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Polymer–$CoFe_2O_4$ Nanocomposites as Flexible Microwave-Radiation Absorbing and High Corrosion Resisting Coating Materials for Biological Applications

Naheda Humood[1], Eman Hammod Abdullah[2], Shahid M. Abu Alais[3], Farhan Lafta Rashid[5], Aseel Hadi[5], and Ahmed Hashim[2]

[1]*College of Dentistry,*
Department of Physics,
University of Babylon,
Babylon, Iraq
[2]*College of Education for Pure Sciences,*
Department of Physics,
University of Babylon,
Babylon, Iraq
[3]*Department of Mechanical Engineering,*
University of Kerbala,
Kerbala, Iraq
[4]*College of Engineering,*
Department of Petroleum Engineering,
University of Kerbala,
Kerbala, Iraq
[5]*College of Materials Engineering,*
Department of Ceramics and Building Materials,
University of Babylon,
Babylon, Iraq

In this paper, nanocomposites made with different contents of $CoFe_2O_4$ nanoparticles and polymer for electromagnetic-wave absorbing coatings and corrosion resisting for environmental applications are investigated. The nanocomposites are prepared as coating materials on aluminium plates with low cost and low weight. The microwave-absorption and corrosion-resistance properties are studied to fabricate the materials having high corrosion resistance and high attenuation for microwaves. The microwave absorption is studied within 8–12 GHz range. The results show that nanocomposites have excellent attenuation for microwaves and high corrosion resistance (improved by 97.7% in comparison with aluminium).

У даній роботі досліджуються нанокомпозити, виготовлені з різним вмістом наночастинок $CoFe_2O_4$ та полімеру, для покриттів, що поглинають електромагнетні хвилі, та захисту від корозії для екологічних застосувань. Нанокомпозити готуються як матеріяли для формування покриття на алюмінійових пластинах з низькою вартістю та низькою вагою. Властивості мікрохвильового поглинання й антикорозійної стійкости вивчаються задля виготовлення матеріялів, що мають високу корозійну стійкість і високе загасання для мікрохвиль. Мікрохвильова абсорбція вивчається в діяпазоні 8–12 ГГц. Результати показують, що нанокомпозити мають відмінне загасання для мікрохвиль і високу антикорозійну стійкість (поліпшену на 97,7% у порівнянні з алюмінієм).

Key words: nanocomposites, corrosion resistance, microwave absorption, attenuation.

Ключові слова: нанокомпозити, корозійна стійкість, поглинання в надвисокочастотному діяпазоні, загасання.

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1. INTRODUCTION

In current days, with the increase of knowledge and recent life approach, the problems effected by more experience to electromagnetic waves contain become more and additional serious attributed to growing of electromagnetic waves applications in local area networks, mobile phones, personal computers, television picture interference of high increase buildings, *etc*. Finding of microwave radiation may be damaging to biological structures like rising the rate of heart, weakening immune responses, DNA damage in cells of brain [1], *etc*. To shelter from these dangerous electromagnetic radiations, there are needs of improvements in materials for microwave absorption with suitable thickness, low cost, high efficiency, low weight, high stability, flexibility, physical and electromagnetic comparability. Materials of magnetic and ferrite nanoparticles of jumbled spinel ferrite absorber is used related to its high resistivity, mechanical hardness, low dielectric loss, chemical stability and high Curie temperature. The microwave absorbing performance depends typically on magnetic loss and dielectric loss of materials. Moreover, upper limit of materials for electromagnetic wave absorbing are predictable to contain wide absorbing band board, low density, strong absorption capability, strong absorption capability and thin absorber. Lately, the nanocomposite of dielectric nanomaterials has been believed as effectiveness to develop the properties of microwave absorbing.

The nanocomposites are able to get not only the complementarity between magnetic and dielectric loss, but, moreover, other chemical and physical properties [2]. It is suggested to select a suitable permeability–permittivity, as needed. Among these substances, magnetic nanoparticles of ferrites are of huge attention in primary sciences, particularly for addressing the primary relations between properties of magnetic and its crystal structure and chemistry [3]. Materials of ferrite display different magnetic and electrical properties of which complex permittivity and permeability, in special, are significant in limiting their huge frequency properties [4]. Cobalt ferrite is known material as inflexible magnetic with an equinoctial saturation magnetization and high coercivity. These properties make the $CoFe_2O_4$ nanoparticles as appropriate for EM absorbing, magnetic recording applications such as high-density digital recording disks, videotapes and audio [3], *etc*.

Metal corrosion is one of the most important subjects faced by industries worldwide number and different coatings types are applied to control it. Recently, different non-chromate coatings, materials of polymer coating were improved as coatings for protection of corrosion. However, in neat polymeric coatings, there are small defects can extend pathways for types of corrosive to permeate and effect in local corrosion to the metallic material. Currently, as an alternative, different nanosize inorganic additives are added to the polymeric matrix to produce a chain of coatings for corrosion protection from organic–inorganic hybrid [5].

The organic–inorganic nanoparticles or nanocomposites have huge applications in various branches such as energy storage [6–11], sensors [12–19], antibacterial activity [20, 21].

The study of electrical, electronic and optical properties of nanocomposites showed that enhancement the properties of polymer or polymer blend by adding of microparticles or nanoparticles [22–34].

2. MATERIALS AND METHOD

The coating materials were prepared with various ratios of commercial polymer as an adhesive material (low cost) and cobalt ferrite nanoparticles (high purity 99.9%, 30 nm, US Research Nanomaterials, Inc., USA). The cobalt ferrite ($CoFe_2O_4$) added to adhesive material with various ratios: 5, 10, and 15 wt.%. The aluminium plates were coated by polymer–$CoFe_2O_4$ nanoparticles with thickness (1 μm).

