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RF Power Absorption Enhancement of Magnetic Composites with Conductive Grid

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To evaluate the electromagnetic power absorption in near field, the magnetic composites with the conductive grids were simulated using the typical permeability frequency profiles. The transmission power absorptions of the magnetic composites on microstrip line were extracted by the 3D FEM simulation program of HFSS. The magnitudes of power absorptions were greatly enhanced up to 98% and broadened the absorbing frequency band over 5 GHz by the insertion of a conductive grid in magnetic composite. The initial frequency of the power absorption can controlled by the change of the ferromagnetic resonance frequencies of the magnetic composite.

Keywords : permeability, magnetic composite, power absorption, conductive grid

1. Introduction

According to the change of the electronic environments such as the increasing the operating frequency, the miniaturization and the functionalization of the electronic devices and components, the electromagnetic interference (EMI) have been increased in near field and far field region. To reduce these complicated EMI, conduction noises and coupling between neighbor transmission signals in electronic circuits and devices, a few kinds of considerations are essential such as the volume, high resistivity, and the high magnetic loss of the magnetic materials as an EMI countermeasure materials in near field. The magnetic films and composites as an electromagnetic noise absorber have been conventionally employed [1-3]. In general, the magnetic composite which is composed of magnetic filler and nonmagnetic matrix has been studied for the applications of near-field electromagnetic noise suppression [4]. However, the magnetic composites have some limitations for practical applications, which are not enough to insert the magnetic filler in composite for noise reduction. In case of the far field region, the conductive grids have been employed conventionally as an EMI countermeasure [5]. The transmission wavelength of plane electromagnetic wave normally incident on the inductive grid is governed by the order of spacing between grid lines. However, in near field, the electromagnetic wave propagated along the signal transmission line was applied on the specimen. Therefore, the electromagnetic wave propagating situation in near filed is quite different with the far field. In order to enhance the electromagnetic (EM) absorption performance and overcome the limitation of the composite, we suggested the hybrid type to enhance the efficiency of the EMI reduction by using the insertion of the conductive grid in conventional magnetic composite. Therefore, the conductive grid effects in magnetic composite on EM noise suppression were simulated in the broadband frequency range from 50 MHz to 6 GHz in near field.

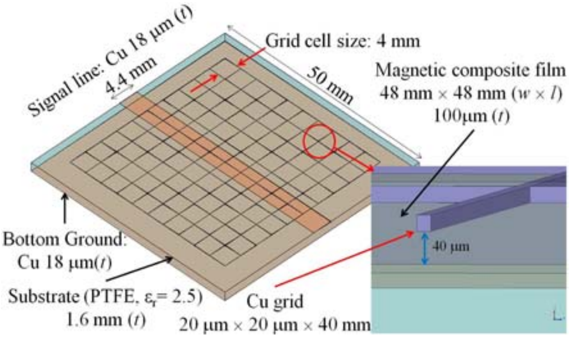

Fig. 1. (Color online) The simulation model for the extraction of the electromagnetic absorption ability of the magnetic composite with conductive grid on microstrip transmission signal line.

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2. Simulation Model

To evaluate the power absorption of the conductive grid effects in magnetic composite using microstrip line (MSL) for signal transmission, the simulation model of the magnetic composite on a signal transmission line was prepared for 3-dimensional electromagnetic simulation as shown in Fig. 1. The conductive grid line is copper, which the dimension of each grid line is 20 mm × 20 mm × 40 mm (*w* × *l* × *t*) with 4 mm- mesh size between grid lines, and the total area of grid layer was 40 mm × 40 mm (*w* × *l*). The grid layer was placed in the center height of the 100 nm thick magnetic composite with the dimension of 48 mm × 48 mm (*w* × *l*). The typical permeability frequency profiles of the magnetic composite were employed the different ferromagnetic resonance (FMR) frequency profiles with the same magnitude of the permeability as shown in Fig. 2, which the permeability frequency profiles was calculated based on the Landau-Lifschitz equation. To simplify the permeability, these calculations of the permeability were supposed that the magnetic moments are aligned with the same directions and the magnetic particles are evenly distributed in the magnetic composite. And the permittivity values of the composite are neglected for the specific verification of the magnetic and the conductive grid effects.

