

The Effect of Ferrite Content on the Thermomechanical and Dielectric Strength Properties of Epoxy Composite

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ABSTRACT

Different concentrations of cadmium ferrite (2%, 5%, 8%, 10% and 15%) were incorporated into epoxy resin. Cadmium ferrite was prepared by conventional ceramic technique. Composites are prepared by mixing the ferrite with epoxy by hand lay - up method at different percentages. The effect of ferrite content on tensile strength, hardness, thermal properties such thermal conductivity, thermal diffusivity and specific heat beside the dielectric strength were investigated. Using ferrite powders as filler to form particulate composite could lead to composite properties improvement. All the measured properties were improved with the increasing of the filler content. The results showed the important role of perfect adhesion between the filler and the polymer on the composite properties. It is found that the uniform distribution of filler particles in all directions of composite leads to the improved properties.

Keywords: Cadmium ferrite, mechanical properties, composites, thermal conductivity, thermal diffusivity, dielectric strength.

تأثير التقوية بالفرايت على الخواص الحرارية و الميكانيكية ومقاومة العزل لمتراكبات الايبوكسي

الخلاصة

تراكيز مختلفة من الكاديوم فرايت (2%، 5%، 8%، 10%، 15%) ادرجت في راتنج الايبوكسي. الكاديوم فرايت اعد بتقنية السيراميك التقليدية. المتراكبات تم تحضيرها عن طريق خلط الفرايت مع الايبوكسي بالطريقة اليدوية وبنسب مختلفة. تم دراسة تأثير محتوى الفرايت على خواص الشد والصلادة والخواص الحرارية مثل التوصيلية الحرارية، الانتشار الحراري، الحرارة النوعية بالإضافة الى مقاومة العزل. استخدام مساحيق الفرايت كتقوية لتكوين المتراكبات ادى الى تحسين خواص هذه المتراكبات. جميع الخواص التي تم قياسها تحسنت مع زيادة محتوى التقوية. اظهرت النتائج الدور المهم للالتصاق ما بين التقوية والبوليمر على خواص المتراكبات. وقد وجد ان التوزيع المنتظم لدقائق الحشوة في جميع اتجاهات المتراكبات يؤدي الى تحسين الخواص.

INTRODUCTION

In the recent information oriented society, the number of communication device that utilize GHz- range microwave radiation has shown a great increase because of their high data transfer rates [1]. To prevent problems arising from electromagnetic interference (EMI), microwave absorbers using spinel- type ferrite [2].

As a result of fast development of mobile communications industry, the importance of reduction of (EMI) between electromagnetic wave radiating system (mobile phone, Bluetooth devices etc.) among the candidates for such applications soft magnets, polycrystalline spinel or hexagonal ferrites and ferrite- epoxy composite [3, 4].

Epoxy resins are widely used in many applications due to their superior adhesion, high strength resistance to creep, heat and chemicals [5, 6].

Cadmium ferrite is antiferromagnetic with a normal spinel structure. It is used in ferrite core, transducers, electromagnetic wave absorbers, magnetic recorder, drug delivery, magnetic fluids and magnetic resonance imaging etc. [7]

Addition of fillers into polymer materials is a common industrial practice. Filler can change properties of composite and create new materials. Filler volume fractions, filler size and shape and interaction between matrix and filler size, have affect the mechanical properties of the composite [8, 9]

Ferrite powder polymer composite has been used extensively in the suppression of electromagnetic noise and embedded induces components due to their superior electromagnetic properties [10, 11].

Dosoudil et al. have studied the effect of frequency dispersion of complex permeability for ferrite-polymer composite material in the range 1 KHZ- 1 GHZ which decreased as the particle size of the ferrite decreased [12].

Abbas et al. have prepared a composite materials of polyurethane with hexaferrite at different percentages, all the dielectric parameters ϵ , ϵ_r and u are found to increase with increasing ferrite content. The composite with 80 vol. % ferrite content has shown a minimum reflection loss of -24.5 dB (99%) [13].

George et al. found that the grain size and porosity of the ferrite filler play a vital role in determining the mechanical properties of the polymer composite [14].

Santiago et al. have found that a proof principal all optical magnetometer has been constructed based nanocomposite materials. Noise equivalence magnetic field sensitivity was observed using 3 ut/ 500 Hz control magnetic field [16].

Park et al. used a cold- pressing technique for fabrication composite of a PTFE (polytetrafluoroethylene) polymer matrix and a wide range of volume fraction of MnZn ferrite. They found that the electromagnetic properties of all prepared composite exhibit good reproducibility and has a high permittivity and good permeability [17].

