Optical and Photo-thermoelectric Properties of Fermi-level Tuned Single-Walled Carbon Nanotubes with a Selected Electronic Structure

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One dimensional materials exhibit remarkable optical and thermoelectric properties owing to their unique electric structures such as presence of van Hove singularities (vHs) in density of states. Such one-dimensional characteristics can be observable when the diameter of the materials becomes less than or around 1 nm. Single walled carbon nanotubes (SWCNTs) are materials which have sufficient structural rigidity with such small diameters, providing us to investigate unique physical properties reflecting one-dimensional nature. Recent progress purification techniques of SWCNTs enable us to understand the physical properties of SWCNTs with a selected electronic structure. To clarify how the Fermi level position influences on the physical properties of networks formed by materials with sharp vHs, we have investigated the electrical, optical and thermoelectric properties of SWCNT networks with an selected electronic structure as a function of Fermi level using electric double layer carrier injection techniques.[1-5)] Here I would like to discuss two new findings in recent our studies.

First, localized surface plasmon resonances caused by one-dimensional structures can have unique influences on optical absorption spectra. There are two localized surface plasmon modes; longitudinal and transverse to the axis. The longitudinal mode contributes to the strong THs absorption of the nanotubes, however, there has been no report on the transverse modes. In a high-carrier accumulated state, a new optical absorption band is formed in infra-red region, and we recently attributed the band to the transverse surface plasmon modes, and manipulated its peak position by changing the amount of injected carriers.[4]

Second, it has been theoretically proposed that one-dimensional materials can exhibit the best performance for thermoelectric energy conversion. We have clarified how the position of Fermi level influences the thermoelectric properties of SWCNTs networks with a selected electric structure.[3] Remarkably, although the Seebeck coefficient of metallic SWCNTs have been considered to be negligible, we found significant increase of their Seebeck coefficients at a highly carrier accumulated state. In such situation, increase of both conductance and Seebeck coefficient can be achieved, breaking the conventional trade-off. By utilizing such anomalous properties and weak thermal coupling of electrons in the metallic SWCNTs, here I demonstrate relatively efficient light-energy conversion in metallic SWCNTs through photo-thermoelectric effects.

References: 1. Yanagi *et al*., *Adv. Mater.* 23, 2811 (2011), 2. Yanagi *et al*., *Phys. Rev. Lett.* 110, 86801 (2013), 3. Yanagi et al., *Nano Lett.* 14 6437 (2014), 4. Igarashi, Yanagi et al., *Phys. Rev. Lett.* 114, 176807 (2015)