In order to evaluate the power absorption ability of the magnetic composite in near field, the transmission MSL technique was employed. The dimension of the MSL with the characteristic impedance of 50 Ω is 18 mm-thick and 50 mm-long Cu signal line on PTFE substrate (50 mm × 50 mm × 1.6 mm) with Cu ground, which is based on IEC standard (IEC 62333). The characteristic impedance can be controllable by the integration of the dielectric and magnetic materials on microstrip line. The absorbed power loss can be calculated by the relation, $P_{LOSS}/P_{IN} = 1 - |S_{11}|^2 - |S_{21}|^2$. The S_{11} and S_{21} are the reflection and transmission coefficients, respectively, which were extracted by using a commercial 3-dimensional electromagnetic field analysis program (HFSS ver. 12, by ANSYS) from 50 MHz to 6 GHz.

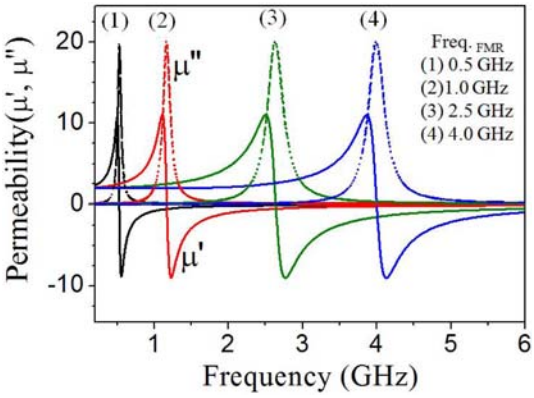


Fig. 2. (Color online) Typical Permeability frequency profiles of the magnetic composites with the different ferromagnetic resonance frequencies.

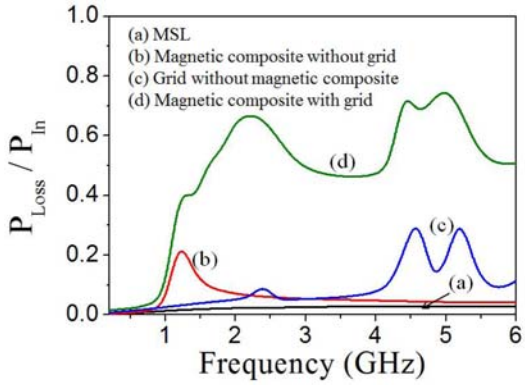
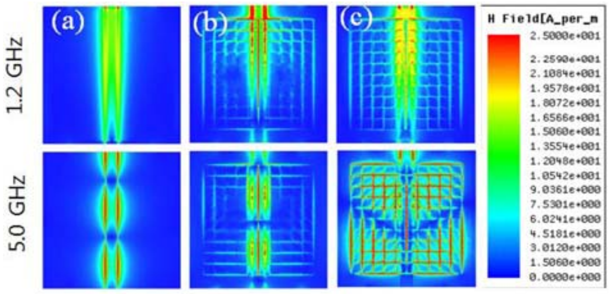


Fig. 3. (Color online) The power absorptions of (a) the microstrip line, (b) the magnetic composite without grid, (c) the conductive grid without magnetic composite, and (d) the magnetic composite with conductive grid, respectively.

3. Results and Discussion

When the power absorption behavior was evaluated for the magnetic composite with an insertion of the conductive grid, the conductive grid without magnetic composite and the magnetic composite without conductive grid, respectively, the permeability profile was employed the FMR frequency (*freq.*$_{FMR}$) at 1 GHz from Fig. 2(b).

Figure 3 shows the power absorption behaviors of the magnetic composite with an insertion of the conductive grid in comparison with those of the conductive grid without magnetic composite, the magnetic composite without conductive grid, respectively, up to 6 GHz. The power absorption of the magnetic composite without conductive grid and the conductive grid without magnetic composite exhibited about 25% at around 1-2 GHz region and 35% at around 4-5.5 GHz region, respectively. In case of the magnetic composite, the frequency region of the power absorption could be depends on *freq.*$_{FMR}$ of the magnetic composite. On the other hand, the power loss of the grid without magnetic composite exhibited the two kinds of peaks which shown the single peak with the 10% maximum value at around 2.4 GHz and the double peaks with the 35% maximum value at 4-5.5 GHz region, respectively. The two peaks seem to be originated from different physical dynamics with the FMR. It could be deduced from the LC resonance which is governed by the electro-



(a) Magnetic composite without grid
(b) Grid without magnetic composite
(c) Magnetic composite with grid

Fig. 4. (Color online) The magnetic fields distributions on the top surface of (a) the magnetic composite without grid, (b) the grid without magnetic composite, and (c) the magnetic composite with grid, respectively.

magnetic signal source frequency due to the inherent frequency selectivity related with conductive mesh structure [5, 6]. However, these conventional theories for far field plane wave are analytically not coincidence with that of the electromagnetic behaviors in near field region.

