International Journal on "Technical and Physical Problems of Engineering" (IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2022 | Issue 53 | Volume 14 | Number 4 | Pages 143-149

SYNTHESIS AND CHARACTERIZATION OF A NOVEL NANO-COMPOSITE MATERIAL FOR MICROWAVE ABSORPTION

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Abstract- Using poly (glycerol/phthalic anhydride) nanoparticles, a radar wave-absorbing material having high-efficiency was fabricated, and the impact of combining thermal paint with these nanocomposites on the electromagnetic absorption capabilities was examined. findings reveal that when the nano polymers proportion is raised from 2 percent to 4% in the presence of iron oxide at 2.5%, an increase in the value of reflectivity is considered, as seen by the results. For reflectivity of up to 38.0 dB at a bandwidth of (8.1-8.4 GHz) and frequency of 8.8 GHz, there is a radar waves distinct attenuation, which is restricted to a (9-9.3 GHz) bandwidth; The nanocomposite material was discovered to have strong qualities in microwave absorbing, which aided in the continual dissemination of work and radiation to weaken it, allowing the waves from the radar to be absorbed and attenuated. It can be used to absorb high-frequency radar waves with great efficiency.

Keywords: Nanocomposite, Electromagnetic Applications, Radar Absorbing Structures, Microwave Absorbing Material.

1. INTRODUCTION

Since the military radar systems introduction that can detect defense-based devices, scientists have been researching radar absorption materials (RAMs). The military sector recognizes X-band frequency radar systems for their high-resolution imaging and better target recognition [1-3]. Since the conclusion of WWII, radar-absorbent materials (RAMs) have piqued researchers' attention because to their amazing and potential applications in the field of modern stealth technologies [4].

Thin absorbent materials with high absorption efficiency, a wide absorption band, and a low weight may be called ideal and are outstanding [5]. To meet the needs of particular applications, the material having absorbing excellent properties must also have strong mechanical properties, resistance at high temperature, oxidation resistance and so on. As radar wave detecting technology advances, high-performance wave absorbers and new multi-functional wave absorbing materials are being developed across the world [6].

In the recent decade, microwave absorbers have gotten a lot of attention. Early investigations concentrated on other materials of dielectric loss, graphite, (porous, coils, and fibers) of carbon [7-12]. The proportion of electromagnetic radiation that a material blocks as it passes through it is known as its shielding efficiency (*SET*). A wide range of materials may be affected by electromagnetic radiation.

A component of the force, denoted by *PR* and *PI*, is reflected, while another force portion, denoted by *PR* and *PI*, is dissipated and absorbed by the materials' front face, leaving the remaining force (*PT*) to be transmitted through the shielding material [13-17]. This suggests that the entire attenuation is the product of three distinct processes: numerous internal interactions (*SEM*), absorption (*SEA*), and reversal (*SER*) [18, 19].

$$SET = 10\log\frac{p_1}{p_2} - 20\log\frac{E_1}{ET} - 20\log\frac{H_1}{HT} \quad (1)$$

$$SET = SER + SEA + SEM \quad (2)$$

where, *T* stands for transmitted, *R* for reflected, and *I* for incident, while *P*, *E*, and *H* stand for energy intensity, electric field, and magnetic field respectively [18]. As a result, *SER* standing for net interaction and reflects SEA's protection against uptake. Because of the influence of the output interface (secondary interactions), the SEM may be ignored, and the formula can be expressed as [18]:

$$SET = SER + SEA \quad (3)$$

A shields of electromagnetic interference primary mechanism is interaction (*SER*). Echo loss is the relative impedance mismatch between the shielding material surface and the EM waves. The response loss may be calculated using [20, 21]:

$$SER = 20\log\frac{z^o}{4z_{in}} = 39.5 + 10\log\frac{\sigma}{2f\pi\mu}\,\alpha\,\frac{\sigma}{\mu} \quad (4)$$

As z^o refers to the overall conductivity, f is frequency, and μ is the relative transmittance. *SER* is the material's conductivity and permeability function (μ), i.e., $SER\, f(\sigma/\mu)$. Therefore; constants μ and σ, the *SER* lowers with frequency. As a result, materials that reflect electromagnetic radiation must include mobile charges carriers (electrons or holes) [22].

