Optics and Photonics of Aligned Carbon Nanotube Films

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We have recently developed a controlled vacuum filtration technique (Fig. 1a) to fabricate wafer-scale films (1 inch [1] and 2 inches [2] in diameter, as shown in Figs. 1b and 1c, respectively) of aligned and packed single-wall carbon nanotubes (SWCNTs); see Figs. 1d-1g. We can further build unique architectures and devices through stacking and doping (Fig. 1c). Here, we summarize some of our recent accomplishments using these unique samples.

We have made the first observation of intersubband plasmons (ISBPs) in gated aligned films [3]. For parallel polarization (Fig. 1h), the S_{11}, S_{22}, and M_{11} transitions disappear as carriers are injected; for perpendicular polarization (Fig. 1i), a new peak due to ISBP appears and grows as the carrier density increases. We have also made the first direct observation of the E_{12}/E_{21} peak in the optical absorption of an aligned (6,5) film (Fig. 1j). We further built an exciton-polariton architecture by incorporating such films inside a Fabry-Pérot microcavity [4]. This system displayed a continuous transition from the strong-coupling to the weak-coupling regime through facile polarization control (Figs. 1k-1m). The obtained dispersion surfaces revealed the existence of exceptional points and two equienergy arcs (Fig. 1n). Furthermore, the vacuum Rabi splitting exhibited cooperative enhancement (Fig. 1o).

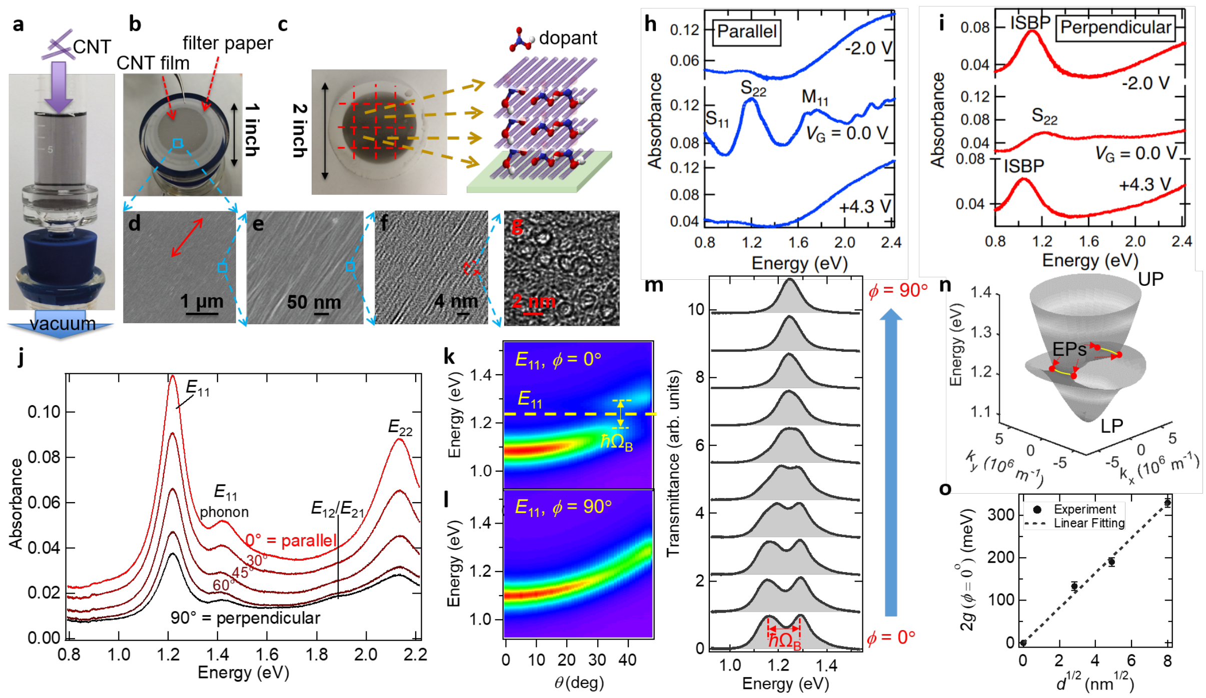

Fig. 1 (a) Vacuum filtration system to produce (b) 1-inch films, (c) 2-inch films and architectures of aligned CNTs; see (d, e) SEM and (f, g) TEM images. (h) Parallel- and (i) perpendicular-polarization absorption spectra for gated and aligned CNTs. (j) Polarization-dependent absorption spectra for an aligned (6,5) CNT film. Transmittance spectra of an exciton-polariton device for (k) $\phi = 0°$ and (l) $\phi = 90°$. (m) Transmittance spectra for varying ϕ. (n) Dispersion surfaces for the device. (o) Vacuum Rabi splitting versus the square root of the film thickness.

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