Collective optical resonances in networks of metallic carbon nanotubes

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In carbon materials, actual optical plasmonics have this far been restricted to graphene, but the experiments we have performed provide novel evidence of plasmonic functionality in a different form of pure carbon [1]. We demonstrate optical resonances in thin films of single walled carbon nanotubes (SWCNTs) with a highly enriched (98%) proportion of metallic chiralities. These resonances are measured in the Kretschmann configuration, and can be seen as intensity dips of up to 90% in reflection spectra beginning at 360 and 650 nm at the critical angle for total internal reflection and moving to longer wavelengths for higher angles of incidence. Unexpectedly, they are only visible when the sample is excited with s-polarized light, the opposite of surface plasmon polaritons on thin metal films. The resonances are dispersive and intense only when the layer thickness is close to 100 nm, implying that a collective excitation might be responsible for the resonance. They are also sensitive to the dielectric environment, clearly distinguishing the data from normal total internal reflection absorption spectra. The length of the CNTs seems to be irrelevant, ruling out localized surface plasmon resonance, and increasing the amount of amorphous carbon only decreases the intensity of the resonance. Corresponding materials of semiconducting and unsorted SWCNTs with similar diameters (1.4 nm) do not display noticeable dispersive resonances. Although additional experimental and theoretical studies are needed to confirm the underlying mechanism, a magnetic plasmon resonance [2] due to intertube effects, possibly within bundles, is a possible explanation. A probable coupling to excitons can also be pointed out, as the resonances are found close to M11 and M22 transition energies of the SWCNTs. If the fundamental reason for the observed phenomenon is connected to a magnetic resonance, metallic SWCNTs might find applications in plasmonic metamaterials.