Raju and Murthy found that the electrical and magnetic properties of the NiZn ferrite- polymer composite depend on the site, shape and amount of the addition. The complex permittivity and permeability were measured over a wide frequency range (1 MHz- 1.8 GHz) at room temperature both of them decreased with an increase of polymer content [18].

The aim of this work is to study the effect of cadmium ferrite content on the mechanical, thermal and dielectric strength properties of ferrite- epoxy composites.

Experimental part

Materials used

The materials which used in the research were Epoxy resin (Euxit 50 KI), hardener (Euxit 50 KII) and prepared Cadmium ferrite from Cadmium oxide and Ferric oxide.

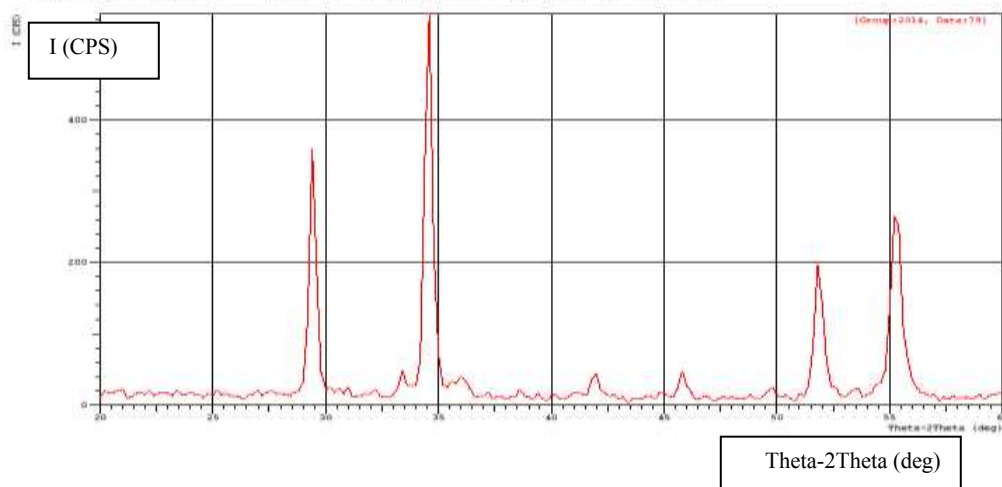
Procedure

Mixing of CdO: Fe₂O₃ stoichiometry for 2hrs and compacted 3 into pellets under 38MPa pressure. Calcination process was carried in a muffle furnace at temperature of 1100°C for two hrs. with 10 °C/min as heating and cooling rate. X- ray diffraction has been used to identify the prepared cadmium ferrite.

The ferrite was milled for fine powder. Epoxy resin is mixed with hardener in ratio of (3:1). Different weight percentages of ferrite powders were mixed thoroughly with the resin using hand lay-up method the good mixture is poured in to the molds slowly in order to avoid air trapping. Samples were left to solidify at room temperature for 24 hrs. The sample was cut in to different shapes due to the characterization such thermal test, hardness and tensile strength beside the dielectric test. The hardness test is performed by using hardness (Shore D) and according to (ASTM DI-2242) standard. Samples have been cut into a diameter of (40mm) and a thickness of (5mm). The tensile test performed according to (ASTM D638) at room temperature with capacity (20KN) applied load and strain rate of (0.5 mm/min) by using the machine type WDW-200E. For study The thermal properties test, two samples with the same dimensions have been prepared according to the standard specifications of instrument (3x2)mm, one of the most precise and convenient techniques for studying thermal transport properties is the transient plane source (TPS) method. It is a modern technique, yielding information on thermal conductivity, thermal diffusivity as well as specific heat per unit volume of material under study. The dielectric strength is performed by the impedance analyzer device.

Results and Discussion

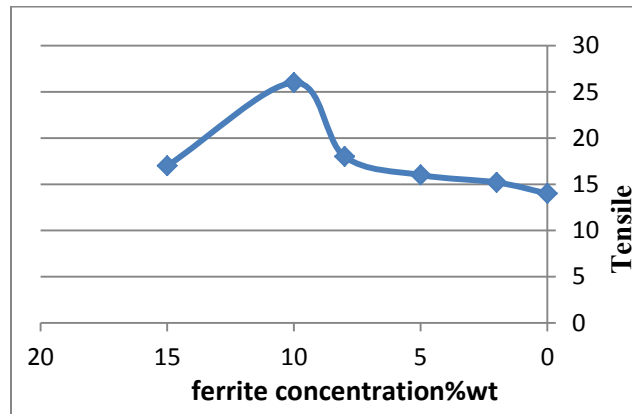
X-ray diffraction patterns of cadmium ferrite sintered at 1100°C under investigation is presented in Fig.1. The XRD confirms the formation of single phase cubic spinel structure. The presence of (220), (311), (422), (333) and (400) planes were observed. The XRD pattern agree with JCPDS card number 02-0975 and no impurity phases were detected in the XRD pattern.



