Terahertz Electromagnetic Interference Shielding Using Single-Walled Carbon Nanotube Flexible Films

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Abstract—**We performed time-domain terahertz spectroscopy on flexible films coated by single-walled carbon nanotube. The films demonstrate good shielding of electromagnetic waves in the terahertz range, maintaining good transparency for visible light. The shielding efficiency can be engineered by the thickness control of the film and by the chemical treatments.**

I. Introduction And Background

Carbon nanotubes have been investigated for the development of useful functional materials due to their fascinating mechanical, electronic, and optical properties. Composites or thin films based on single-walled nanotubes (SWNTs) have attracted great attention lately for potential applications of advanced, flexible engineering materials. Particularly there have been increasing needs for lightweight electromagnetic interference (EMI) shielding materials owing to their technical importance in high-speed circuit operations.[1] With increasing speed of electronic devices, it is imperative to extend EMI shield to the terahertz region.

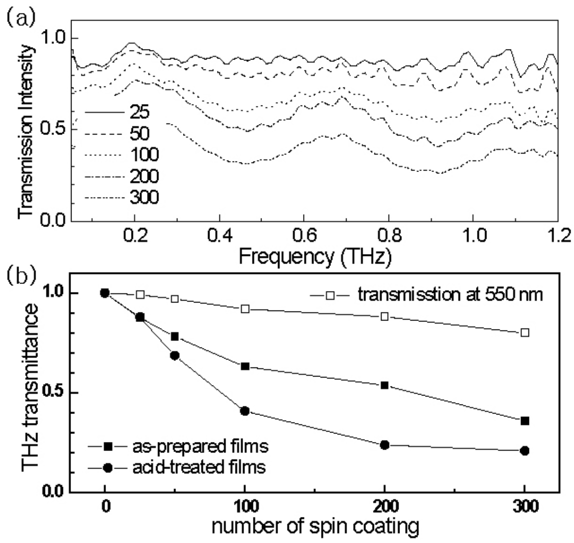
In this study, we fabricated SWNT-coated PET films using spin-coating method and performed time-domain terahertz spectroscopy to measure the transmittance of the nanotube films. Our films exhibit effective terahertz shielding, while maintaining good transparency for the visible light.

II. Results

The fabrication of SWNT-coated film begins with arc-made SWNTs dispersed in dichloroethane (DCE) via ultrasonic agitation for 12 hours. The SWNT-dispersed DCE solutions were centrifuged at 48,000 g for 20 minutes to induce sedimentation of large CNT bundles and any other carbonaceous materials. Decanting the upper portion of centrifuged solution, SWNT-network films were cast on flexible PET substrates using a spin coater (sample area ~ more than 500 mm^2). For time-domain THz experiments, we used a high resistivity GaAs as an emitter and a ZnTe crystal as a detector. Femtosecond laser pulse with λ=800 nm was used to generate and detect the transmitted pulses using electro-optic sampling techniques.

Fig. 1a shows normalized, transmittance plots in the THz frequency domain for a series of SWNT films spin-coated 25, 50, 100, 200, 300 times respectively, on PET substrates. With increasing spin-coating times (i.e., with increasing thickness of SWNT films), the transmission decreases over entire frequency range from 0.1 to 1.5 THz. The oscillations found in the frequency domain (Δf ~ 0.45 THz) correspond to the Febry-Perot interference fringes originating from the thick PET substrates. It is also found that the transmission is higher toward the low frequency regimes, which indicates the Drude-like response of our nanotube films in the THz range. It is also inferred from the dielectric constant measurements that the efficient THz shielding originates from the enhanced absorption rather than the reflection at the nanotube film surface. The electrical conductivity measurements also confirm our observations.

The THz shielding efficiency can be further improved with treatments of nitric acid on the films. For the acid treatment, SWNT films on substrates were immersed in 13M HNO_3 for 1 hour, and then rinsed thoroughly and baked at 80 C under vacuum. In Fig 1b, we plot the maximum THz transmittance for both as-prepared and acid-treated films, deduced from the time-domain, peak amplitudes. The transmission measured at 550nm is also shown for comparison. The amount of THz transmission changed dramatically after the acid treatments, for instance, from 0.54 to 0.24 for 200-coated films. The enhanced terahertz absorption reflects the increased conductivity of the nanotube films from the acid treatment, manifested by the reduced sheet resistance. Also note that our film shows good visible-range transmittance of more than 80 %. This clearly suggests that the SWNT-based films can work as optically transparent, flexible films capable of shielding terahertz electromagnetic waves.



References

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