New Insight on a Vertically Aligned Single-Walled Carbon Nanotube Film and an Application to All-Fiber Passive Mode-Locker

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A new insight is gained on the structure of the vertically aligned single-wall carbon nanotubes (VA-SWNTs) [1-3] generated by alcohol catalytic CVD (ACCVD) technique [4]. The thickness-controlled growth of VA-SWNTs by using in-situ laser absorption method is now a routine [2]. Our recent finding of the simple removal method using hot-water [5] enabled us to transfer this film to various flat substrates for various applications. At the same time, transferring this film on transmission electron microscopy (TEM) grid made it possible to directly observe the morphology of nanotubes from the top. To our surprise, the average number of nanotubes of a bundle is less than about 10. Electronic properties measured by EELS and X-ray absorption revealed that nanotubes are virtually electronically isolated [6].

The saturable absorption functionality of SWNTs is well suited for the use in passively mode-locked lasers including ultrashort pulse formation with notable attractions including wide operating bandwidth ranging from 1 to 2 μm, ultra-short recovery time (~500 fs), high optical damage threshold, and excellent compatibility with fibers and nano-devices due to their extremely miniaturized foot print [7, 8]. Recently, we propose and demonstrate a novel all-fiber mode-locking scheme in which the evanescent field of the propagating light in the fiber interacts with the SWNTs to induce loss modulation in the laser cavity [9]. In this study, hot-water removed VA-SWNT film is attached onto a D-shaped fiber instead of the previously tried randomly sprayed SWNTs [9]. With this new configuration, each SWNT direction is aligned with the electric field of the evanescent field of guiding light. We successfully demonstrate the mode-locked laser. The pulsed output has 0.5 nm of spectral FWHM, and a 5.7 MHz repetition rate [10]. This new scheme highlights some remarkable advantages including (i) simple and safe SWNTs deposition process, (ii) maximized SWNTs interaction with the field of propagating light due to the SWNTs alignment, (iii) high (~100%) yield rate and reliability for the device manufacturing, and (iv) low SWNTs density threshold to achieve mode-locking.

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