NANO HIGHLIGHT
Functionalizing Nanotubes for Novel Properties and Devices – an Integrated Theoretical and Experimental Approach

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In collaboration with Prof. M. Prato (Universita' di Trieste, Italy) Francesco Stellacci and collaborators have developed a novel chemical approach to synthesize rings of single walled carbon nanotubes that have been extensively imaged with atomic force microscopy. All images showed samples composed of fully formed rings, broken rings, amorphous aggregates (of any size) and straight tubes. The percentage of straight tubes was always < 1%; indeed in most images there was no straight tube. Because of their size and size distribution (overall radius and ring thickness) we have concluded that these rings are composed of bundles of nanotubes. The main property that these nanotube rings have shown is a clear magnetic response to variable electric and magnetic fields, that we believe is due to the formation of eddy currents leading to a magnetic dipole. We have proven that these nanorings are magnetic through a series of experiments. First, we were able to image rings using magnetic force microscopy (MFM). Second, we used an alternating gradient force magnetometer (AFM) to qualitatively measure the magnetic response of the rings. We found a strong linear paramagnetic behavior. The most convincing proof of the magnetic properties came from a relatively simple experiment illustrated in Figure 1. We placed two strong permanent magnets (NdFeB 0.5 Tesla surface field) opposite to each other in the middle of two of the walls of a cuvette containing the rings. After a few minutes most of the carbon material collected at the edges of the magnets (where the magnetic field is stronger) while a certain percentage precipitated. After collecting the material near the magnet and at the bottom of the cuvette, AFM samples were separately prepared and imaged. The material found at the bottom turned out to be composed of amorphous carbon and of broken rings. In striking contrast the material collected near the magnets was primarily composed of fully formed rings and had a visibly lower percentage of amorphous carbon. Almost no broken ring was observed.

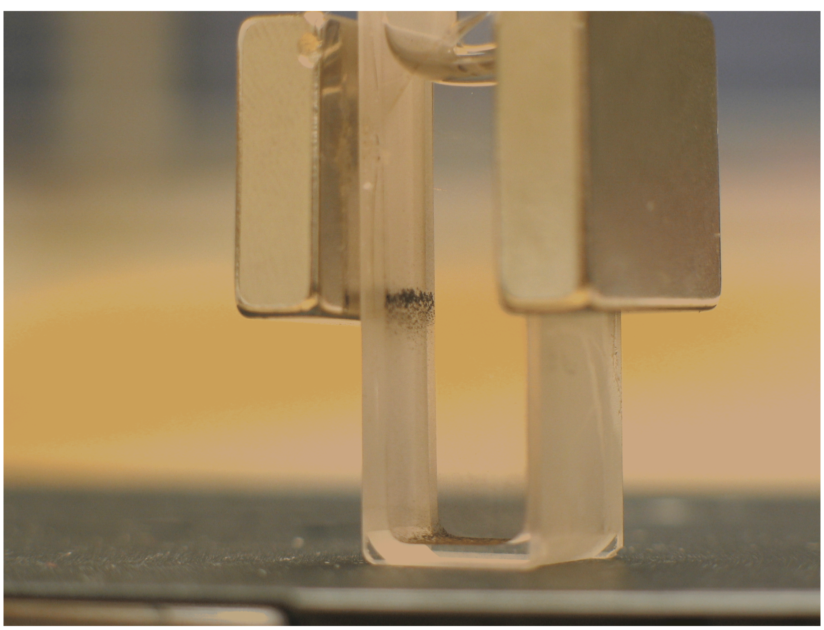

Figure 1: *Photograph of a cuvette filled with hexane on which two magnets (0.5 Tesla surface magnetism) are attached. The black powder that is viewable at the edge of the magnets is constituted on carbon nanotubes rings. The black powder at the bottom is constituted of amorphous carbon and broken rings..*