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Synthesis and Characterization of the Epoxy/MgO Nanocomposites Thin Films for Anti-UV Coatings

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Abstract

The spin coating technique successfully prepared the Epoxy/MgO nanocomposite thin films. Epoxy/nanocomposites thin film filled with different weight ratio (2, 4, and 6 wt.%) of MgO nanoparticle. The morphological, Fourier-transform infrared spectroscopy (FTIR), and optical properties of samples were studied. The FE-SEM images show the homogeneous and smooth surface of the pure sample and the appearance of clusters after being filled with MgO nanoparticles. The FT-IR tests showed functional groups of MgO within the epoxy nanocomposite, which increased in intensity with the increase in MgO wt.%, as for the optical measurements, which include absorbance, transmittance, absorption coefficient, and optical energy gap measurements, they showed that the samples have high absorbance for ultraviolet rays, and this absorbency increases with the increase in the MgO nanoparticle wt.%. Whereas, maintaining their absorption for visible wavelengths, absorption coefficient calculations showed high value of ultraviolet rays and its increase with an increase in the MgO wt.%, while did not notice a clear effect on the optical energy gap with an increase in the MgO wt.%. This makes the Epoxy/MgO nanocomposite thin films candidates for use in transparent coatings for anti-UV rays.

Keywords: Epoxy/MgO, anti-uv coating, spin coating, thin films.

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Introduction

Epoxy resin is a type of versatile synthetic polymer that has strong sticking power, durability, and chemical resistance. It contains the epoxy groups or oxirane groups. These types of groups take part in a chemical reaction that leads to curing or polymerization. Once it cures, epoxy becomes a stiff and hard material that strongly adheres to various materials including metals, plastics, ceramics and composites [1,2]. Apart from its ability to stick on objects properly, epoxy resin can be modified thus enabling the attainment of properties such as flexibility, toughness or even resistance to high temperatures. Epoxy is transparent after being cured so it has applications that require optical clarity [3]. Magnesium oxide (MgO) nanoparticles are minute particles of magnesium oxide. A ceramic compound made up of magnesium and oxygen with a crystalline structure depends on such factors as synthesis techniques and conditions. There are various methods for synthesizing MgO nanoparticles, including chemical precipitation, sol-gel processes, and vapor-phase techniques [4]. These approaches enable the control of particle properties such as structural, electronic, optical, and mechanical properties. At the nanoscale, quantum size effects begin to dominate leading to changes in electronic as well as optical features of MgO nanoparticles [5]. This is affected by electrical conductivity and optical behavior. The MgO nanoparticles can have optical transparency in the visible to near-infrared spectrum. Such property is highly beneficial for applications like transparent materials and optical coatings. UV light may be absorbed by MgO nanoparticles, depending on their size and structure. These qualities might be advantageous for applications involving UV protection [6,7]. Epoxy/MgO nanocomposite thin films are formed by blending epoxy resin with MgO nanoparticles. Consequently, this mixture goes through a curing process that forms a solid crosslinked polymer network. The last step involves the deposition of the material in the form of nanocomposite film using methods like spin coating or drop casting. The combination of nano MgO and epoxy produces unique properties in these thin films, where the epoxy matrix is hardened and strengthened by MgO nanoparticles, thereby improving the mechanical strength and toughness of the whole film [8,9]. Also, Epoxy/MgO nanocomposite thin films are heat resistant making them appropriate for thermal applications. The size and dispersion of MgO nanoparticles affect their optical properties. Depending on these factors, thin films may be UVabsorbing thus protecting the user while allowing them to see through the window. Thus, these materials are also suitable for electronic applications as they retain electrical insulation properties both epoxies and MgO. As such, Epoxy/MgO nanocomposite thin films can be used in various sectors due to their versatile nature. These include; optical devices, electronic components and protective coatings which require improved mechanical strength, thermal stability and optical transparency [10-12]. In this research, Epoxy/MgO nanocomposite thin films will be prepared using the spin coating method, and their structural and optical properties will be studied to obtain anti-UV rays films.

