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Radar absorbing composite structures dispersed with nano-conductive particles

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ABSTRACT

Nano-composites are typically used in radar absorbing structures (RAS) to improve their electromagnetic (EM) wave absorbing performances. The nano-composites are generally composed of E-glass/epoxy composites dispersed with carbonaceous nano-conductive particles such as carbon black and carbon nanotubes (CNT). Because the EM wave absorbing performance of the nano-composite RAS is dependent on the particle concentration of the nano-composites, investigation of its performance with respect to the different nano-composite composition is highly necessary.

In this study, the nano-composite RAS were designed using the optimum design method with the various selected nano-composites. The EM wave absorbing performance of the RAS were obtained by numerical simulation with respect to the nano-composites and verified by experimental measurement. Additionally, the effects of the carbonaceous nano-conductive particles on the mechanical properties of the nano-composites were measured. Finally, the optimum nano-composite RAS was suggested considering both electromagnetic and mechanical performances.

1. Introduction

Stealth technologies for high performance weapon system require composite structures to increase durability and operational capabilities. The stealth function of a weapon system is achieved by reduction of the radar cross section (RCS), which is the product of effective area and power density in the direction facing the radar [1]. Therefore, RCS reduction technology with composite structure has been commonly used and previous research has been focused on increasing stealth performance using low-observable radome and radar absorbing structure (RAS).

The low-observable radome is a composite structure that is applied to the radar antenna system of the weapon system to reduce RCS. The low-observable radome has selectivity with regards to electromagnetic (EM) waves wherein the in-band EM wave frequency transmits through the radome structure, while the out-of-band EM wave is reflected by the radome structure [2]. The low-observable radomes are generally composed of composite sandwich constructions with composite faces of either E-glass/epoxy or aramid/epoxy composites [3–5]. Additionally, hybrid composites composed of both E-glass/epoxy and aramid/epoxy composites have recently been utilized in low-observable radomes [6,7].

The radar absorbing structure is composed of a nano-composite with the high dielectric properties as dielectric constant and loss tangent to induce the absorption of EM wave energy by ohmic loss and cancellation of the EM wave by the destructive interference of the reflected EM waves [8–10]. The high the dielectric properties for the nano-composites were usually gained using a high concentration of carbonaceous conductive particles [11–13]. Additionally, the optimum design method for the nano-composite RAS was developed because the dielectric property of the nano-composite affects the EM wave absorbing performance of the RAS [2]. Moreover, use of the ultra-high molecular weight polyethylene (UHMWPE) fabrics for the nano-composite RAS to protect from the external impact load was developed to improve the mechanical performance without decreasing the EM wave absorbing performance [14].

In this study, the E-glass/epoxy nano-composites dispersed with carbonaceous nano-conductive particles such as carbon black (CB) and carbon nanotubes (CNT) with respect to the weight percents (wt.%) were fabricated and dielectric properties in the X-band frequency range (8.2–12.4 GHz) were measured. Then, the optimum design method was applied to select the nano-composite candidates with high EM wave absorption, as shown in Fig. 1.

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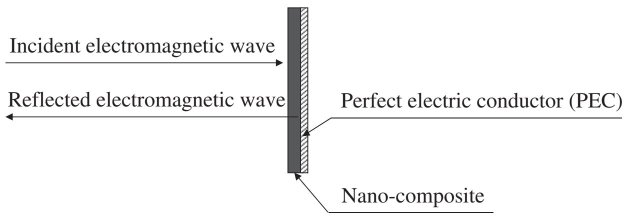

Fig. 1. Schematic diagram of the nano-composite RAS.

Additionally, the dispersion characteristics of the selected nano-composites were investigated using scanning electron microscope (SEM) images. The nano-composite RAS were fabricated using the selected nano-composites. Then the EM wave absorbing performances were obtained by numerical simulation and verified by experimental measurement. The 3-D numerical simulations for the EM wave absorbing performance of the nano-composite RAS were executed with commercial EM wave analysis software (CST Microwave Studio®, CST Gmbh, Germany), and the actual EM wave absorbing performances were measured by the free space measurement method (HVS Technologies, Pennsylvania, USA). Then, the effects of the carbonaceous nano-conductive particles on the mechanical performance of the nano-composites were investigated by tensile property measurement. Finally, the optimum nano-composite RAS was suggested considering both the EM wave absorbance and mechanical performances.