Absorption loss is a supplementary technique for electromagnetic interference prevention (*SEA*). According to the plane wave theory [21], the electromagnetic wave amplitude decreases considerably when it moves through the matter. As a result, absorption losses are created by material heating and losses of ohmic caused by the currents generated. For materials having conductivity nature, the loss of absorption (*SEA*) in decibels (dB), is expressed as follows [18]:

$$SEA = 20\log e_a^{\alpha} = 8.7d\sqrt{df\,\pi\sigma\mu\alpha} \tag{5}$$

As constants d and a are for thickness and slab attenuation, respectively. The amount by which the strength of an electromagnetic wave is weakened when it travels across a material is determined by a constant called the constant of attenuation. *SEA* depends on electrical conductivity (σ), transmittance (μ), and sample thickness (d), [23]. When shielding is accomplished via the process of adsorption rather than interaction, this reliance on and indicates that shielding in metals that are conductive ferromagnetic is done. Furthermore [24]:

$$\alpha = \frac{4\pi n}{\lambda_o} \tag{6}$$

where, λ_0 is the length of wave in vacuum and n refers to the index of refractive, and μ-1 is given for non-magnetic materials. thus [18],

$$\alpha = \frac{4\pi\varepsilon_2^1}{\lambda_o} \tag{7}$$

2. EXPERIMENTAL PART

A unique nano co-polymer was employed and developed as an electromagnetic radiation absorbing materials for radar applications. In this work, which included:

2.1. Polymeric Nano Material Preparation

The following steps were used to prepare the nano co-polymer in the ratio of 5:2: at a temperature of 110 degrees Celsius, phthalic anhydride of 740.5 gr, or 5.0 moles were dissolved in 65 ml of DMSO. When the combination turned into a transparent solution, glycerol of 184 grammes, or 2.0 moles were added to the round-bottom flask with a capacity of 250 ml. For the suspension solution, p-Xylene of 15 ml was dropped in batches over 15 minutes to remove any water molecules generated during the esterification process. Filtration was used to capture the solid white precipitation. A wide range of TEM, AFM, ^{1}H-NMR, and FTIR methods were used to study the co-polymer of these nanoparticles [25-27].

2.2. Different Mixtures Proportions Preparation

Heat resistance paint and polymeric material weights and ratios are shown in Table 1. The mixes were made according to the information listed in the table, as well as the mixing weights and ratios of the thermal dye and polymeric material that were utilized based on 20 grams.

2.3. Specimens

It was decided to make steel pieces that were (10.5×10.5) centimeters in size. The surface is cleaned, smoothed, and polished using emery papers to get it ready for the pigment, as well as to remove any dirt, dust, oxides, or sediments that could have been on it. This process was similar to how vehicle painters prepare the surface before painting it. In accordance with the standard protocol followed by scientific sources, the surface was cleaned using either acetone or alcohol. After the cleaning procedure, a primer from (Wurth, Germany) was used as a base layer primer to boost the adhesion. This was done after the washing process. Following the step of combining the nanomaterial with the thermal dye in order to dilute the paint, the paint was sprayed with the addition of thinner before being applied.

Table 1. Heat resistance paint and polymeric material weights and mixing ratios

Mixture No.	Nano Polymer Weight %	Nano Fe_3O_4 Weight %	Nano Polymer Weight (gr.)	Nano Fe_3O_4 Weight (gr.)	Paint Weight (gr.)	Total Mixture Weight (gr.)
Paint only	-	-	-	-	-	20
1	2%	2.5%	0.4	0.5	19.1	20
2	4%	2.5%	0.8	0.5	18.7	20

3. RESULTS AND DISCUSSION

3.1. Nano Co-Polymer Characterization

Figure 1 reveals the diagram of FT-IR, at 3055 cm^{-1} weak broadband is shown caused by the bond of hydrogen and because of the compensation on the aromatic ring that occurs on both sides, the firmness emerges at 897 and 734 cm^{-1}. The esteric (C-O) bond having a strong sharp crest at 1069 cm^{-1}. The riding bundles at 2992-2871 cm^{-1} belongs to the symmetric and asymmetric (C-H) bond and the alcoholic (O-H) bond as it revealed a riding band at (3057 cm^{-1}) as a result of the aromatic (C-H) bond, and a strong riding bundle at (1770 cm^{-1}) emerges back to the Isterian (C=O) band, and riding bundles at 1495-1584 cm^{-1}. It corresponds to the (C=C) aromatic. At 13.12 ppm, to understand the single signal of the distinctive proton in carboxylic acid group, see Figure 2 (^{1}H-NMR spectrum).

