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Structure Dependence of CNT Forests on Optical and THz Properties

Hiroshi FURUTA[1], Kazuki SEKIYA[1], Adam PANDER[1], Hiroki MIYAJI[1], Yuji KUSUMOTO[1], Junthorn UDORN[1], Akimitsu HATTA[1], Keisuke TAKANO[2], Makoto NAKAJIMA[2]

[1] Kochi University of Technology, [2] Inst. Laser Engineering, Osaka University
E-mail: furuta.hiroshi@kochi-tech.ac.jp

1. Introduction

Recently, black body absorption has been reported in high-density and vertically-oriented carbon nanotube (CNT) forests. [1] Unique optical properties of CNT forests opened the next door of opt-electronics applications. In this paper, we report anisotropic optical properties of vertically aligned CNT forests with varying structures (vertically alignment, height, area density and so on.) in UV-VIS, IR, and THz regions.

2. Experimental

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. Optical spectra in UV-VIS, IR, and THz regions were obtained by ellipsometry, FT-IR, THz absorption measurements, respectively.

CNT forests of various degree of vertical alignment were prepared at the same height of about 2μm on Si wafers. Figure 1 (H2, M2, and L2) shows cross-sectional SEM images of these CNT forests with various vertical alignment with (H2) higher orientation, (M2) moderate orientation, and (L2) lower orientation. Growth densities, obtained from SEM images, were 1.8×10^{11} for H2, 1.2×10^{11} for M2, and $0.5\times10^{11}/cm^2$ for L2[2]. π plasmon absorption peaks[3] at 4.5 and 5.5 eV were observed in absorption coefficient spectra, and the ratio of 4.5/5.5eV were interpreted as the vertically alignment of CNTs[3] in the forests.

The ellipsometric parameters were derived for the CNT forests. Figure 1 shows the spectra of phase shift (Δ) in p- and s-waves for sample H2, M2, and L2 for the various incident beam angle of 63 to 75°. The phase-shift increased for higher density and higher degree of vertically alignment of CNT forests. CNT forests with higher degree of vertical alignment showed increasing of real and imaginary refractive index in lower freq. of 0.3 – 1 THz.

Frost-column like CNT forests [4] were fabricated, in which carbon films are supported by low-density and vertically aligned CNT forests. Figure 2 shows cross-sectional SEM images. The average growth height of the forests were 1.64μm (3s1s), 1.58μm (5s1s), and 1.42μm (15s1s), respectively. Figure 2 shows optical reflectance of the frost-column like CNT forests. Optical interference were clearly observed, and the pitches of the oscillation corresponded to the forest height.

3. Conclusions

Structure control of CNT forests for the application of optical media were discussed. Anisotropic optical index of vertically aligned CNT forests are interpreted by the anisotropic electrical conductance of nano-rods of CNTs.

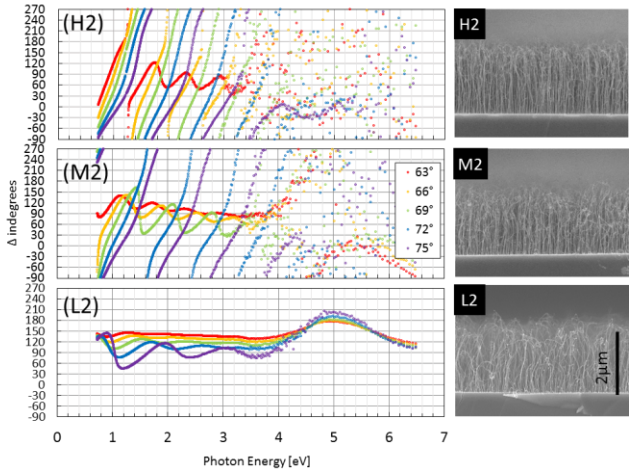

Figure 1. Phase shift spectra of ellipsometric parameters for (H2) highly oriented, (M2) moderate, and (L2) lower orientation forest sample.

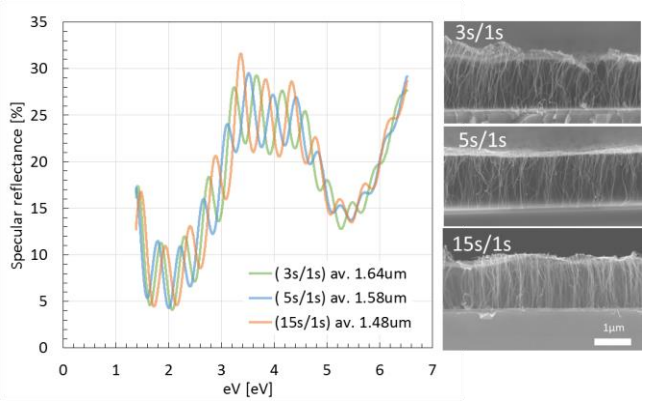

Figure 2. Specular reflectance for the frost-column like CNT forest sample (3s1s) 1.64μm, (5s1s) 1.58μm, and (15s1s) 1.48μm height.

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