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The effect of Finemet Amorphous alloys on EMI shielding effectiveness of Epoxy/CNT Nano-Composite

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1- Introduction

Increasing usage of devices in commercial, military and electronic products such as computers, modems and etc. which emit the electromagnetic waves can cause noise and thermal pollution. One of the main harmful effect of electromagnetic waves is health problems such as leukemia. Shielding materials can prevent further harmful effect on nature and humans.

Three different mechanisms to shield EMI are reflection, absorption and multi-reflections. Reflection is primary EMI SE mechanism which require electrical conductivity in shield material. Scientists reported that the EMI SE increased with increasing conductivity. Second EMI SE mechanism is absorption which need existence significantly electrical and/or magnetic dipoles in shield material. In order to achieve multi-reflection (the last EMI SE mechanism), the shield material need to have remarkable interface.

Different type of materials can used as shielding material. Among them, polymer matrix composites because of low weight and high strength to weight ratio has attracted attention. In recently years, carbon materials such as graphene, graphite, carbon Nano-tubes (CNT) and Nanofibers show good shielding behavior. CNT has advantages such as high aspect ratio, low density and unique structure that can be used as fillers in polymer matrix composites which cause to improvement in mechanical and electrical properties of composites. Scientists showed dominant mechanism of EMI SE in polymer/CNT (such as polystyrene and polyurethane) is reflection. Also, in Nanocomposites shielding effectiveness value in X-band frequency (8.2-12.4 GHz) is independent of frequency and increased with increasing CNT.

In this paper, shielding effectiveness value of nanocomposites epoxy/CNT with 0.1 and 0.5% wt. reinforcement with Finemet amorphous alloys, according to WR90 standard, is investigated.

2- Experimental

For synthesis of nano-composite, Multi-walled Carbon Nano-Tubes (CNTs), Finemet Amorphous alloys (composition $Fe_{73}Cu_1Nb_3Si_{13.5}B_{9.5}$) and resin epoxy was used. In order to distribute CNT in Epoxy, acid functionalized of CNT is necessary. For this purpose, 0.1 gr CNT and 5 mL nitric acid were sonicated in ultrasonic bath for 2 h followed by mixed in magnetic stirrer at 50℃ for 2 h. Washing with deionized water to achieve pH=7 was done and the blend was dried in oven at 90℃ for 8 hours.

CNT and epoxy were mixed completely at 50℃ for 15 min followed the hardener was added to the blend (resin to hardener weight ratio 9:1) and poured the blend into mold with 1 mm thickness. After 24 h under pressure for removing gas bubbles, all samples were cut with dimension 0.4 × 0.9 inch (according to WR90 standard). Then, Finemet amorphous single layer was placed among the epoxy/CNT nano-composites with hand layup process. Epoxy/CNT 0.1 and 0.5 %wt. reinforcement with Finemet amorphous alloy were denoted by CNT0.1 and CNT0.5 respectively.

The X-ray diffraction (XRD) pattern with Cu-Kα radiation at λ=1.5404 Å in the scattering range (2θ) of 10-80° in steps of 0.1° was used to characterize the products. The magnetic property of nanocomposites was measured by vibrating sample magnetometer (VSM) test (Kashan researcher magnetic company). The microwave measurements were done by network analyzer (VNA) NA E8363B with WR90 standards according to XR90 standard.

3- Results and Discussion

Fig. 1 shows the XRD pattern of Finemet alloy which existence a wide pick at 44 degree depict that all ribbons have amorphous phase.

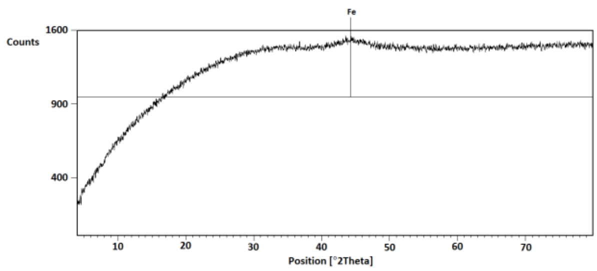

Fig. 1 X-Ray diffraction pattern of Finemet Amorphous Alloy

Fig. 2 shows the VSM test of CNT0.5 nanocomposite at room temperature. As seen, sample is soft ferromagnetic and do not resistance in changing applied field. This can be concluded that EMI SE in samples with absorption mechanism is low. Table 1 shows the magnetic parameters of CNT0.5 nanocomposite.