In the region of 7.48-7.79 ppm, the multiply is a result of all aromatic ring protons, while the signals at 3.68-3.66 ppm and 4.26-4.28 ppm of methyl protons are attributed to the copolymer's methyl protons, respectively. The signal of aliphatic alcohols', on the other hand, has vanished, suggesting that this is a copolymer. The exterior surface of the copolymer nanoparticles is illustrated by the AFM images (Figures 3a and 3b). The surface roughness modulus of the copolymer was measured to be 22 nm, and its square root was equivalent to 26.6 nm. This lends credence to the idea that the black side of nanoparticles plays a key role in the regular crystal structure, surface uniformity, and surface quality. In addition, the typical height of the particles was 106.37 nm on average.

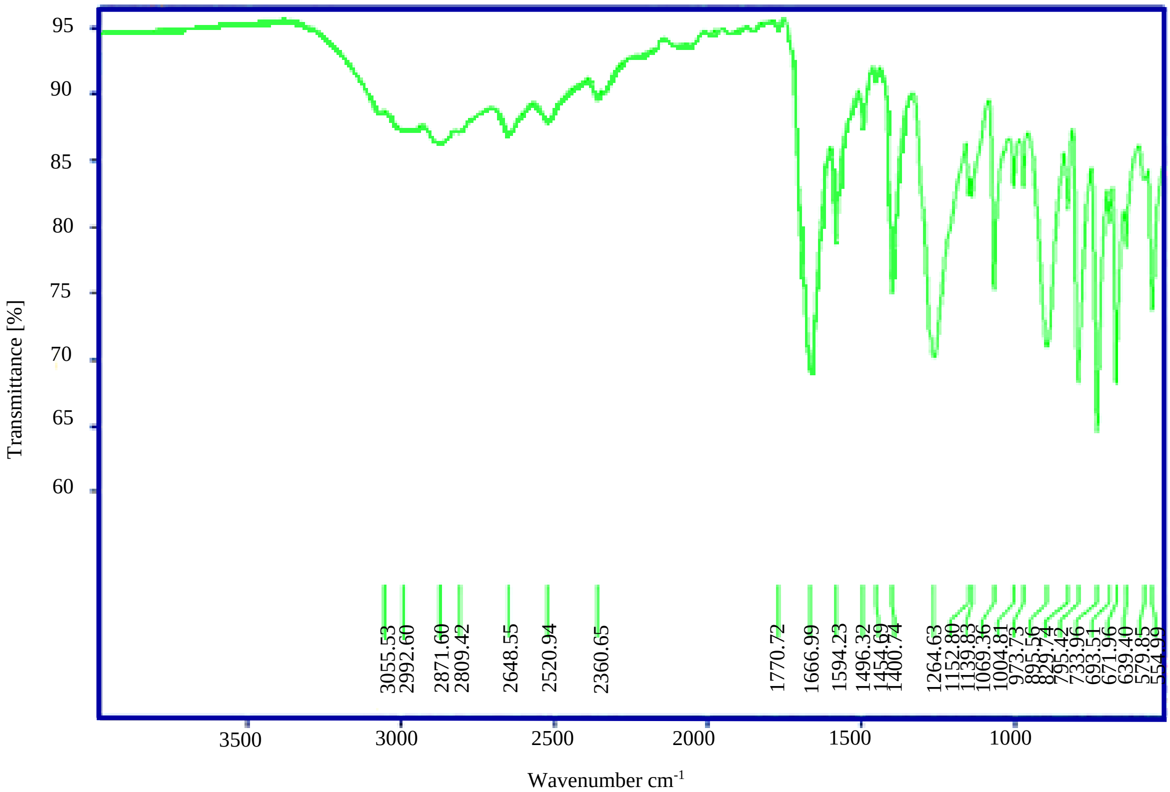

Figure 1. Nano co-polymer FT-IR

