PREPARATION AND ELECTROMAGNETIC PROPERTIES OF MAGNETIC PARTICLES EMBEDDED COMPOSITE FILMS FOR NEAR-FIELD ELECTROMAGNETIC NOISE SUPPRESSION

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1 Introduction

In high-frequency operating digital electronic components, system in package (SiP), radio frequency identification (RFID), the near-field electromagnetic (EM) nosie as well as the far-field EM noise by interference between the component and signal source is the critical problem. In order to avoid the EM interference coupling between signal lines and to improve the signal intergrity of the electronic devices at high-frequency region, the conducting noise should be reduced or removed on signal line [1-3]. Loss generation by magnetic resonance has been utilized to suppress only the EM noise and signal interference. The EM noise suppression can be performed more effectively by the absorption mechanism using the magnetic loss than by simple shielding.

Commercially, conductive materials such as metals, graphite, and polymer embedding conductive fillars have been used for EM shielding in far-field. In case of near-field, the nosie suppression by EM absorption was more effective than those by EM shielding by conductive materials. Generally, the conventional magnetic particles have the shape of a sphere or flake. Especially, the flake type of Fe-Si-X alloy or Sandust (Fe-Si-Al-X alloy) is known for good magnetic materials due to their high permeability and moderate aspect ratio. However, there are still a few drawbacks. It is difficult to fabricate lightweight EM absorbers due to their heaviness. Even at high weight fraction in polymer matrix, they have some limitations for implementing effective absorbing performance in the range of GHz frequency, which could be attributed to the insufficient aspect ratio. To overcome the limitations, the hollow structure of ultra-fine metallic fibers was proposed [4]. It is expected that the hollow structure can give a clue to make light EM absorbers and the fibrous particles can enhance effective permeability as well as permittivity although their intrinsic properties are not changed. Many studies on the fabrication of fibrous metallic fibers have been conducted. However, they had too high specific density or low aspect ratio.

In the present study, Fe-Co hollow fibers were prepared by the electroless plating process and the heat treatments. The Fe-Co hollow fibers embedded composite films have been fabricated by film casting coupled with mixing processes of homogenizer and three-roll mill. The microstructure of the composites has been characterized by scanning electron microscope (SEM). The EM properties of magnetization and power loss of composite films have also been measured by vibration sample magnetometer (VSM) and microstrip line based on IEC standard (IEC 62333-2), respectively.

2 Experimental Procedures

The Islands-in-the-Sea polyester fiber (70% PET/30% COPET), SESIL, provided by SAEHAN Company was used as a substrate. Sodium dodecyl benzene sulfonate (SDBS, Aldrich) and NaOH were used as a cleaning and hydrolysis [4].

Fe-Co hollow fibers were fabricated by electroless plating and heat treatments. Before metal coating, the substrate polymer fibers were pretreated by aqueous SnCl2 solution followed by PdCl2 activation solution. First, Nickel (Ni) was deposited on the pretreated polymer fibers. Next, Fe-Co metal layer was plated on the Ni-coated polymer fibers. Ratio of Fe to Co was controlled with varying the content of $FeSO_4$ and $CoSO_4$ during the plating. In order to remove polymer substrates for the hollow structure and crystallize the metallic portion, heat treatment was conducted under the inert gas at the different conditions; 500℃ for 1 hr, 600 ℃ for 1 hr and 750℃ for 1 hr.

Fe-Co hollow fibers embedded composite films have been prepared by film casting coupled with homogenizer and three-roll mill for uniform dispersion of the nano-particles in polymer matrices. Figure 1 shows two steps mixing method. First of all, nano particles and resin were mixed roughly by mechanical stirrer. The premixure was underwent shear mixing by three-roll mill (80E, EXAKT, Germany) for uniform dispersion of nanoparticles in the resin matrix. The composite film was prepared by COMMA type film caster. After casting, the film was dried and cured.

