Shape Effects of CNT Forest Metamaterials on IR and THz Properties

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1. Introduction

Anisotropic black body absorption has been reported in high-density and vertically-oriented carbon nanotube (CNT) forests[1]. Recently, THz wave generation was reported from perpendicularly aligned CNT films placed on substrates[2]. Unique optical properties of CNT forests opened the next door of opt-electronics applications. Size and shape controlled CNTs is a candidate of metamaterial nano-rod antenna in THz to the visible range. In this paper, we report anisotropic optical properties of vertically aligned CNT forests with/without SRR (Split ring resonator) patterning in IR and THz regions.

2. Experimental

The SRR metamaterial shape patterning of the deposited catalyst was carried out by using Focused Ion Beam (FIB) combined with a FIB secondary etching process [3]. SRR metamaterial shapes of CNT forests were grown on the catalyst of metamaterial shapes. CNT forests were grown on Si substrates by catalytic thermal CVD using a C_2H_2 gas source utilizing Fe catalyst films on AlO or Al support layers. The influence of geometrical parameters (shape, height, etc.) of CNT forest metamaterials on the total reflectance in the infrared regime was investigated by the FT-IR spectrometer (JASCO FT/IR 660 PLUS) combined with an IR microscope (JASCO IRTRON IRT-30) using a non-polarized incident light with a 28um diameter circular measurement area. IR ellipsometry spectra were obtained for un-patterned CNT forest by IR-VASE Mark II ellipsometer (J.A. Woollam).

Figure 1(a) shows CNT forest SRR metamaterial patterns formed on Si wafers with various gap distance in the SRR shapes of A, B and C. Growth heights of these CNTs were estimated about 0.75um by SEM observation. Figure 1(b) shows FT-IR reflectance spectra of the CNT forest metamaterial patterns of A, B and C. Reflectance of CNT forest patterns decreased in sample B of narrow 0.5um-gap SRR, as shown in Fig.1(c), which indicate a resonance absorption in CNT forest SRR metamaterial shape patterns.

THz waves generation were observed from 4-5 um thickness, highly-aligned and high-density CNT forest film by the laser pulse incident beams at the incident angle of 45 degrees[3]. Ellipsometric parameters of the CNT forests were obtained for the CNT forests, those indicated strong anisotropic electric refractive index.

3. Conclusions

Effect of CNT forest metamaterial pattern shapes on IR reflectance spectra and THz generation of CNT forests were investigated. Anisotropic optical index of vertically aligned CNT forests are interpreted by the anisotropic electrical conductance of nano-rods of CNTs.

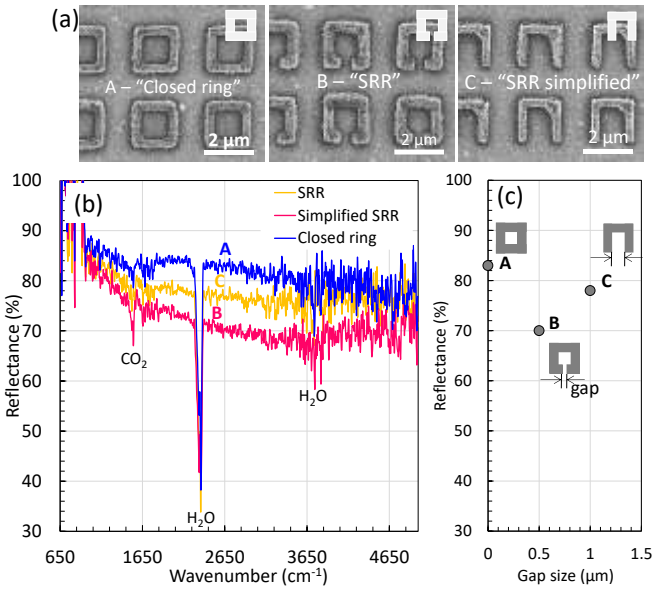

Figure 1. (a) SEM images of CNT forest metamaterial pattern shapes on Si substrates, (b) infrared reflectance spectra of the fabricated patterns [4, 5], (c) reflectance vs. gap size of SRR. The reflectance spectra were normalized to the Si substrate.

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