Type of presentation: Poster

MS-2-P-2542 Atomic resolution of nanocrystalline Ge and SbTe encapsulated inside carbon nanotubes

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We have the ability to image individual atoms using high resolution transmission electron microscopy (HRTEM) yet for most materials this has only been achieved whilst looking at a section of a larger system. There has been relatively little work investigating nanocrystalline systems that have been formed inside extremely small growth spaces[1]. This is of interest due to the possibility that with this bottom up growth method we may see the formation of new structures[2].

Melt filling is a technique that allows us to encapsulate materials inside ≈1 nm carbon nanotubes (CNTs) therefore allowing us to image molecules formed inside confined spaces. This is achieved by grinding a combination of CNTs and the desired material. It is then heated to above its melting temperature, cooled and annealed, repeatedly, inside a furnace before being dispersed onto a lacy carbon grid. The dispersed filled carbon nanotubes were then imaged using a JEOL ARM200F TEM/STEM at 80kV accelerating voltage, a HRTEM is required as individual atomic resolution is essential. The CNTs were commercially acquired and had a range of diameters from 1.1 – 1.6 nm. Two systems were investigated, Germanium (Ge) and Antimony Telluride (SbTe). Once successfully filled the systems were then recreated using Crystalmaker and simulated using SimulaTEM in an attempt to reproduce the achieved image.

Ge was successfully filled into CNTs but rendered a small filling ratio due to the Ge reacting with the lab glass used during the melting phase. Even though the filling ratio was low, filled CNTs were captured with high resolution. The Ge was found to be growing in the [010] crystal orientation relative to the bulk with lattice spacings that are consistent with bulk Ge. The system captured in Figure 1 has been recreated and simulated to prove it has formed from bulk Ge. Streaking is visible on the atomic spots of Ge, this is due to the CNT being tilted rather than exactly perpendicular to the beam.

SbTe also successfully filled into the CNTs but again with a low filling ratio. Two different systems were observed within the SbTe sample; the first a 4 atom motif and the second a 5 atom (Figure 2). This is of high interest as a single atom variation will affect the quantum structure of the system. Both systems were recreated and found to have lattice spacing similar to that of the bulk with growth once again in the [010] direction, this is due to SbTe and Ge both having a FCC crystal structure.

[1] J Sloan et al. "Two layer 4: 4 co-ordinated KI crystals grown within single walled carbon nanotubes." Chemical Physics Letters 329 (2000): 61-65.

[2]R Carter et al. "Correlation of structural and electronic properties in a new low-dimensional form of mercury telluride." Physical review letters 96 (2006): 215501.

