as shown¹⁰

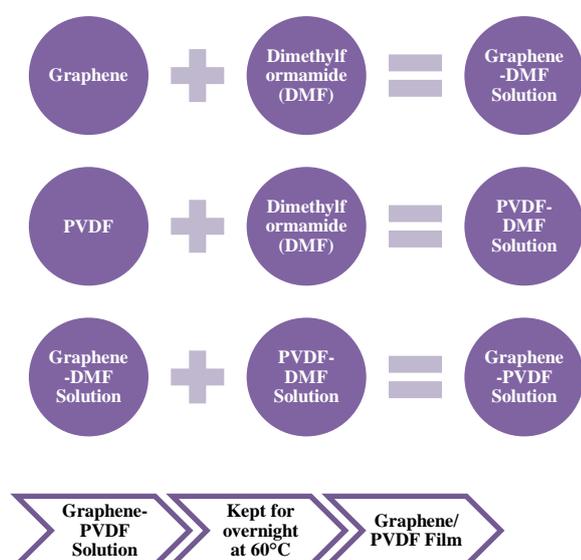


Figure 1 – Synthesis Protocol for graphene/PVDF Film

Generally, composites are made up of two components, namely, filler and matrix¹¹. PVDF as used here forms a matrix and graphene acts as a filler. These fillers are then mixed with polymer matrix using solvent casting method¹². The 40 mg of graphene is mixed with 25 to 30 ml of the DMF solution which is sonicated in the water bath type sonicator for 1 hour to get the graphene-DMF solution. Further, 1.96g of PVDF is mixed with 25 to 30 ml of the DMF solution which is also sonicated for the same period to get the PVDF-DMF solution.

Finally, the graphene-DMF solution and PVDF-DMF solution are mixed well through ultrasonication for half an hour, followed by the magnetic stirring at 60° C with 300 to 400 rpm for 1 hour. The final solution is kept in hot air oven at 60° C for 24 hours. After 24 hours, the graphene/PVDF film is obtained.

Results and Discussions

Graphene, PVDF and graphene/PVDF film were analyzed using XRD to study the structural properties. Figure 2 a.shows the prominent peak at 26.38°, which indicates the presence of graphene, which is compared with JCPDF reference code. The crystalline size of graphene is found to be 22.45 nm. Figure 2 b.shows the major peak position of the PVDF at 20.34°, which is also compared with JCPDF reference code.

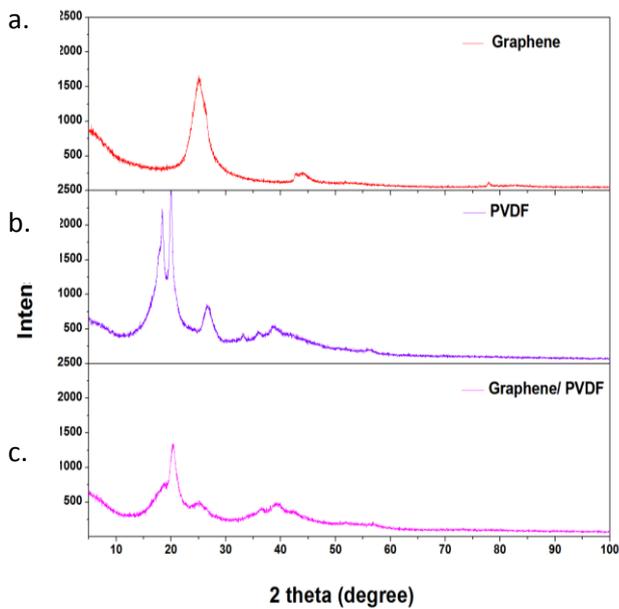


Figure 2 – XRD pattern for a. graphene, b. PVDF and c. graphene/PVDF Film

Figure 2c. shows the undesirable peak at 20.34° , which confirms the presence of the PVDF polymer while the smallest peak at 26.38° establishes the presence of the graphene. The XRD pattern of the graphene/PVDF film is compared with the JCPDF reference code for the confirmation of the presence of graphene/PVDF in the film. The strong diffraction peaks at $2\theta = 20.34^\circ$ and 26.38° are assigned to be (100) and (021) phase crystals respectively.