The composite film has been characterized by scanning electron microscope (SEM). The EM properties of magnetization and power loss of composite films have also been measured by vibration sample magnetometer (VSM) and

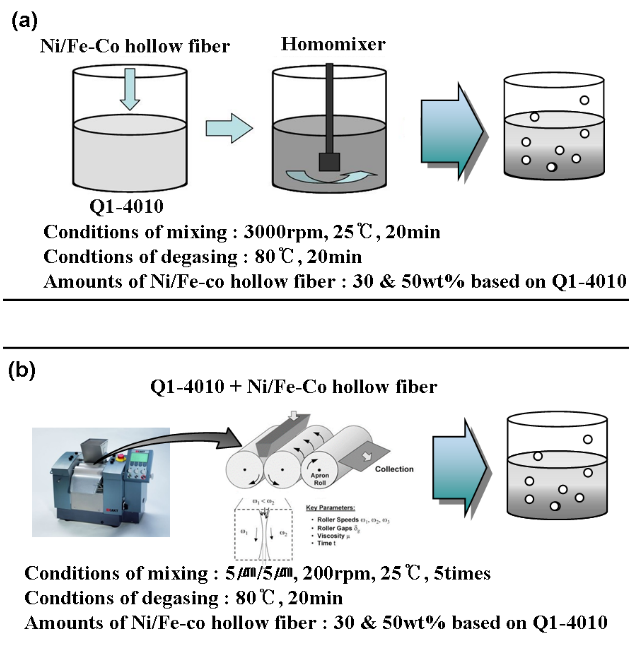

Fig. 1. Schematic diagrams of two different mechanical dispersion methods; (a) Homomixer, (b) Three-roll mill.

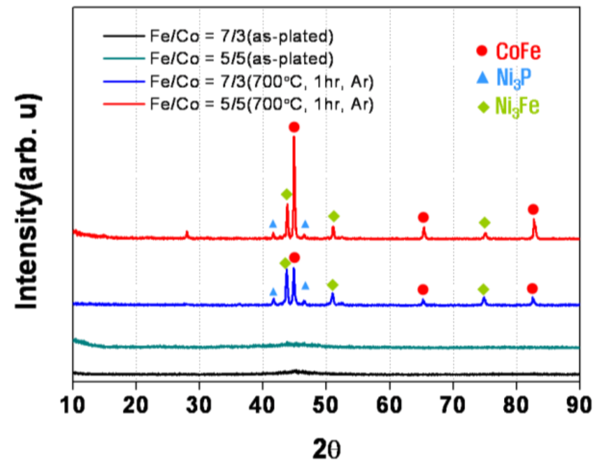

Fig. 2. X-ray diffraction pattens after heat treatment of Ni/Fe-Co hollow fibers with two different Fe/Co ratio (w/w) at 700℃.

microstrip line based on IEC standard (IEC 62333-2), respectively.

3 Results and Discussion

Figure 2 shows the X-ray diffraction patterns of as-plated fibers and heat-treated fibers with two different atomic compositions (Fe:Co = 7:3, 5:5). As the heat treatment caused amorphous metal layers to be crystallized, some peaks were observed and the peaks became shaper with the increased temperature, which could be simply understood. The atomic ratio of Fe to Co in hollow Ni/Fe-Co fibers was controlled by varying the concentration of $FeSO_4$ and $CoSO_4$ during the electroless plating [4].

Figure 3 shows the representative images of Fe-Co hollow fibers fabricated by the electroless plating and the heat- treaments. The fiber has the exact tubular shape with the inner Ni layer with thickness of 100 ~ 200 nm and the outer Fe-Co layer with

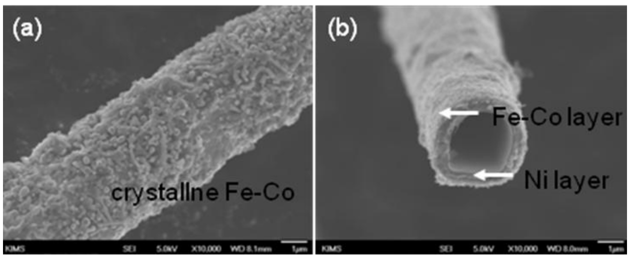

Fig. 3. SEM images of Fe-Co (Fe:Co = 5: 5) hollow fiber; (a) surface image; (b) cross-section image.

thickness of 500 ~ 700 nm. The fiber was 2.5 μm in diameter and approximately 200 μm in length.

Figure 4 shows the images of cast composite film at various fiber concentrations and casting thicknesses. The Fe-Co hollow fibers were homogeneously dispersed in the matrix. The casing thickness of composite films was various from 50 μm to 350 μm. As shown in Fig. 5, fiber type fillers exhibited the higher power loss than particle type fillers indicating that the aspect ratio of fillers probably influences permittivity and permeability. From our previous work [5], it was confirmed that hollow Ni/Fe metal fibers increased permittivity effectively. In case of Co atomic fraction, hollow fibers with 7:3 Fe-Co ratio were more efficient than 5:5 fibers. The $Fe_{70}Co_{30}$ composite has higher power loss than $Fe_{50}Co_{50}$ composite due to the grain structure after the thermal exposure at 700℃.

