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Contactless temperature control by a carbon wrapped nanoscaled thermometer

One of the research fields at IFW Dresden focuses on the application of nanotechnology in biomedicine, especially of filled carbon nanotubes for temperature control in tumour cells. First results on the development of such a nanothermometer for biomedical application have been published recently in the scientific journal „Nanomedicine“.

Nanoparticles for diagnostics and therapeutic usage on the cellular level are already tested in medical pilot studies. The application of filled and multifunctional carbon nanotubes (CNTs) for biomedical application is the topic of investigations within e.g. the European Research Training Network (RTN) CARBIO which is coordinated at the IFW Dresden since October 2006. The idea is to use CNTs as a container for several purposes: they are able to transport sensors, heating elements as magnets as well as drugs without problematic contact between the container content and the tissue itself. Within this project, researchers at IFW are investigating magnetic fillings in CNTs, which can destroy tumour tissue by hyperthermia: filled CNTs are heated via magnetic induction in external ac-magnetic fields after being inserted into the tumour tissue. Since the hyperthermic heating has to be monitored continuously, accurate temperature control on a cellular level is mandatory. Up to now, in clinical treatments temperature is controlled by invasive methods, i.e. by placing thermocouples or fiberoptical thermometers into the tumour tissue.

Looking for a non-invasive method to control the temperature, the scientists at IFW Dresden tested several differently filled CNTs using the nuclear magnetic resonance technique (NMR). The research results within CARBIO demonstrate that multi-walled CNTs filled with copper iodide (CuI) can be used as such a nanothermometer (Fig. 1). For filling with CuI multi-walled CNTs, consisting of 10 to 40 carbon layers with the inner diameter varying from 5 to 20 nm and the typical tube length from 10-30 μm, were opened using a three-step procedure: first, the tubes were thermally treated at 450 C in air, then sonicated in HCl and finally treated with HNO_3. The opened CNT were put in a silica glass ampoule together with CuI in excess and heated at 600 C for 24 h. At this temperature CuI is completely sublimated and transported into the opened CNT thanks to the capillarity effect.

Nuclear magnetic resonance measurements reveal that the CuI-filling has temperature-dependent parameters – one of them is the spin-lattice relaxation time which is the time the nuclei of the metal filling need to return to equilibrium state after magnetic stimulation. By measuring this parameter in CuI-filled CNT, it is possible to determine the temperature in the surrounding of the CNT. These NMR investigations have been performed in the temperature range from 5 to 320 Kelvin (which equals to max. 47 ° Celsius) and hence cover the typical temperature range for a hyperthermic treatment (heating around 43 °C). For CuI-filled CNTs the observed accuracy is about 2 Kelvin, which gave a clear “proof-of-principle” for such a

nanothermometer and is a good starting point to focus on the search for other filling materials in the future in order to increase the temperature accuracy.

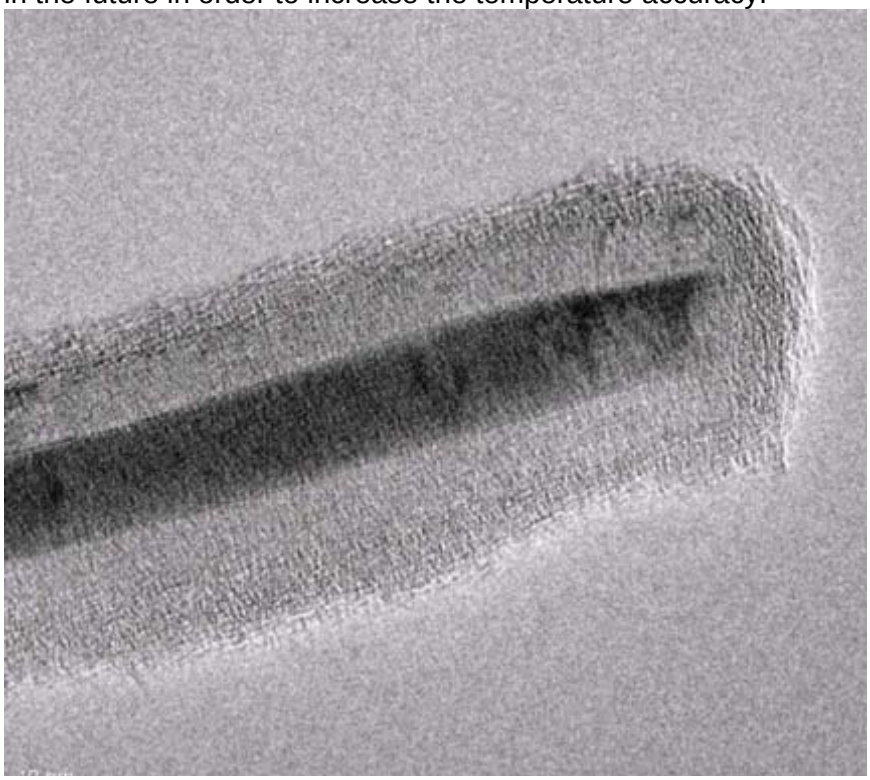

Fig.1: Transmission electron microscopy (TEM) image of a carbon nanotube (light grey) with copper iodide filling (black); inner diameter about 10 nm, outer diameter about 30 nm.

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