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Dynamic instability of individual carbon nanotube growth revealed by *in situ* optical imaging

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Current models of carbon nanotube growth assume that the nanotube growth rate is unambiguously fixed by its chirality and the growth conditions, an assumption which is at the heart of all current strategies of chirality selection based on kinetics. Here, we report on *in situ* optical imaging of hundreds of long individual carbon nanotubes under real growth conditions (at ambient pressure, on a substrate) using the method of homodyne polarization microscopy [1,2]. Our observations reveal that, despite overall constant growth conditions, most CNTs display dynamic instability during their growth (Fig. 1) [3]. This instability is characterized by stochastic fluctuations between different growth rates, and between growth, pause and etching (*i.e.* shrinkage of tube length), a behavior reminiscent of that observed for microtubule growth. Statistical analysis shows that the growth rate of a CNT varies essentially between two values whose ratio is similar for all CNTs. Structural fluctuations of the catalyst nanoparticles or of the nanotube-catalyst interface might be the cause of the dynamic instability revealed by our *in situ* observations.

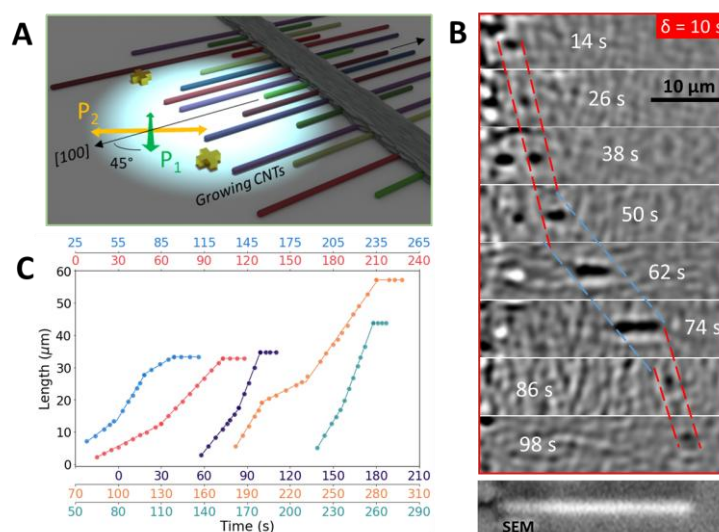


Figure 1. (A) Principle of the *in situ* optical imaging of individual CNTs during growth on ST-cut quartz by homodyne polarization microscopy. (B) Changes of growth rate with no change of CNT structure: snapshots of an *in situ* video in differential mode (*i.e.* with a time delay of 10 s between the frame and the reference frame used for background correction) and corresponding SEM picture after growth. (C) Examples of kinetic curves displaying abrupt changes of growth rate.

[1] Liu et al, Nature Nanotechnology (2013), 8, 917.

[2] Comprehensive model of the optical spectra of carbon nanotubes on a substrate by polarized microscopy, L. Monniello, H.-N. Tran, R. Violla, G. Prévot, S. Tahir, T. Michel, V. Jourdain, Physical Review B (2019), 99, 115431.

[3] Submitted.