The microwave absorption is studied within 8–12 GHz range. The impedance of microwave for sample, Z, and the reflection loss, RL, are determined using [35]:

$$Z = Z_0\sqrt{\frac{\varepsilon_r}{\mu_r}}\tanh\left[i\left(\frac{2\pi ft}{c}\right)(\varepsilon_r\mu_r)^{1/2}\right], \tag{1}$$

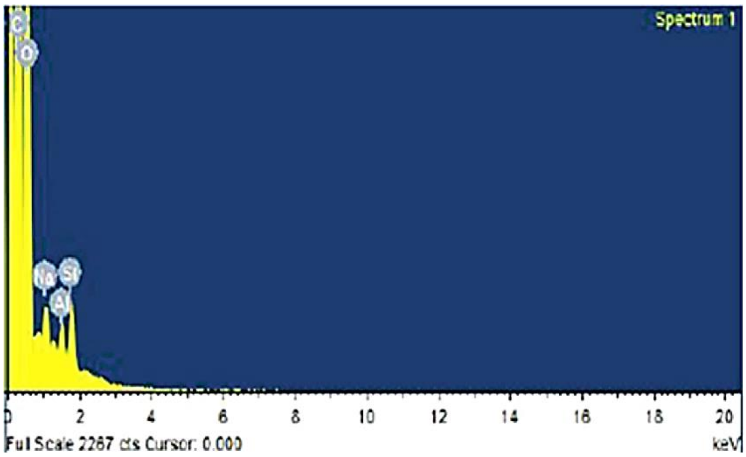

Fig. 1. EDS of adhesive polymer.

$$RL = 20\log\left|\left(Z - Z_0\right)\left(Z + Z_0\right)\right|, \quad (2)$$

where μ_r and ε_r are the relative permeability and relative permittivity; c—speed of light, f—wave frequency, and t—thickness. For the case of metal-backed samples, Z and RL may be obtained from the coefficient of complex reflection scattering S_{11} [35]:

$$Z = Z_0\left(1 + S_{11}\right)\left(1 - S_{11}\right), \quad (3)$$

$$RL = 20\log\left|S_{11}\right|. \quad (4)$$

Figure 1 shows the EDS of adhesive polymer.

3. RESULTS AND DISCUSSION

Figure 2 represents the reflection losses of polymer–$CoFe_2O_4$ nanocomposite–aluminium with frequency at thickness of 1 μm of polymer–$CoFe_2O_4$ nanocomposite coating. According to results, polymer–$CoFe_2O_4$ nanocomposite–aluminium absorbs microwave irradiation with high rate. The large board microwave absorption of the polymer–$CoFe_2O_4$ nanocomposite–aluminium are created from suitable multiple scattering; impedance matching and interfacial polarization causes more microwaves' attenuations [36].

Figure 3 explains the corrosion current with ratios of $CoFe_2O_4$ nanoparticles. As shown, the polymer–$CoFe_2O_4$ nanocomposite film on aluminium can be acted as a physical barrier improving the corrosion resistance [37]. The corrosion resistance is improved by 97.7% in comparison with aluminium.

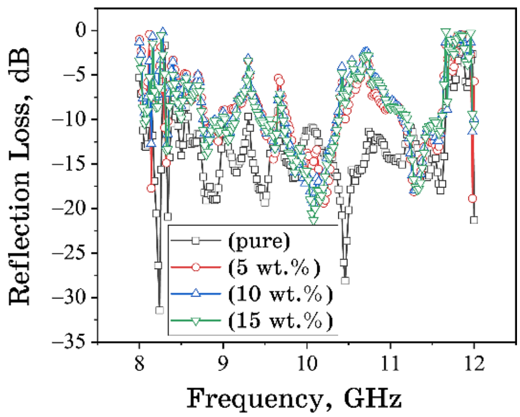

Fig. 2. Reflection losses of polymer–$CoFe_2O_4$–aluminium with frequency.

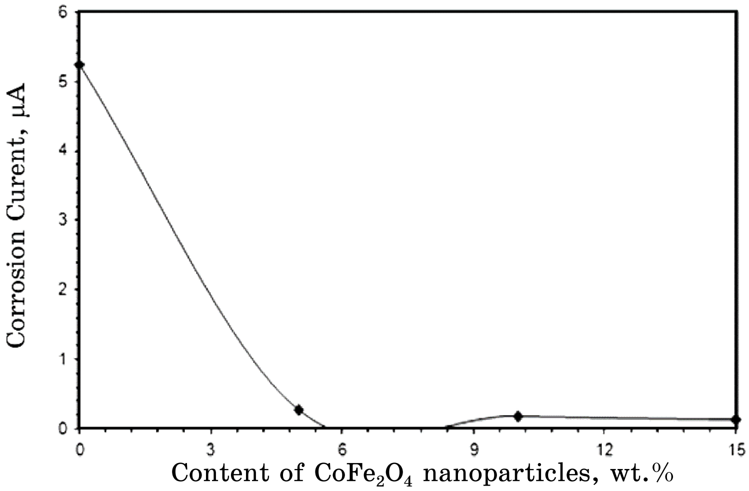

Fig. 3. Corrosion current with ratios of $CoFe_2O_4$ nanoparticles of polymer–$CoFe_2O_4$ film on aluminium plates.

4. CONCLUSIONS

There are high reflection loss of polymer–$CoFe_2O_4$ coated on aluminium plates and high absorbance for microwave irradiation.

The polymer–$CoFe_2O_4$ nanocomposite adds the reflection loss of aluminium and high microwave attenuation.

The corrosion resistance is improved by 97.7% in comparison with aluminium.

The corrosion current reduces as $CoFe_2O_4$ ratio is rising.

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