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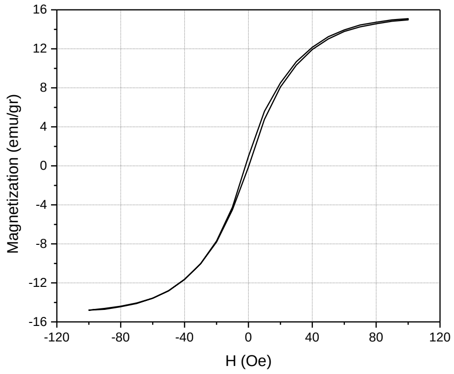

Fig. 2 Vibrating Sample Magnetometer test of CNT0.5 composite

Table 1 Magnetic characteristic of CNT0.5

Magnetic characteristic	Value
Saturate Magnetization (M_S)	16 emu/gr
Remanence (M_R)	0.9 emu/gr
Coercivity (H_e)	1.84 Oe

Fig. 3 illustrates the shielding effectiveness of CNT0.1 sample at 8-10 GHz. S11 and S12 show the reflection and shielding effectiveness, respectively. According to Fig. 3, the average S21 for CNT0.1 sample is -15 dB. Also. Dominant EMI SE is reflection mechanism which can be related to existence of Finemet amorphous alloys and CNT content.

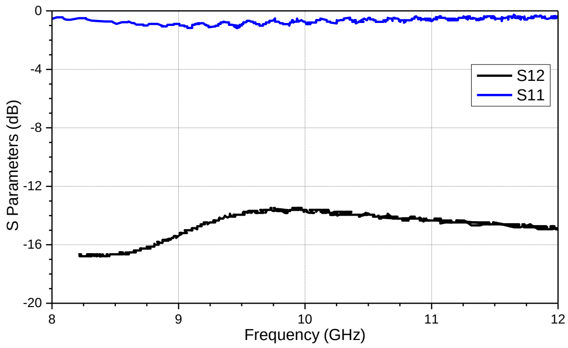

Fig. 3 Shielding Effectiveness of CNT0.1 versus Frequency

Fig. 4 demonstrates the S12 (SE) of CNT0.1 and CNT0.5 samples in frequency range 8-10 GHz. According to Fig. 4, the average S12 of CNT0.5 sample is -20 dB. As the presence of CNT in nanocomposite, the conductivity of samples increased.

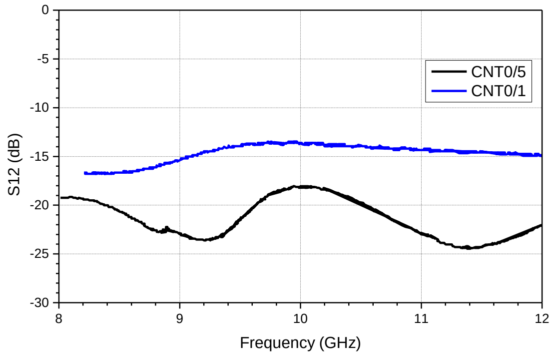

Fig. 4 Shielding Effectiveness (S12) of CNT0.1 and CNT0.5 versus X-band Frequency

Fig. 5 shows the S11 (reflection) of CNT0.1 and 0.5 sample between 8 to 10 GHz. The average S11 for CNT0.5 sample is -2 dB which is reduced in compare to CNT0.1. It can be related to increasing CNT content and EMI SE and decreasing reflection, SE is increased by other mechanisms.

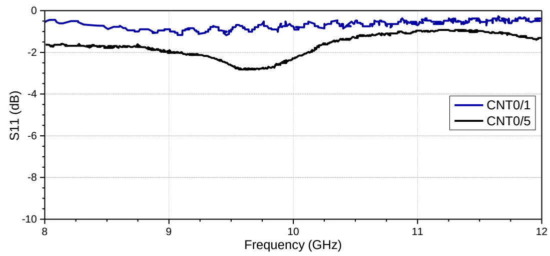

Fig. 5 Reflection (S11) parameter of CNT0.1 and CNT0.5 versus X-band Frequency

4- Conclusions

In this paper single layer Epoxy/CNT (0.1 and 0.5 wt.) reinforcement with Finemet amorphous alloy as shielding material between 8 to 10 GHz was investigated. XRD pattern shows Finemet ribbons are amorphous. VSM test was done to study the magnetic properties of samples that shows the samples have soft ferromagnetic behavior. CNT0.1 and CNT 0.5 samples reduced the power of incident wave 15 and 20 dB, respectively. Dominant mechanism in EMI SE in all samples was reflection mechanism. With increasing CNT content, EMI SE of samples was increased.