Exploring the use of filled carbon nanotubes for biomedical applications

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Carbon nanotubes (CNTs) have been advocated as promising agents for biomedical applications including *in vivo* imaging, tumour targeting and drug delivery systems. One added advantage of using nanotubes is that their inner cavity can be filled with a chosen payload whilst the outer surface can be modified to improve their dispersability and biocompatibility.

A key step towards the characterisation and application of filled CNTs is the complete removal of the large amount of unwanted external material present after the filling step, whilst preserving the encapsulated payload (of the same nature). An absence of species outside the CNTs will reduce the side effects during targeting. We have developed two complementary methodologies for the containment of materials inside single-walled carbon nanotubes (SWCNTs), namely by closing their ends by thermal annealing[1] and by using fullerenes as corks[2]. These nanocapsules (filled and sealed SWNTs) can then be readily purified by stirring the sample in a suitable solvent.

In the context of drug delivery systems we have investigated methods that allow a controlled discharge of the encapsulated payload by lowering the pH of the media. Here, we demonstrate that removable ‘‘corking’’ of SWCNTs in aqueous media using pH sensitive ‘‘corks’’ is feasible [3]. As a test for the successful containment and release of the filling material, we chose copper and uranium salts as the cargo, not for medical or related reasons but because the presence of copper into washings can be detected with high sensitivity by UV–vis spectroscopy, and because the heavy atoms of uranium can be easily detected in filled SWCNTs by high resolution transmission electron microscopy (HRTEM). Thus, in this ‘‘proof-of-principle’’ study we demonstrate the use of acid-sensitive functionalized fullerenes as removable ‘‘corks’’ for the containment and controlled release of the cargo contained within SWCNTs by lowering of the pH in aqueous media (Figure 1). It is well known that the pH of primary tumours and regions of inflammation and infection is lower than physiological.

We will also present recent results on the development of “hot” filled SWCNTs for *in vivo* radioemitter localization and imaging [4]. The nanocapsules were prepared by first filling the SWCNTs with $Na^{125}I$, followed by their sidewall functionalisation with carbohydrates (Figure 2). Short SWCNTs were employed in this study to further improve the biocompatibility of the materials. Effectively, the nanocapsules (filled SWCNTs with closed ends) guaranteed essentially zero leakage of the radionuclide and remained stable *in vivo* for extended periods. The sealing of iodide within single-walled carbon nanotubes enabled its biodistribution to be completely redirected from tissue with innate affinity (thyroid) to lung. Surface functionalization of these nanocapsules offers versatility towards modulation of biodistribution of the radioemitting crystals in a manner determined by the capsule that delivers them.

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References

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Figures

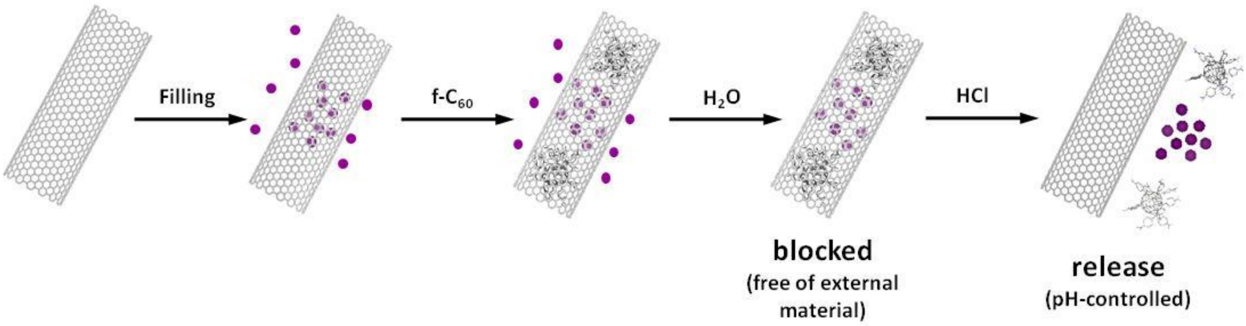

Figure 1. *Schematic representation of the use of functionalized fullerenes as removable corks for SWCNTs [3].*

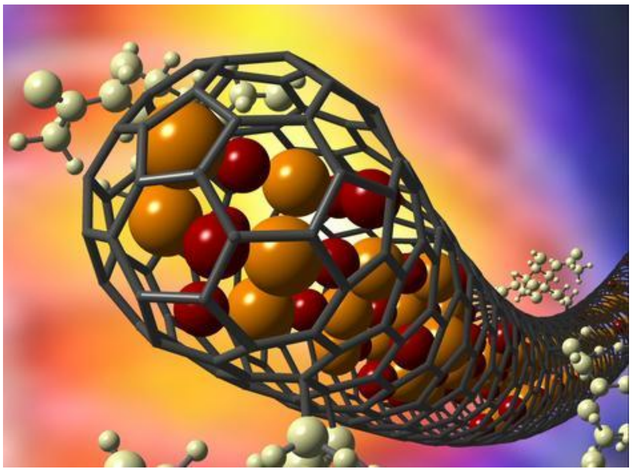

Figure 2. *Schematic representation of the "hot" nanocapsules developed encapsulation $Na^{125}I$ [4].*