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Electromagnetic wave absorption characteristics of multiwalled carbon nanocoils

Usaburo Eguchi[1], Hirofumi Takikawa[2], and Yoshiyuki Suda[2]

[1]*Department of Electrical and Electronic Engineering, Tsuruoka National College of Technology, Tsuruoka, Yamagata 997-8511, Japan*
[2]*Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan*

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We have studied the electromagnetic wave absorption properties of a multiwalled carbon nanocoil (MWCNC), a promising lightweight and wide-band electromagnetic wave absorber. Experiments were conducted using several types of paste with various weight concentrations of MWCNC compounded into an organic binder. The results revealed the significant electromagnetic wave absorption potential of the MWCNC. They also verified that its electromagnetic wave absorption effect is strongly dependent on MWCNC concentration, so that there is an optimal MWCNC composition. The increased sample thickness enhances electric conduction loss and encourages electromagnetic wave absorption, even in a high-frequency range. Consequently, the MWCNC has been demonstrated as a new outstanding electromagnetic wave absorber.

1. Introduction

Recently, the effect of electromagnetic waves emitted from information devices has become a source of concern for the human body and many electronic devices. Electromagnetic wave absorbers such as ferritic materials and carbon particulate materials are used as effective measures for improving such electromagnetic wave environments today. However, these materials have a small electromagnetic absorbing capacity and are heavy and difficult to extend to an applicable frequency range.[1–8]

In this study, we specifically examine multiwalled carbon nanocoils (MWCNCs) of spiral morphology among carbon nanomaterials and investigate their electromagnetic wave absorption characteristics to confirm the practicality of the MWCNC as a new electromagnetic wave absorber.[9–15]

The MWCNC is a graphitic carbon fiber of spiral shape having a chiral structure, a fiber diameter of 20 nm, a coil diameter of about 100 nm, a length of about 50 µm, and an internal structure of 10–30 layers.[16] MWCNCs are produced by catalytic chemical vapor deposition (CCVD), in which the material gas (C_2H_2) reacts in an electric furnace with Fe and Sn, which are both metal catalysts. CCVD precipitates carbon fibers of spiral morphology. The MWCNC comprises carbon (c), hydrogen (H), iron (Fe), and tin (Sn), as well as zeolite; it is a chiral material with no symmetry axis because of its double helix geometry.[17,18] Figure 1 shows transmission electron microscopy (TEM) images of the MWCNC.[9]

The electromagnetic wave absorption mechanism is given as follows. Electromagnetic wave absorption losses are generally categorized into electric conduction loss, dielectric loss, and magnetic loss. Because the MWCNC can be regarded as a conducting coil, its equivalent circuit is presumed as shown in Fig. 2.

Electromagnetic wave absorption loss is generated by the internal resistance R, the coil L, and the capacitor C of an equivalent circuit. Flux linkage also varies along with a change of electromagnetic waves. As a result, electromagnetic induction takes place and induction current occurs in the coil L. It causes Joule heating in the internal resistance R, which results in electric conduction loss. The MWCNC yields a high induced current because of its multiwalled structure. Furthermore, many MWCNCs contained in a sample enhance electric conduction loss.[8]

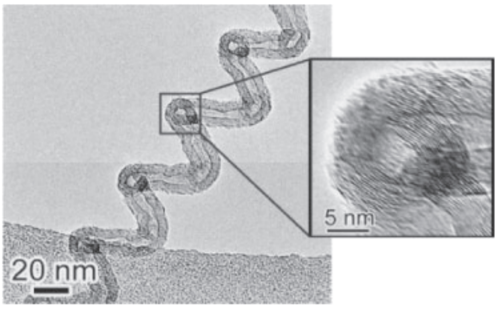

Fig. 1. TEM image of MWCNC.

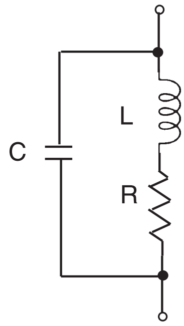

Fig. 2. Schematic of the equivalent circuit of MWCNC.

Dielectric loss takes place because the fiber spacing of MWCNCs functions as a capacitor, i.e., a nanocoil with numerous turns has many capacitors. In addition, many MWCNC/organic binder/MWCNC capacitors also exist because a sample comprises an organic binder mixed with MWCNCs. An organic binder is a transparent, viscous high-polymer material, whose electrical properties are exemplified by a large capacitive reactance and a low resistance. Dielectric loss occurs when the polarity change in dielectric polarization arising from the capacitors (C) and induced by an AC electric field cannot follow the transition speed of the AC electric field. It is enhanced when a high-frequency AC electric field is impressed on many capacitors.[8]

Furthermore, because the MWCNC is a chiral material, the polarization plane of electromagnetic waves is rotated in the MWCNC, and the rotational speed of a polarized wave differs between levorotation and dextrorotation, so that

