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Utilizing real time transmission electron microscopy to understand the mechanisms of nanotube nucleation, growth and growth termination

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In order for carbon nanotubes to find widespread application, we must have a deeper understanding of the mechanisms by which they nucleate, growth and cease growth, in an effort to fully control the resulting structures. Here we will describe how we can exploit the unique capabilities of in-situ environmental cell transmission electron microscopy to observe multiple aspects of these processes. With this approach we can directly visualize how the catalysts that mediate nanotube growth respond to various changes in the growth environment, and correlate these changes with the resulting nanotube structures. In the first part of the presentation, we will investigate how dynamic changes in the catalyst morphology are correlated with the termination of growth in vertically aligned SWNT arrays. In particular, we have investigate how the processes of catalyst coarsening, Ostwald ripening and diffusion into the catalyst support can lead to growth termination, and we will describe how changes in the growth feedstock - in particular the incorporation of controlled amounts of water vapor - can alter the catalyst evolution. In the second portion of the presentation, we will describe how altering other aspects of the growth feedstock - in this case the carrier gas, in combination with the water vapor content - can not only affect catalyst morphological evolution, but can also significantly bias the chiral distribution of the resulting nanotubes. We will correlate the changes in growth ambient with a faceting / defacting transition, as well as a resulting change in the rate of Ostwald ripening.