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Electron Energy Loss Spectroscopy of Carbon Nanomaterials

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Carbon nanomaterials, such as fullerenes and nanotubes, have many potential applications, such as drug carriers [1] and in quantum nanotechnology [2]. In order for these materials to fulfill their potential, it is important to have a good understanding of their properties and how to alter them.

Electron energy loss (EEL) spectroscopy provides a probe of the unoccupied density of states (DOS) of a material. Monochromation of the electron source means that it is possible to get high energy resolution spectra, which, along with simulated spectra, can be used to obtain a better understanding of the electronic structure of a material. Previously this combination of experiment and theory has been used to look at fullerene crystals [3]. In particular, the affect of changes in bond length on the DOS and EEL spectra has been studied [4].

We are currently extending this investigation to look at the interactions between nanotubes and fullerenes encapsulated inside them. A schematic diagram of a C_{60} molecule and a single-walled nanotube filled with C_{60} molecules is shown in Figure 1. We are using the newly installed monochromated FEI TITAN at Imperial College London to acquire high energy resolution spectra from similar peapod systems. This microscope can be operated at 100 kV and the energy resolution is ~0.15 eV. Monochromation is particularly important to this study as we are looking for small differences in the fine structure of the edge.

Experimental EEL spectra have been obtained from La@C_{82} nanocrystals and a single-walled nanotube filled with La@C_{82}. The major isomer of La@C_{82}, which is thought to have C_{2v} symmetry, has been used to make the nanocrystals and to fill the nanotubes. The carbon K-edge from La@C_{82} is shown in Figure 2, alongside that from C_{82}. Pristine C_{82} is thought to have C_2 symmetry. The π^* peak in the C_{82} appears narrower than that in the La@C_{82}, which is not surprising as there is less symmetry in the La@C_{82} case.

Figure 3 shows examples of two carbon K-edges from the La@C_{82} peapod sample. Figure 3a is a spectrum from an area of the sample containing lanthanum and 3b is from an area which does not contain lanthanum. The area which does not contain lanthanum is likely to be an unfilled nanotube. This is supported by the similarity of the spectrum to that of a single walled nanotube. Apart from the relative heights of the π^* and σ^* peaks, there are two main differences between the spectra which are a shift in the peak labelled A and a decrease in the peak labelled B in the case without lanthanum. We are currently using modelling to try to understand the origin of these differences.

In summary, we are currently extending the previous investigation [3,4] combining experimental and simulated EEL spectra from fullerene nanocrystals to peapod materials. We have focused on La@C_{82} peapods and have obtained experimental spectra from La@C_{82} nanocrystals and single-walled nanotubes filled with La@C_{82}.

References

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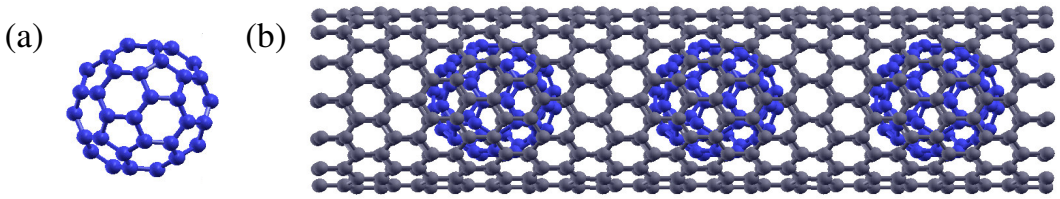

FIG. 1. Schematic drawings of a C_{60} molecule (a) and a single-walled nanotube filled with C_{60} molecules (b)

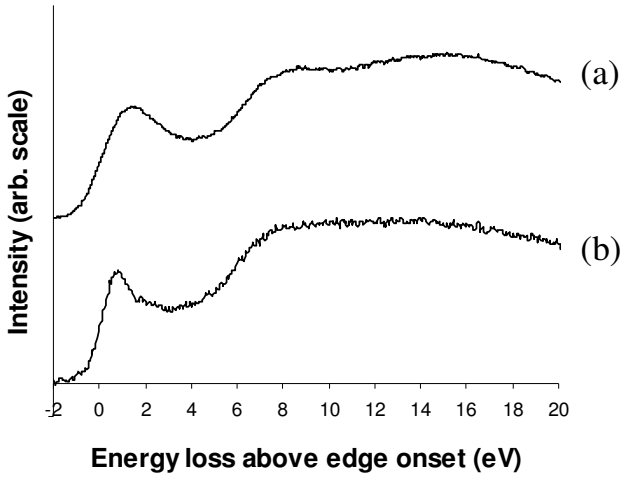

FIG. 2. Carbon K-edge from La@C_{82} (a) and C_{82} (b)

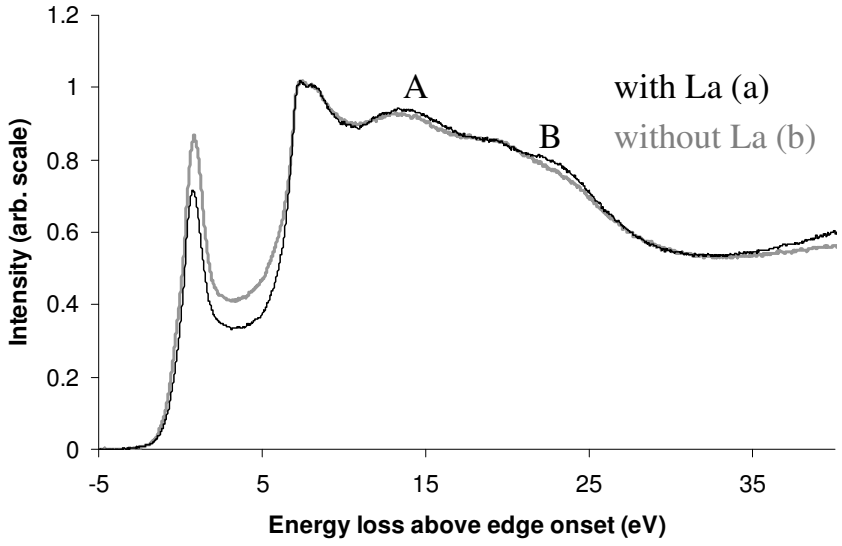

FIG. 3. Carbon K-edges from a sample of nanotubes containing La@C_{82}: one (a) is from a region with La and one (b) is from a region where there was no La (likely to be an unfilled tube)