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# Cross-polarized optical excitation of single-walled carbon nanotubes

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Because of the depolarization effect, cross-polarized optical absorption of single-walled carbon nanotubes (SWNTs) has been believed to be negligible. However, in photoluminescence (PL) excitation spectra of micelle wrapped SWNTs, clearly identified PL peaks due to cross-polarized excitation gives an important measure of optical transition energy of E12 or E21 [1]. The relative strength of absorption is order of 1/10 compared with parallel excitation. Recently, we also decided E12 quasi-dark exciton states which are not completely dark because of the symmetry breaking by the slight asymmetric structure of valence and conduction band. The cross-polarized absorption must be dominant in the absorption of vertically aligned film of SWNTs when excited from the top of a film. In our previous study of polarized UV/Vis absorption, pi-plasmon absorption at 5.25 eV was observed in contrast to 4.5 eV for parallel excitation [2]. The consistent physical view of electron energy loss spectroscopy (EELS) is now being explored [3] with the understanding that the bundle size of such a vertically aligned SWNT film is as small as 5-8 nanotubes. We also discussed the cross-polarized Raman scatterings from such vertically aligned SWNTs. However, we found that the discussion is much more complicated because of the existence of almost isolated nanotubes in a film. Results of detailed polarized Raman study and PL spectroscopy on such a film is discussed.

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