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Femtosecond laser-induced structural modification with formation of linear carbon chains in single-walled carbon nanotube networks

There has been a growing need for technologies to modify the structure of carbon nanotubes (CNTs). Also, an effective method to generating molecular junctions between adjacent tubes is essential because the performance of a CNT network significantly deteriorates at the interface between tubes.[1] Therefore, intensive investigations were performed for transforming the CNT structures with formation of covalently bonded junctions between adjacent CNTs by electron beam irradiation[2] and Joule heating.[3]

In this work, a femtosecond laser was employed as a tool to induce structural transformations in CNTs since an ultrashort laser pulse can selectively deposit energy over a period shorter than the electron phonon relaxation time. We demonstrated that femtosecond laser irradiation can transform single-walled nanotubes (SWNTs) into multi-walled nanotubes (MWNTs) and form molecular junctions between adjacent SWNTs.[4]

Commercial SWNT (signle-walled nanotube)-DI(deionized) water solutions from Brewer Science were used in this work. Template-guided fluidic assembly was used to assemble SWNT arrays on SiO_2/Si substrates. Metal pads were patterned on the assembled SWNT sample using the conventional lift-off process. A Ti:sapphire femtosecond laser (wavelength = 800nm, full width half maximum = 50 fs, pulse energy < 3 mJ, repetition rate = 1 kHz) was employed in the experiment.

The diameter and wall number of the transformed nanocarbons increased with the laser pulse number. The transformed nanocarbon networks exhibit extraordinarily strong coalescence induced mode in Raman spectra. By controlling the number of incident laser pulses, the electrical conductivity of CNT networks was enhanced two-times. The density function theory computation and experimental results indicate that the linear carbon chains between CNT walls expanded the interlayer spacing, with the linear carbon chain being under higher strain.

This work indicates that the proposed process has strong potential in practical applications of CNTs because the transformed CNTs retained their tube structures without increasing structural defects. Furthermore, the femtosecond laser processing technique is controllable and easily extendible into multiscale (nano- to macro- scale) applications as a fast, selective, scalable and non-destructive method.

References

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Figures

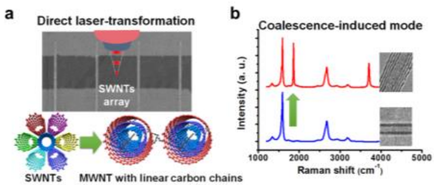

Figure 1: (a) Schematic of the laser transformation process and (b) Raman spectra and TEM images of the carbon nanotubes before and after laser irradiation.