Carbon Onions and Nanotubes as Compression Cells on the Nanoscale

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Graphitic nanoparticles consisting of either spherically or cylindrically closed graphene layers exhibit unique properties when irradiated with energetic particles such as electrons. The removal of carbon atoms from the layers under the beam leaves vacancies which are able to migrate and colaesce at sufficiently high temperature. Multiple vacancies can vanish by bond reconstruction and the formation of non-six-membered rings. Such a closure of holes leads to a reduction in surface area of closed graphitic structures. Hence, a shrinkage of carbon nanotubes or onions can be induced by electron irradiation. Such experiments are usually carried out in an electron microscope because all structural alterations can be visualized in real time with atomic resolution.

Interesting effects are observed when hollow carbon onions or nanotubes are filled with foreign materials, e.g., metallic nanocrystals. Under electron irradiation, the collapsing graphitic shells exert pressure onto the encapsulated crystals which are, then, subjected to elastic or plastic deformation. On the one hand, information about the compressive stress or pressure inside onions or tubes can be gained by observing the behaviour of the encapsulated crystals. On the other hand, such nanoencapsulates enable us to study the plastic deformation of individual nanocrystallites with high spatial resolution.

In this contribution it will be shown that carbon onions or nanotubes can be used as nanolaboratories for the study of structural transformations in individual nanocrystals. Deformation, phase transformations, chemical reactions, confinement effects, or diffusion in nanocrystals are studied by applying in-situ electron microscopy of graphitic nanoencapsulates.