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Termination mechanism of carbon nanotube forest growth
MOSTAFA BEDEWY, ERIC R. MESHOT, YONGYI ZHANG, HAICHENG GUO, University of Michigan, ERIC VERPLOEGEN, Massachusetts Institute of Technology, WEI LU, A. JOHN HART, University of Michigan — Understanding the termination event in the growth of carbon nanotubes (CNTs) by chemical vapor deposition (CVD) is a roadblock in the pursuit of ultra-long CNTs, which would be useful for many of applications. Our previous in situ measurements show that vertically-aligned CNT "forest" growth terminates abruptly, which is not predicted by widely suggested models of diffusion-limited growth. In this work, we complement forest height measurements with mass and density measurements, and with spatial mapping of CNT diameter, alignment, and spacing along the forest sidewall by small-angle and ultra-small-angle synchrotron X-ray scattering (SAXS, USAXS). Accordingly, we reveal that the areal density of growing CNTs begins to decay long before the forest height terminates, indicating that gradual deactivation of catalyst particles is collectively responsible for the limitation to CNT forest height. Considering that mechanical and surface interactions among CNTs create the self-supporting forest structure, a gradual decay of CNT density can lead to an abrupt loss of CNT alignment at the forest base when the CNT-CNT spacing increases sufficiently. This proposed mechanism is supported by finite element models of CNT-CNT buckling and contact.

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