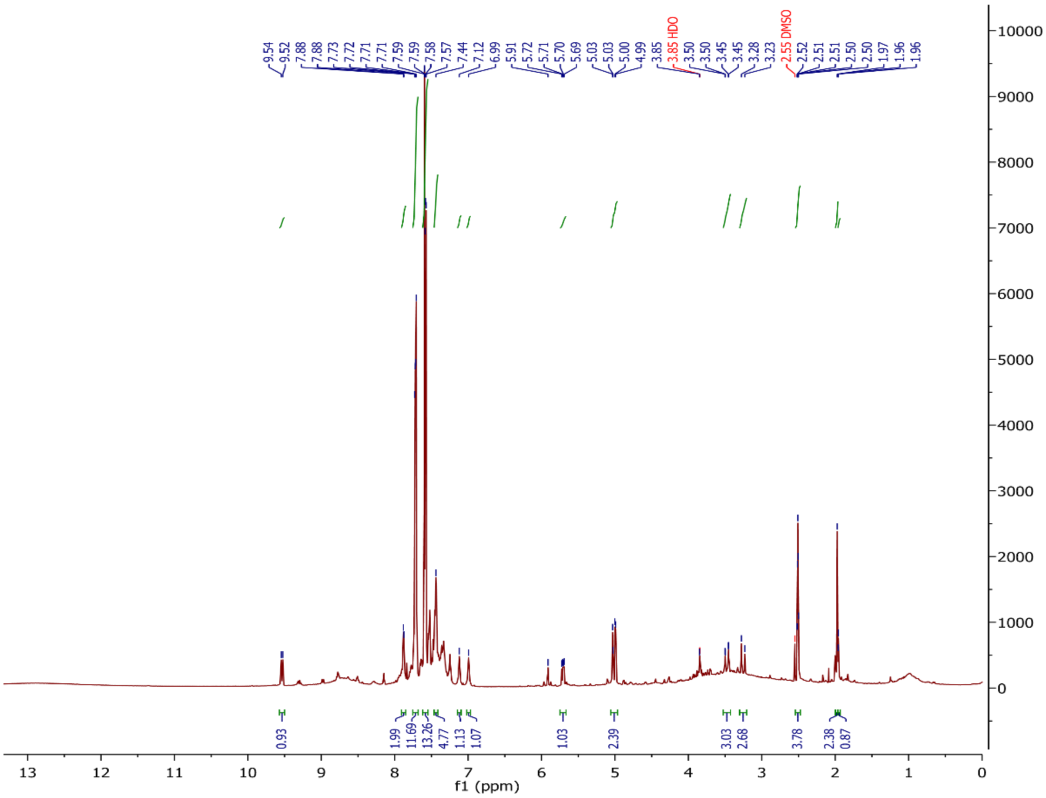

Figure 2. [1]H-NMR Spectrum

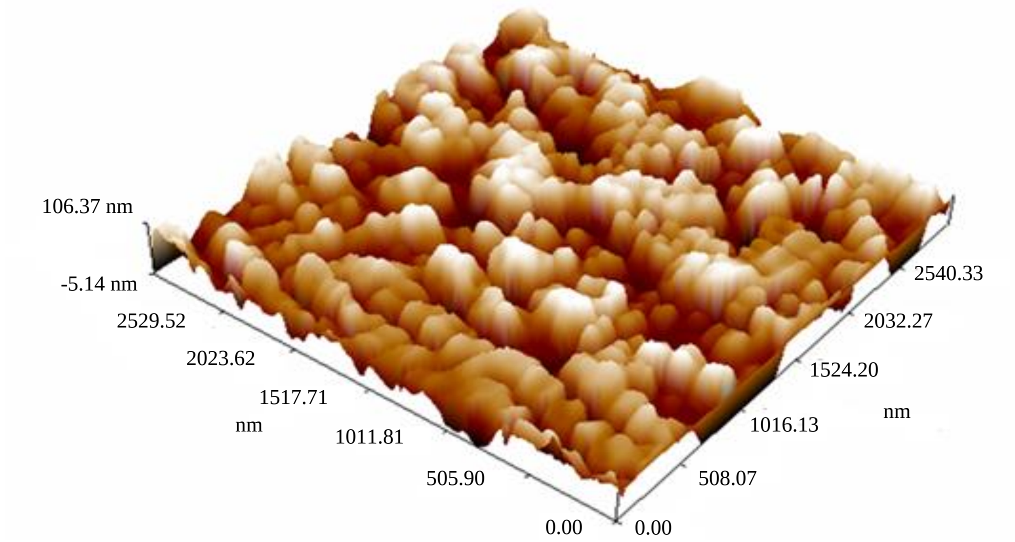

Figure 3. (a) 3D AFM Image

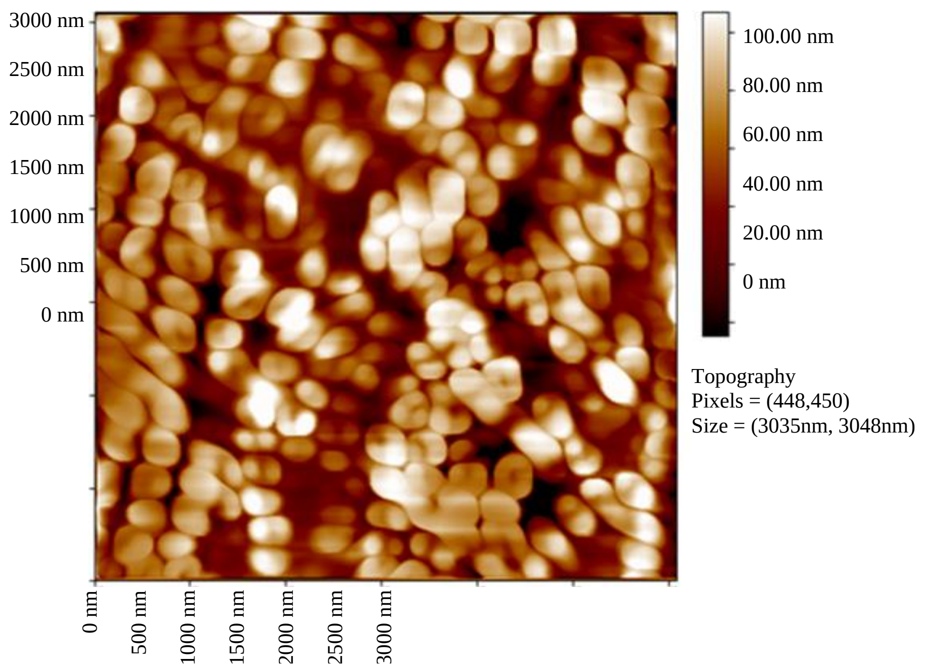

Figure 3. (b) 2D AFM Image

The particle size distribution of nano co-polymer is shown in Figure 4. The nanoparticles TEM micrographs of nano co-polymer having uneven layer-shaped particles of varied shapes and sizes on a shape of semi-sphere are shown in Figure 5. It was discovered that the nanoparticles of the co-polymer had an average size of 106.37 nm [28].

3.2. Reflectivity Loss

For samples manufactured with the device of radar wave attenuation and tested inside at 8-12 GHz (x-band), the frequency was evaluated with reflectivity loss. Figure 6 illustrates the relationship without coating between frequency and the reflectivity loss. When the nano polymer added to the coating is 2 percent, it reaches a value of 24.64 dB at a frequency of 8.3 GHz, which is equal to 0.4 gram, as shown in Figure 7, when there are 2.5% iron oxide nanoparticles present.

At different frequencies, other magnitudes of the energy loss reflection can be found. When the nano polymers percentage is raised to 4%, i.e. 0.8 gram, with the presence of iron oxide at 2.5% to the thermal coating (heat resistance paint), a dramatic rise in the loss magnitude of reflectivity is observed.

Figure 8 illustrates the reflectivity up to 43.44 dB at a bandwidth of (8.1-8.4 GHz). As a consequence of these findings, it was discovered that the nanocomposite material had strong absorbing microwave waves properties in, which assisted in the continuous radiation dissemination and worked to weakening it, also helped attenuate and absorb the waves of radar [29, 30].