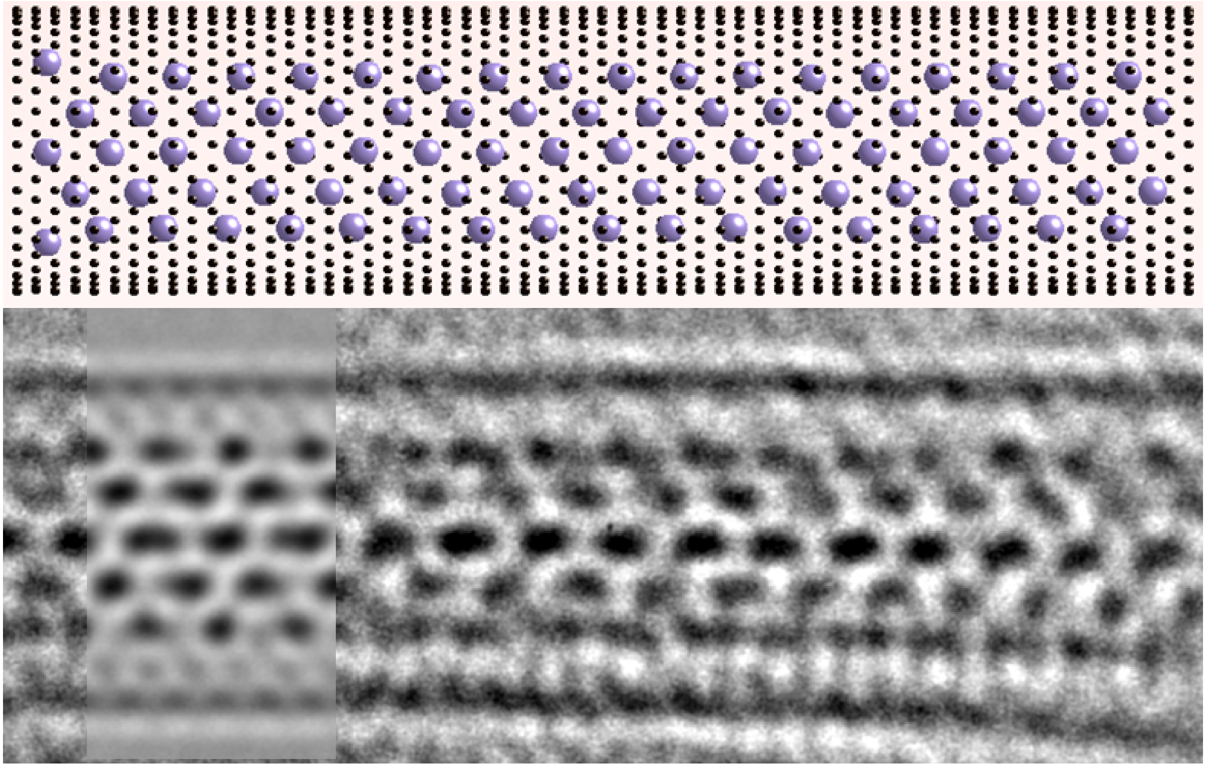

Fig. 1: Crystallographic simulation of Ge encapsulated inside a CNT and an image of the encapsulated Ge with an overlay of the simulated system.

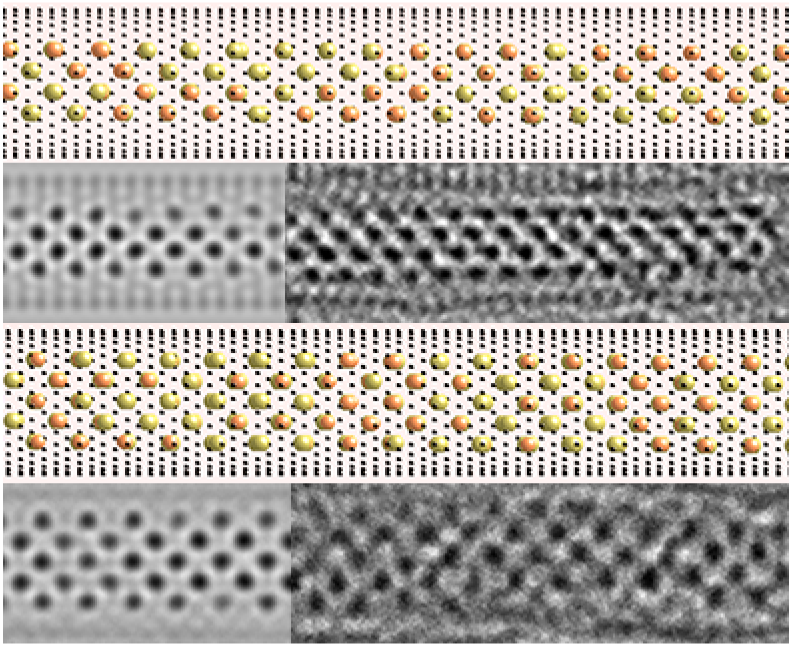

Fig. 2: Crystallographic simulations of encapsulated SbTe, below is the captured structure with the simulation superimposed. Both 5 layer and 4 layer SbTe systems are included.