When the graphene is mixed with PVDF, the broadness of XRD peak increases, which indicates the nanocrystalline nature of the film. This is reflected in the reducing crystalline size of the graphene/PVDF film, as found to be 15.6 nm. The dislocation density (δ), defined as the length of dislocation lines per unit volume, increases as graphene is mixed with PVDF.

Figure 3 shows the FTIR pattern for graphene, PVDF and graphene/PVDF film. There is no significant peak found in figure 3 a, which is mainly due to the lack of oxygen species in the graphene. The figure 3b, shows the FTIR pattern for PVDF, the peak at 424 cm^{-1} and 448 cm^{-1} correspond to the β -phase, while the peak at 494 cm^{-1} corresponds to the α -phase.

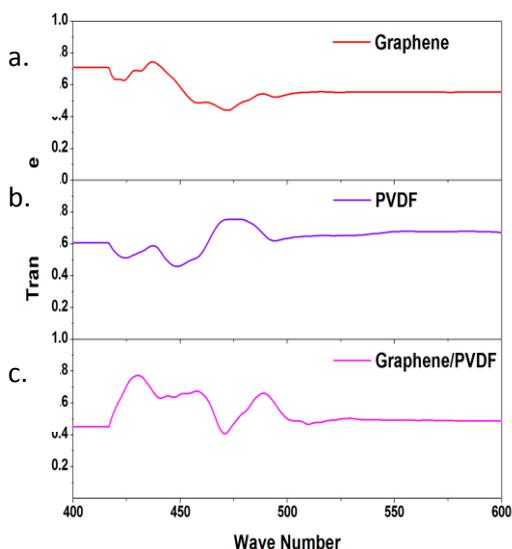


Figure 3 – FTIR pattern for a.graphene, b. PVDF and c. graphene/PVDF Film

The annealing temperature will not affect the β -phase crystallization of PVDF. The figure 3c, shows the FTIR pattern for graphene/PVDF film, with no significant peak for graphene. Further, there is no formation of functional groups like COOH, NH₂, etc in the graphene/PVDF film.

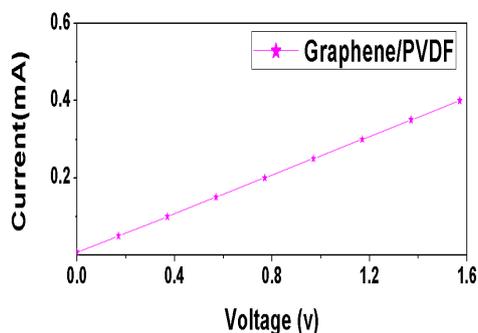


Figure 4 – I-V Characteristics of graphene/PVDF Film

The I-V Characteristics of the graphene/PVDF Film is analyzed using the four-probe method. Figure 4 shows the linear relationship between current and voltage, which indicates that graphene/PVDF film obeys the Ohm's law. The linearity of the graphene/PVDF film is flexible which may be exploited for the electronic switching applications.

Conclusions

The graphene/PVDF Film has been synthesized successfully using the wet chemical method. We have investigated the structural, optical and electrical properties of the film. Pure graphene and PVDF are analyzed using XRD. The peak at 20.34° shows the presence of the PVDF polymer and the peak at 26.38° shows the presence of the graphene, confirming the formation of graphene/PVDF film. The crystalline size of graphene/PVDF film is decreased as compared to graphene and is found to be at 15.6 nm. The optical properties for graphene/PVDF film analyzed using FTIR, shows no significant peak, because of the lack of oxygen species in graphene. There is also no formation of functional groups like COOH, NH₂, etc, when the graphene is functionalized with PVDF. The electrical properties of the graphene/PVDF film, analyzed using the four-probe method, indicates that the film has the ohmic nature. This way, the synthesized graphene/PVDF film can be suitable for electronic switching applications.

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