DEVELOPMENT OF FLEXIBLE POLYMER NANOCOMPOSITE FILMS FOR ELECTROMAGNETIC INTERFERENCE (EMI) SHIELDING APPLICATIONS

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College	:	*Nitte Meenakshi Institute of Technology, Bengaluru*
Branch	:	*Department of Electrical and Electronics Engineering*
Guides	:	*Dr. Shreeram V Kulkarni* *Dr. Praveen Naik* *Dr. Devarajan Alagarasan*
Students	:	*Mr. Varuna M* *Mr. Yuvraj Singh* *Ms. Chandana A*

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Electromagnetic Interference, Polymer Nanocomposite, Reduced Graphene Oxide, Zinc Nanoparticles, Drop Casting, X-ray Diffraction.

Introduction:

The rapid increase in electronic devices and wireless communication systems has made electromagnetic interference a serious concern in our modern technology. The consequence of this situation is a serious issue associated with electromagnetic interference (EMI). Electromagnetic interference occurs when unwanted electromagnetic radiation interrupts the flow of signals and causes malfunction of equipment[1]. This creates the need for the use of effective EMI shielding materials. Such shielding materials should be light-weight, flexible, anti-corrosive and easily manufacturable. Traditional shielding materials which include copper, aluminum, and steel offer great EMI shielding but are quite heavy, not flexible and very easily affected by corrosion, hence unsuitable for portable electronic devices. Polymer nanocomposites are, therefore, a suitable replacement due to the combination of the mechanical properties of polymers with the electric and dielectric properties of nanofillers. Polymer nanocomposites are, therefore, a suitable replacement due to the combination of the mechanical properties of polymers with the electric and dielectric properties of nanofillers. In this project, the development of a nanocomposite thin film was done by incorporating polyvinyl pyrrolidone, reduced graphene oxide, and zinc In this project, a hybrid nanocomposite film made of PVP, reduced graphene oxide, and zinc nanoparticles was developed using a simple solution-based process. The work focuses on creating a material that is lightweight, flexible, and suitable for next-generation EMI shielding applications [2].

Objectives:

1. To prepare Zn+rGO+PVP composite thin films using the drop casting method that will be able to provide effective electromagnetic interference shielding through lightweight and flexible structures.

2. To develop prototypes with an optimized filling agent concentration from the solution process on the glass substrate.
3. To perform the characterization study for synthesized prototypes by means of structure (XRD) and microstructure (SEM) analysis.
4. To provide a developed prototype along with a recipe.

Methodology:

1. The intended project is centered on developing flexible Zn-rGO-PVP polymer nanocomposite films with potential application as EMI shielding material using an efficient yet inexpensive fabrication method. The procedure was undertaken in three steps: preparation of materials, fabrication of thin films, and structural characterization.
2. In the first step, polymer matrix was fabricated. Polyvinylpyrrolidone (PVP) was selected due to its good film-forming capabilities, flexibility, and solubility in ethanol. 0.20 grams of PVP was dissolved in 20 ml of ethanol using ultrasonication to obtain a complete dissolution without the risk of forming lumps, hence a homogeneous solution.
3. Secondly, 0.20 grams of rGO was introduced into the solution of PVP since the graphene sheets are known to agglomerate easily. Ultrasonication was done once more to achieve even distribution of the filler into the polymer matrix. The reduced graphene oxide was chosen as the conductor filler due to high conductivity and large surface area, which creates conductive paths capable of interacting with EM waves. After achieving a homogeneous PVP-rGO combination, 0.60 grams of zinc powder was added into the solution. Zinc nanoparticles help enhance conductivity and create interface polarization. The mixture was then stirred continuously using a magnetic stirrer for about one hour to ensure uniform mixing and prevent particle sedimentation. At the end of this process, a stable and well-dispersed Zn–rGO–PVP suspension was obtained.
4. The prepared solution was then used to fabricate thin films through the drop-casting method. A clean glass substrate was selected as the base surface, and the nanocomposite suspension was slowly deposited onto it using a dropper. The substrate was left undisturbed at room temperature so that the ethanol could evaporate naturally. After drying, a thin and flexible composite film was formed on the glass substrate.
5. Finally, the fabricated film was analyzed using X-ray diffraction (XRD) to study its structural properties and understand the distribution of fillers within the polymer matrix

Result and Conclusion:

1. The X-ray diffraction (XRD) pattern of the Zn–rGO–PVP composite, shown in Fig. 4, is characterized by a broad "hump" rather than the sharp, defined peaks typically of crystalline materials. This broad halo, centered between $2\theta \approx 20–30°$, suggests that the composite material is predominantly amorphous and lacks long-range periodic atomic order.
2. This absence of crystal form is mainly caused by the Polyvinylpyrrolidone (PVP) matrix. Usually, PVP displays rather broad diffraction halos within the range of 20–

25° because it is essentially an amorphous substance. Being the main constituent of the matrix, PVP thus strongly affects the diffraction pattern.

3. Reduced Graphene Oxide (rGO) plays an additional role here. Although pure rGO gives a broad diffraction halo for the (002) plane at $2\theta \approx 24–26°$, these layers get exfoliated within the matrix due to random dispersing throughout the polymer. This results in a mixing of rGO diffraction peaks with the halo formed by the amorphous PVP.
4. However, it is notable that there is an absence of any diffraction peak specific to Zinc (Zn). In this case, it suggests that the Zn nanofiller might be either very tiny for detection using X-ray Diffraction or very well dispersed within the polymer material. Besides, there appear to be strong interactions at the interface between Zn, rGO, and PVP. It means that interfacial reactions may disrupt the crystal formation. As a consequence, the matrix ensures that Zn particles remain in a highly disordered semi-crystalline state. Functionally, this feature plays an important role for EMI shielding because numerous structural defects and interfaces lead to polarization and dielectric losses.
5. To sum up, XRD analysis shows that the Zn-rGO-PVP composite is predominantly amorphous. In general, its amorphous nature can be associated with the fact that neither Zn nor rGO sheets are able to form a crystal lattice in this matrix.

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Future Scope:

The future scope of this project includes:

1. Optimizing the composition ratio of Zn, rGO, and PVP to improve conductivity and shielding performance.
2. To minimize film thickness and improve uniformity for practical electronic applications.
3. Additional characterization studies such as SE, SEM, TEM, electrical conductivity testing, and thermal analysis for understanding of the internal structure and properties.
4. Investigating the incorporation of alternative conductive or magnetic fillers, including carbon nanotubes, MXene, or ferrite nanoparticles, with the aim of augmenting shielding efficiency.