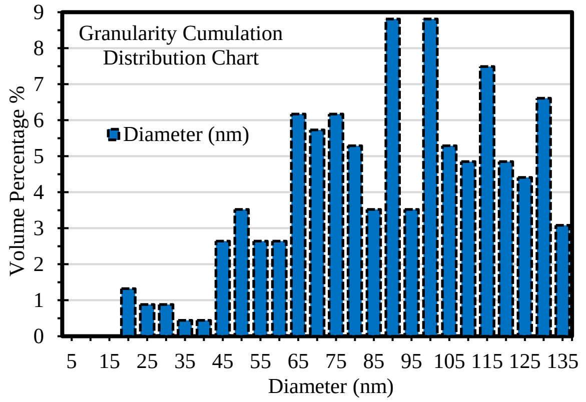

Figure 4. particle size distribution

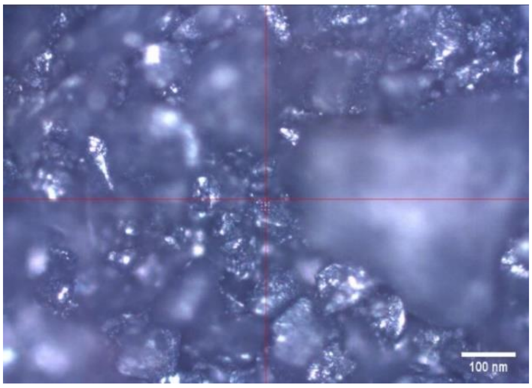

Figure 5. Nanoparticles co-polymer TEM micrographs

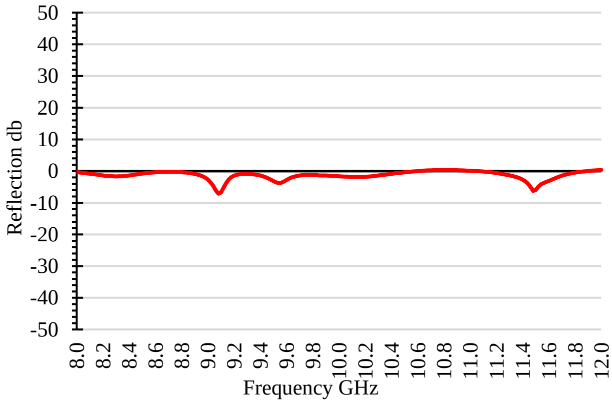

Figure 6. Frequency vis reflectivity at (0%) nano polymer

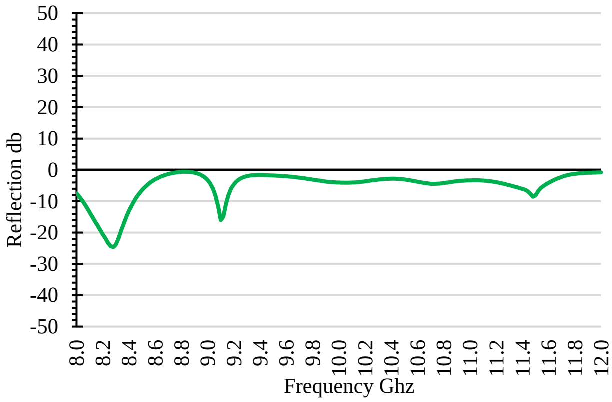

Figure 7. Frequency vis reflectivity at (2%) nanopolymer

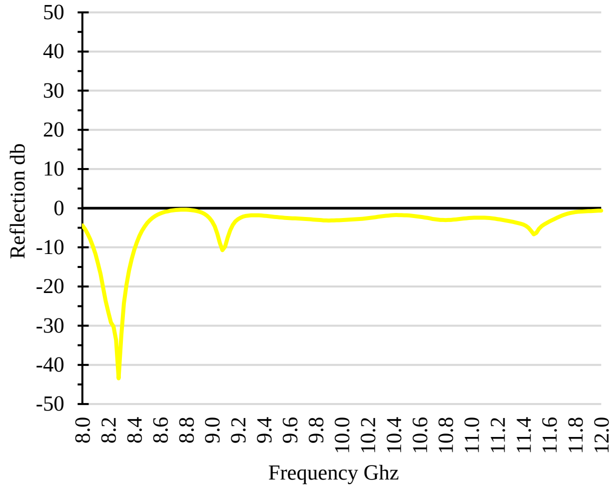

Figure 8. Frequency vis reflectivity at (4%) nano polymer

4. CONCLUSIONS

Condensation polymerization of glycerol and phthalic anhydride yielded a nanoparticles copolymer that was effectively melted utilizing the melting procedure by condensation polymerization. The dark side of nanoparticles clearly plays an important role in a regular crystal system, surface homogeneity, and surface finish quality as shown by the AFM images of nano co-polymers. These copolymer nanoparticles have an average particle size of 106.37 nm, which was determined from the images of the TEM micrographs of the uneven layer-shaped particles. The reflectivity loss value increases dramatically when the nano polymers proportion is increased to 4% and the iron oxide content is 2.5%. Researchers discovered that the nanocomposite material has excellent microwave absorption qualities, which helped to keep the radiation dispersed and weaken it, allowing it to be more effectively used to absorb and attenuate radar waves.

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