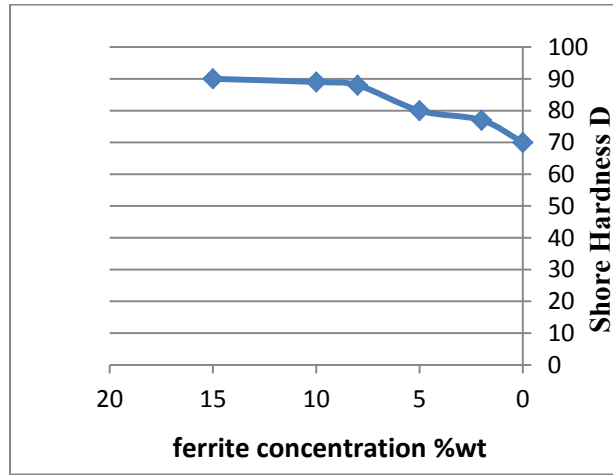
Figure(1) XRD of cadmium ferrite.

Fig. 2 shows the tensile strength of composite reinforced with different concentration of cadmium ferrite. The tensile strength of a filled polymer is more difficult to predict because it depends strongly on the local polymers filler interaction. The result indicated that the tensile strength increases with increasing the concentration of ferrite. The optimum tensile strength is obtained at 10% with an increasing of 27% compared to the non-filler epoxy. The incorporation of cadmium ferrite as filler addition actually is associated with the improvement of tensile strength. The effect of good interface between the ferrite and epoxy is very important to the material to stand the stress [18]. When load is applied, the matrix will distribute the force to ferrite which carry most of the applied load. As for that, the lower value of tensile strength at lower filler content is due to the flaws created by the filler added. This flaw acts as stress concentration and cause the bond between

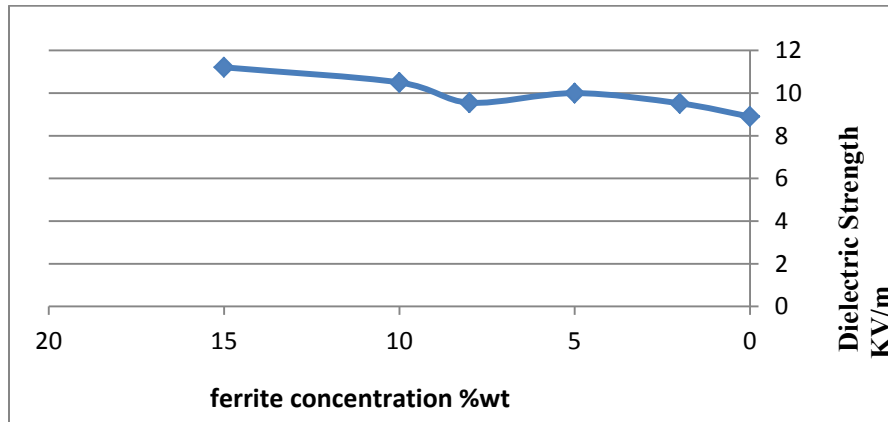
the filler and matrix to break [18]. The behavior also predicted with the result of shore hardness as shown in Fig. 3, where the highest value also at 10%. Fig. 4 shows the dielectric strength as a function of the amount of addition. It was confirmed that the dielectric strength is increased with increasing of ferrite content. The dielectric strength influenced mainly by the surface area of the filler. As the filler concentration increased, surface area also increases and results in low resistivity. This is due to the large surface area which leads to a short aggregate distance. In addition it has been reported that dielectric strength is partially associated with the degree of cross linking. Fig. 5 displays the thermal conductivity with different filler content. At increasing the ferrite content the thermal conductivity of composite increased having the maximum value at 8% then decreased. For understanding the mechanisms behind the above results, it is of great importance to elaborate about the phonon conduction mechanisms. There are several factors that affect the phonon conduction inside the composite such as: number of phonon active mode, damping of phonon vibrational amplitude, the length of the mean free path of the phonon [19]. Fig. 6 demonstrates the dependence of thermal diffusivity of composite with different filler concentration. It is apparently seen from the plot that the thermal diffusivity is linearly increasing with the filler content until 5% of ferrite content and then decreased sharply with the content ratio. This seems to follow thermal conductivity trend. This behavior may be due to the structural defects that exist in the amorphous behavior of matrix and acts as thermal resistant by stray scattering of phonons. The obtained values above of thermal diffusivity are affected by several factors, e.g heat losses or temperature-dependent and physical properties. Fig. 7 shows the experimental results of the specific heat of the composite. At increasing the ferrite contents the specific heat is increased linearly having the highest value at 15%. The specific heat was depended on the mass and shape of the composite samples and increased with the increasing of the temperature. So the composite shows increasing trend of specific heat.