When the conductive grid was inserted in the magnetic composite, the power absorption of the composite was greatly enhanced in broad band frequency region. The signal source power of MSL was absorbed about 43% at FMR frequency region (~2 GHz) by the magnetic composite with the insertion of the conductive grid. The magnitude of the power loss was almost double in comparison with that of the magnetic composite without conductive grid. The power absorption beyond the *freq*.$_{\mathrm{FMR}}$ region exhibited high absorption ability (maximum 76% at around 5 GHz) up to 6 GHz.

Enhancement of the power absorption by the insertion of conductive grid in magnetic composite could be explained that the electromagnetic wave source from MSL induced the current on conductive grid. And then the magnetic field by the induced current on conductive grid distributed to the whole area of the magnetic composite. Figure 4 shows the magnetic field intensity on the top surface position of the magnetic composite without grid, the grid without magnetic composite and the composite with grid at two significant operating frequencies (1.2 GHz and 5 GHz), respectively. The magnetic field was mainly distributed along the signal line of MSL for the magnetic composite without grid, while it spread along the grid lines for the grid without magnetic composite. In case of the magnetic composite with the insertion of grid, the magnetic field was strongly distributed along grid lines over the entire region of the magnetic composite. The magnetic field delivered from the transmission signal line was distributed over the whole area of the magnetic composite by the conductive grid. As a result, whole volume of the composite contributed to the power absorption as shown in the magnetic fields distributions on top surfaces.

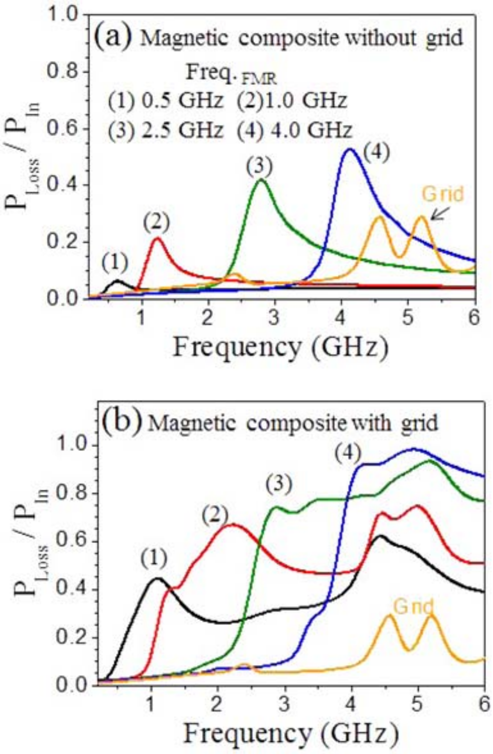


Fig. 5. (Color online) The Power absorptions of (a) magnetic composite without conductive grid and (b) the magnetic composite with conductive grid with the different ferromagnetic resonance frequencies.

To evaluate the power absorption behaviors with the various *freq*.$_{\mathrm{FMR}}$ of the magnetic composite, the permeability frequency profiles with *freq*.$_{\mathrm{FMR}}$ (0.5 GHz, 1.0 GHz, 2.5 GHz, and 4 GHz) in Fig. 2 were employed. The power losses of the magnetic composite with grid were simulated in comparison with those of the magnetic composite without grid as shown in Fig. 5. In Fig. 5(a), the power absorptions of the magnetic composite without grid exhibited the at each *freq*.$_{\mathrm{FMR}}$ and the magnitude of the power losses were increased with the increment of *freq*.$_{\mathrm{FMR}}$ that the maximum values of the power losses exhibited from 7% (0.5 GHz) up to 54% (4 GHz). The power losses for the magnetic composite with the insertion of the conductive grid were abruptly increased at each *freq*.$_{\mathrm{FMR}}$. And the magnitude of power losses were exhibited the maximum values with the increment of *freq*.$_{\mathrm{FMR}}$ from 45% (1 GHz) up to 98% (5 GHz). These results imply that the beginning frequency of the power loss can be controlled by *freq*.$_{\mathrm{FMR}}$ of the magnetic materials and enhanced the power loss by the insertion of the conductive grid line in magnetic composite.

4. Conclusion

The magnetic composites with conductive grid and without conductive grid were evaluated their power absorptions by the microstrip line method. The magnetic composite with conductive grid exhibited the high power absorption and the broadband frequency performance in comparison with those of the magnetic composite without conductive grid. As simulation results, the conductive grid in magnetic composites has an important role in a magnetic fields distribution in the whole volume of the magnetic composites for the enhancement of power absorption in near field.

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