Based on the results, magnetic hollow fibers are effective fillers for EM absorbing materials and improve the EM noise suppression in high frequency band due to excellent electromagnetic properties such as high permittivity and high permeability.

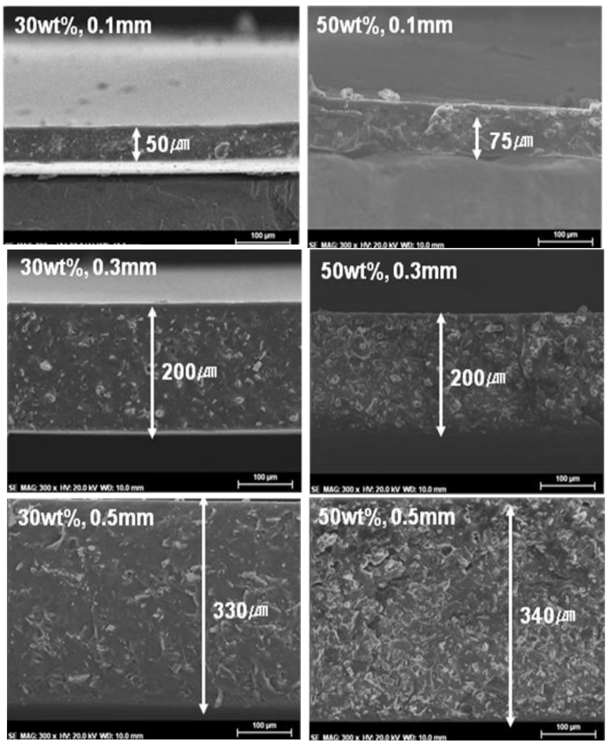

Fig. 4. SEM images of cast composite films with different concentration of magnetic fibers and casting thickness.

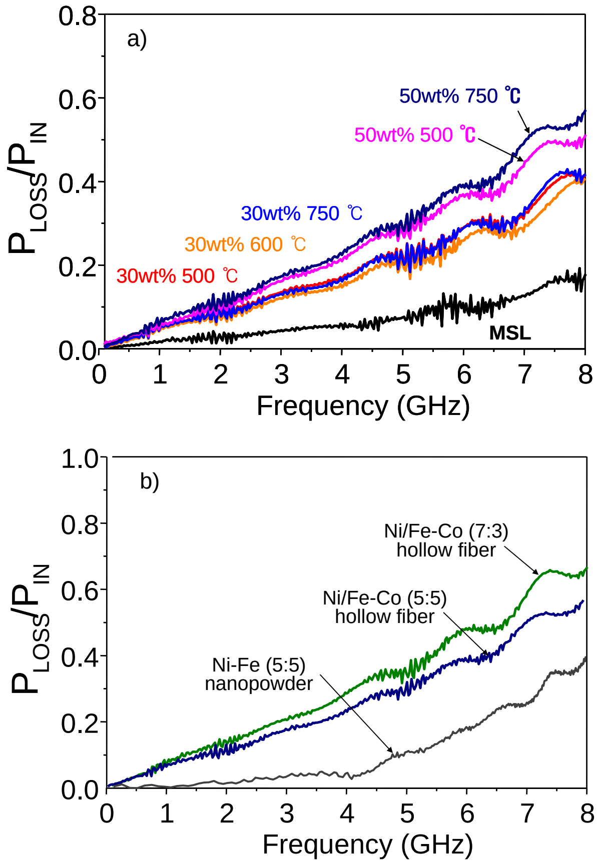

Fig. 5. EM absorbing properties (power loss) of composite films fabricated at a) different heat treatment conditions and with b) different atomic compositions.

4 Summary

The near-field EM absorbing composite films containing magnetic Ni/Fe-Co hollow fibers were fabricated through electroless plating, heat treatments, and two mixing processes of homogenizer and three-roll mill. The ratio of Fe and Co in hollow Ni/Fe-Co fibers was controlled by varying the concentration of $FeSO_4$ and $CoSO_4$ during the electroless plating. The $Fe_{70}Co_{30}$ composite has higher power loss than $Fe_{50}Co_{50}$ composite due to the grain structure after the thermal exposure at 700℃. Based on the results, it is confirmed that the magnetic hollow fibers are effective fillers for EM absorbing materials and improve the EM noise suppression in high frequency band due to excellent electromagnetic properties such as high permittivity and high permeability.

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