Onset of rippling in MWCNTs studied with in situ TEM force measurements

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When carbon nanotubes (CNTs) are bent they can deform in localized buckling or rippling deformations. The force-deflection relation is only linear up to a critical strain, where the rippling or buckling begins, and then the relation becomes non-linear with a concomitant drop in the bending stiffness (for a review see e.g. [1]). These two effects have important implications for the design of future nanoelectromechanical systems (NEMS) that utilize bending of CNTs. Several theoretical studies have investigated this phenomenon but there is still a lack of experimental data to compare with [1]. In a previous study we have measured the critical strain for the rippling onset of CVD-grown MWCNTs using in situ SEM force measurements [2]. We found that a large defect density in the MWCNT will shift the critical strains to higher values than theoretically predicted [3-4].

In this study we have performed in situ TEM force measurements on individual, arc-discharge grown, MWCNTs. We found values of the critical strain that are lower, compared to the values of the CVD-grown, owing to the high crystallinity of arc-discharge grown tubes. The values are comparable to previous predictions for SWCNTs [3] and thick MWCNTs [4], but there is also an influence from the geometry. We find a dependence of the critical strain on both the number of walls and the nanotube diameter, and we discuss this effect in terms of a radial stiffness that supports the outermost walls in a MWCNT.