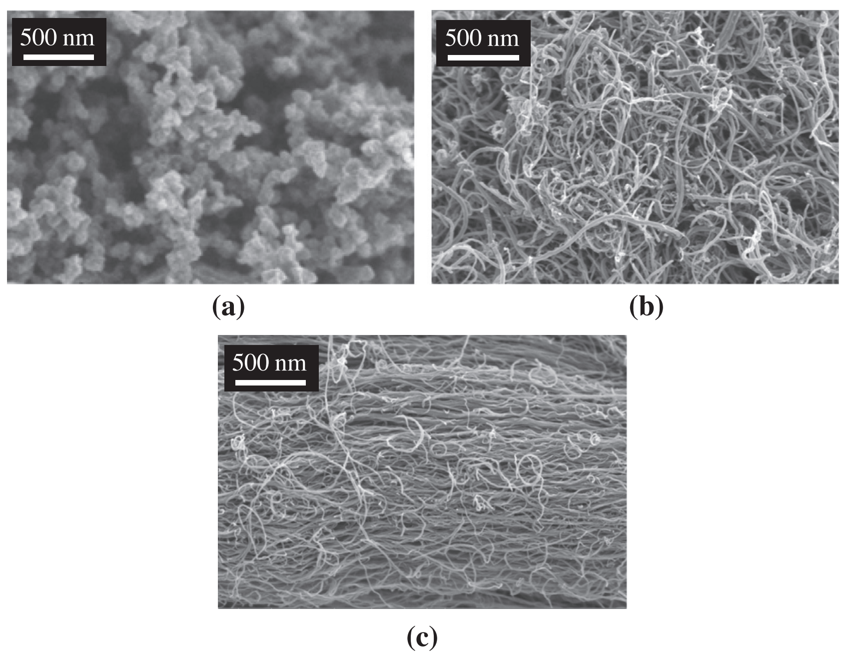

Fig. 2. SEM images of the carbonaceous nano-conductive particles: (a) carbon black; (b) carbon nanotube; (c) high aspect ratio carbon nanotube.

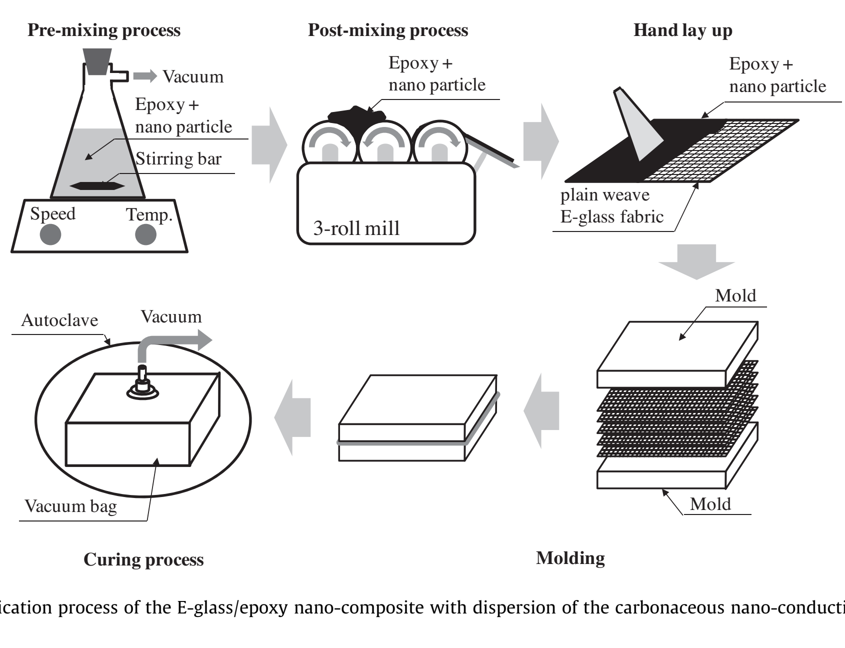

Fig. 3. Fabrication process of the E-glass/epoxy nano-composite with dispersion of the carbonaceous nano-conductive particles.