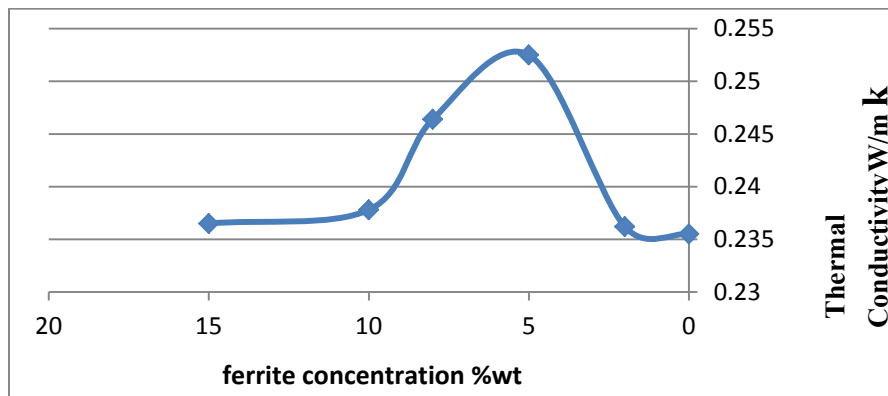
Figure(2) Tensile Strength of composites and epoxy.



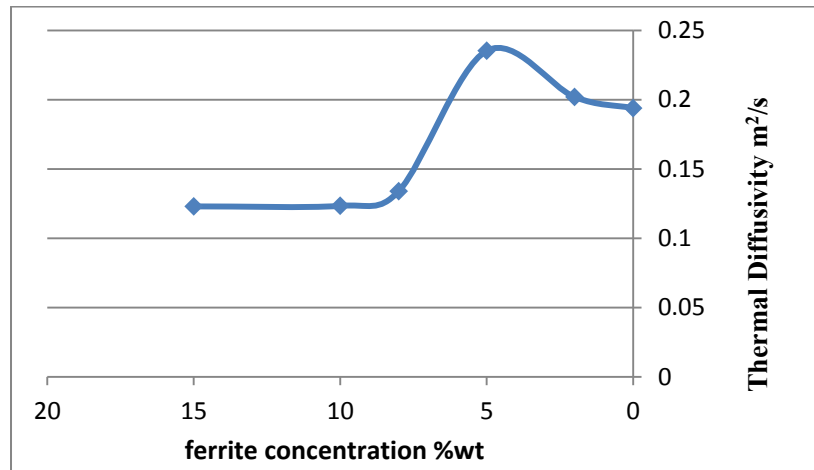
Figure(3) Shore Hardness V(D) of composites and epoxy



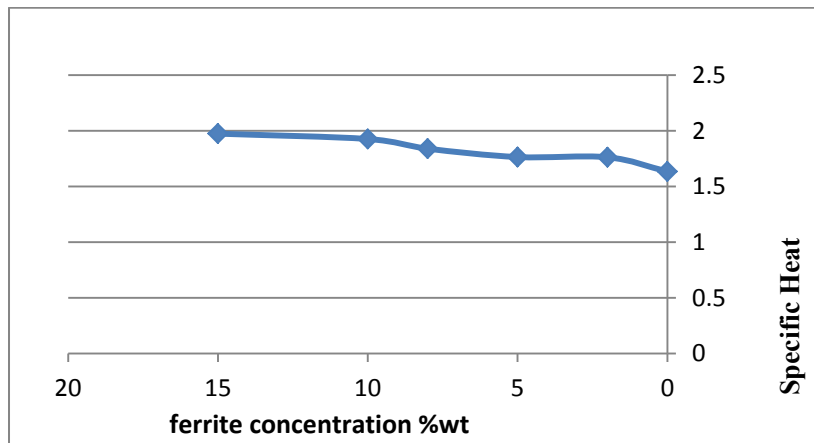
Figure(4) Dielectric Strength of composites and epoxy.



Figure(5) Thermal Conductivity of composites and epoxy.



Figure(6)Thermal Diffusivity of composites and epoxy



Figure(7) Specific Heat of composites and epoxy.

CONCLUSIONS

From the results above, the following remarks can be concluded:

- 1- The mechanical properties of composite show that the tensile strength as well as hardness increased by increasing filler content. This increase is attributed to the improvement of interfacial bonding between filler and epoxy.
- 2- The thermal properties indicate that the increase of filler concentration yielded significant increase in the thermal conductivity and thermal diffusivity.
- 3- Addition of ferrite improved the dielectric strength of the composite due to the uniform crystal size distribution.

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