Novel Optical Processes in Globally Aligned Carbon Nanotube Films

Rice University[1], ◦Natsumi Komatsu[1]

E-mail: nk31@rice.edu

Macroscopically ordered arrays of single-wall carbon nanotubes, including fibers (1D), films (2D), and crystals (3D) of aligned carbon nanotubes, have long been sought. Such low-dimensional macromaterials are expected to possess uniquely anisotropic electronic, mechanical, thermal, magnetic, and optical properties, which can be useful for a variety of device applications.

During the last several years, a method known as controlled vacuum filtration has been developed for producing wafer-scale crystalline films of single-wall carbon nanotubes in which nanotubes are nearly perfectly aligned and maximally packed [1]. Recently, we have found that the alignment direction in the filtration process is predetermined by parallel grooves that exist on most commercial filter membranes [2]. We further created periodically spaced parallel grooves on the filter membrane, which successfully defined the direction of the global alignment of nanotubes in a precise and reproducible manner.

In this talk, we will discuss our recent progress in aligned film preparation as well as studies on their optical properties. Very recently, we have performed time-domain teharetz spectroscopy experiments on highly aligned films and discoved giant polarization rotation: up to ∼20˚ through single-pass transmission, and up to ∼110˚ upon a single reflection [3]. The amount of polarization rotation was a sensitive function of the angle between the polarization direction of the incident beam and the nanotube alignment direction, exhibiting a “magic” angle at which the total rotation through transmission and reflection becomes exactly 90˚. Furthermore, we have produced aligned and (6,5)-enriched nanotube film devices and observed electroluminescence with polarized emission. The emission intensity exponentially grew with the applied in-plane voltage, indicating impact excitation of excitons, and strongly depended on the direction of the current with respect to the alignment direction.

Acknowledgements

This work was supported by the Basic Energy Science (BES) program of the U.S. Department of Energy through Grant No. DE-FG02-06ER46308 and the Robert A. Welch Foundation through Grant No.C-1509, in collaboration with Andrey Baydin and Ali Mojibpour.

References

[1] X. He, W. Gao, L. Xie, B. Li, Q. Zhang, S. Lei, J. M. Robinson, E. H. Haroz, S. K. Doorn, W. Wang, R. Vajtai, P. M. Ajayan, W. W. Adams, R. H. Hauge, and J. Kono, Nat. Nanotechnol. **11**, 633 (2016).

[2] N. Komatsu, M. Nakamura, S. Ghosh, D. Kim, H. Chen, A. Katagiri, Y. Yomogida, W. Gao, K. Yanagi, and J. Kono, Nano Lett. **20**, 2332 (2020).

[3] A. Baydin, N. Komatsu, F. Tay, S. Ghosh, T. Makihara, G. T. Noe II, and J. Kono, Optica **8**, 760 (2021).