Empirical modeling of broadband complex refractive index spectra of single-chirality-enriched carbon nanotube membranes

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Carbon nanotubes have attracted much attentions because of their excellent intrinsic optical, electronic, mechanical, and thermal properties since their discovery [1]. Previous experiments using individual carbon nanotubes have demonstrated high electrical/thermal conductivities [2,3], strong light-matter interaction arising from excitons [4,5], structure-dependent tensile strengths with ultrahigh strength-to-weight ratio [6], and high thermal stability [5]. These exceptional properties potentially provide various promising applications for electronics, photonics, structural materials, and thermal management. Since many of such physical properties strongly depend on their chiral structure (chirality), fabrication of single-chirality-enriched nanotube assemblies are desired. However, most of their fundamental physical property values has still been unavailable in the literature, as has prevented researchers and engineers from designing the devices using single-chirality nanotube assemblies. In particular, systematic knowledge on their broadband complex refractive index spectra and their chirality dependence, which is essential for designing devices using carbon nanotubes as optofunctional materials, has still been limited.

Here, we report broadband complex refractive index spectra of single-chirality-enriched single-walled carbon nanotube (SWCNT) membranes from far-infrared to visible regions. Free-standing and on-sapphire SWCNT membranes were fabricated via filtration of SWCNT solutions prepared by separation method using gel chromatography [7,8]. The thicknesses of the SWCNT membranes were determined as several tens of nanometer using a stylus profilometer. We measured reflection and transmission spectra in far-infrared-to-visible wavelength region using the combination of Fourier transform infrared spectrometer (0.06–1.77 eV) and a home-made optical setup (1.1–3.1 eV). The spectra were analyzed using a phenomenological model that accounts for the excitons, their phonon sidebands, and other contributions; the complex refractive index spectra per unit density were derived. The real and imaginary parts of the refractive indices of the SWCNT membranes at the first subband exciton resonance were determined to be around 2.7–3.6 and 1.2*i*–2.4*i*, respectively. In the presentation, we will discuss the empirical formula for the complex refractive index of a single-chirality-enriched SWCNT membrane, which will facilitate designing various nanotube-membrane-based optical devices.

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