Material and Methods

The Epoxy/MgO nanocomposite thin films were prepared used the spin coating method. The epoxy resin was supplied from Sikadur-Sika, and MgO nanoparticles from the Nano Research Lab with partial sizes of 30–20 nm and purity of 99%, where epoxy was mixed with MgO nanoparticles powder with weight ratios (0, 2, 4, and 6 wt.%). Due to high viscosity of epoxy, it was difficult for nanoparticles to spread through it, so the samples were placed in an ultrasound bath for two hours, then stirred for 30 minutes to get a homogeneous solution, then the hardener was added in a ratio of 1:10, and it was placed directly in the spin coating at 1500 rpm for one minute on glass substrate, the samples were left to dry well for two days. Morphological examinations were carried out using a field-emission electron microscope (FE-SEM TESCAN MIRA3 FS-SEM) to study the morphology of the samples. A Shimadzu FTIR-8400S spectrometer in the range of 400–4000 cm^{-1} was used to study the functional groups of the samples. Finally, a spectrophotometer (SHIMADZU UV-1650) was employed to carry out the optical measurements.

Results

To know the effect and spread of MgO nanoparticles in epoxy thin films, samples were imaged using FE-SEM, and figure 1. shows the FE-SEM images of thin films for pure epoxy and epoxy filled with 6 wt.% MgO. From this figure, noticed that the morphology of pure epoxy thin film has a homogeneous and almost smooth surface, free of lumps and defects. While epoxy/MgO nanocomposite, there is a noticeable change in the morphology of the thin films through the appearance of clusters that are approximately the same size and have an almost uniform spread in the epoxy thin films. The functional groups of pure epoxy and the effect of MgO wt.% nanoparticles on them were studied through FTIR spectra is shown in Figure 2. It noticed that the pure epoxy has peaks at wavenumbers (3001, (1708 and 1436), 1253, 1114, 1069, and 699) cm^{-1}, which correspond to C-H stretch in aromatics, C-C stretching vibration in aromatics, asymmetrical aromatic C-O stretch, asymmetrical aliphatic C-O stretch, symmetrical aromatic C-O stretch, and -CH out of plane deformation in aromatics, respectively. When MgO nanoparticles are added, new peaks at 2887 and 465 cm-1 appear, and the intensity of these peaks increase with the increase in wt.% of MgO nanoparticles, this peak corresponds to Mg-O stretching and bending vibrations stretching and bending vibrations of H-O, respectively [13-14]. Figures 3 and 4 show the absorption and transmittance spectra of pure and doped epoxy thin films with different weight ratios of MgO nanoparticles. It can be noticed that the Epoxy/MgO thin films have high absorbance in the ultraviolet wavelength range and increase with an increase in the weight ratio of MgO nanoparticles, where the absorption coefficient at the wavelength is 270 nm, which was calculated through the relationship [15]:

$$\alpha = \frac{2.303\,A}{t}$$ (α absorption coefficient, t the film thickness, A absorbance)

