Theory of a Carbon-Nanotube Polarization Switch

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Recently, it was suggested that the polarization dependence of light absorption into a single-walled carbon nanotube (CNT) is altered by carrier doping [1]; a CNT absorbs light whose linear polarization is parallel to the tube's axis, but not when the polarization is perpendicular to it. This is a well-known property of an undoped CNT, which enables aligned CNTs to function as an optical polarizer [2]. Charge doping of a CNT inverts the polarization dependence; a doped CNT transmits parallel polarized light and absorbs perpendicular polarized light (Fig. 1). To change the polarization direction of light transmitted through a typical Polaroid lens, it is necessary to rotate the lens itself. However, according to the theory of doping dependence, a CNT polarizer can invert the polarization of the transmitted light by 90° without having to spatially rotate the polarizer; in order words, it is expected to function as a polarization switch.

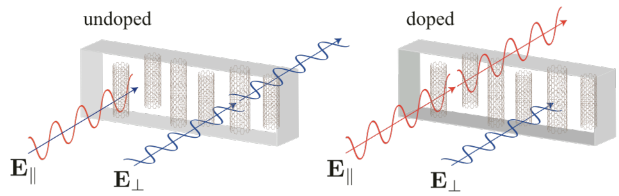

Fig.1 (left figure) Undoped CNTs transmit only perpendicular polarized light. (right figure) Doped CNTs transmit only parallel polarization. Since the polarization of the transmitted light rotates 90 degrees by doping, the aligned CNTs function as a polarization switch.

We specify theoretically the doping level at which the polarization anisotropy is reversed by plasmon excitation (Fig. 2) [3]. The plasmon energy is mainly determined by the diameter of a CNT, because pseudospin makes the energy independent of the details of the band structure. We argue that the effect of doping on the Coulomb interaction appears through the screened exchange energy, which can be observed as changes in the absorption peak positions (S_{22} and S_{33}).

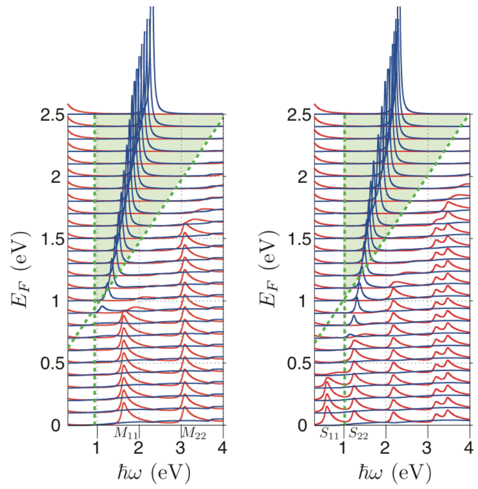

Fig.2 Doping with approximately 1 eV creates a transient region where the polarization anisotropy starts to be reversed. The green area shows the region where single particle excitation does not exist.

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[2] S. Shoji *et al.*, Phys. Rev. B **77**, 153407 (2008); B. G. Kang *et al.*, Nanotechnology **21**, 405202 (2010); He *et al.*, Nature Nanotechnology 11, 633 (2016).
[3] K. Sasaki and Y. Tokura, accepted for publication in Phys. Rev. Applied.