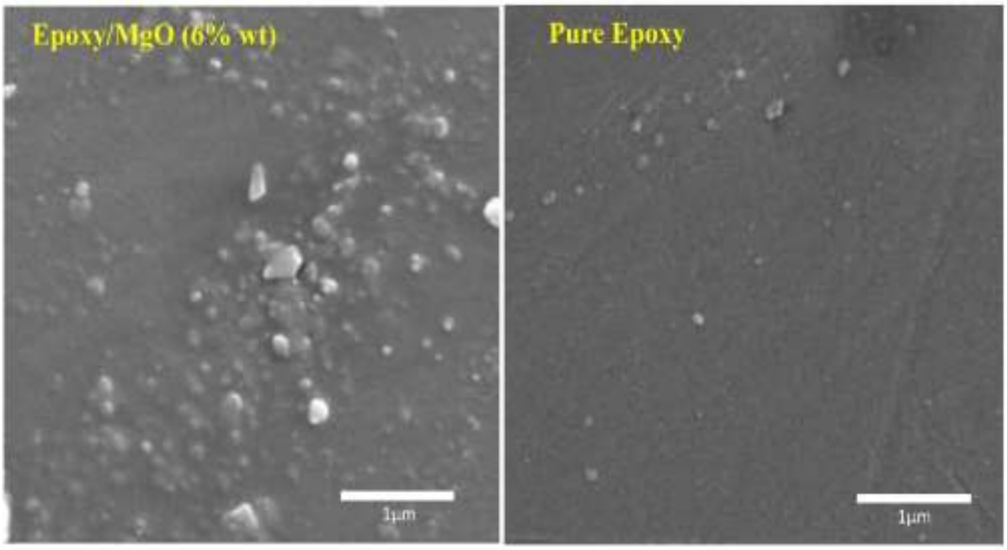

Figure 1: FE-SEM images of epoxy and Epoxy/MgO nanocomposite thin films with 6 wt.% of MgO nanoparticles.

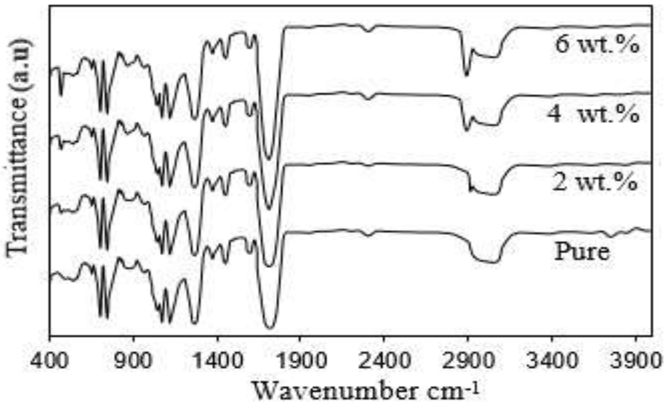

Figure 2: The FTIR spectra of epoxy and Epoxy/MgO nanocomposite thin films.

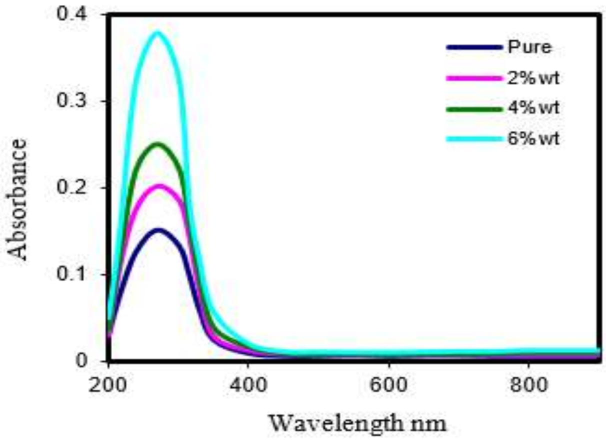

Figure 3: Absorbance spectra of epoxy and Epoxy/MgO nanocomposite thin films.

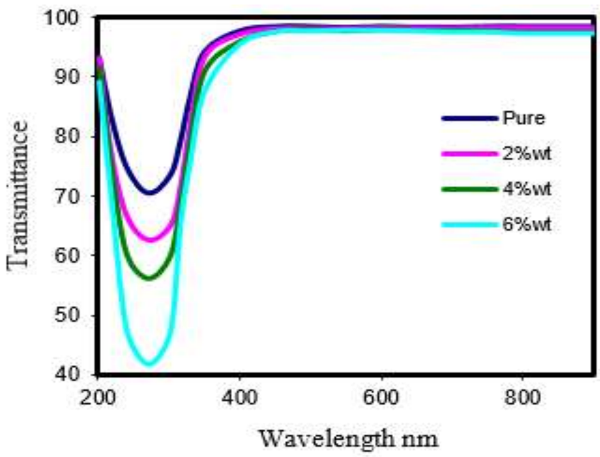

Figure 4: Transmittance spectra of epoxy and Epoxy/MgO nanocomposite thin films.

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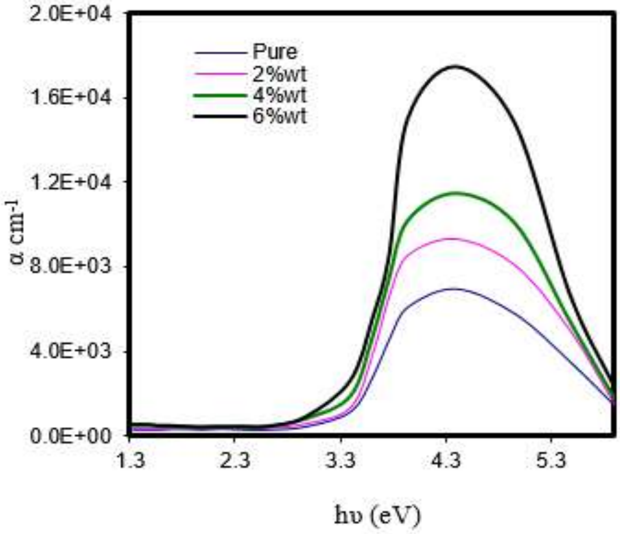

Figure 5: The variation of α with (hν) of epoxy and Epoxy/MgO nanocomposite thin films.

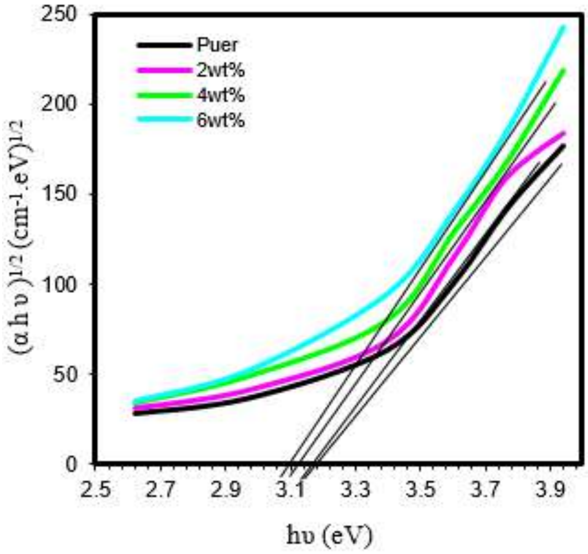

Figure 6: The variation of $(\alpha h\nu)^{1/2}$ with (hν) of epoxy and Epoxy/MgO nanocomposite thin films.

It increases from α = 6969 cm^{-1} for pure epoxy thin films to α =17480 cm^{-1} for Epoxy/MgO thin films at 6 wt.% (Figure 5). While the samples maintained their absorbance and transmittance in the visible wavelengths, it was noticed that the doping had a slight effect on the absorbance and transmittance spectrum in the visible range, where the optical energy gap that was calculated from figure 6 and relationship below [16]:

$\alpha h\nu = B\,(h\nu - Eg)^2$ (hν photon energy, B constant, Eg optical energy gap)

It is almost constant and decreases by a very small value when the weight ratio of MgO nanoparticles increases, Eg =3.2, 3.18, 3.1,3.08 eV for pure, 2, 4, and 6 wt.%, respectively. This is what enables the use of Epoxy/MgO thin films in coatings that prevent ultraviolet rays.

Conclusion

It can be concluded from this work that epoxy and Epoxy/MgO nanocomposite thin films can be successfully prepared using the spin coating method and that the morphology of the samples is affected when added MgO nanoparticles. Adding the MgO nanoparticles allows for epoxy/MgO thin films to maintain the absorbance and transmittance of the samples in the visible range, but it has a clear effect on the absorbance and transmittance in the ultraviolet range, and this is what makes the Epoxy/MgO nanocomposite thin films an effective film for anti-ultraviolet coating.

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Ethical clearance: None

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