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CARBIO

Carbon nanotubes are the epitome of versatility: their strength and unique properties make the tiny tubes of rolled-up carbon sheets a matter of intense interest to engineers, physicists and chemists alike. Only their potential toxicity has caused some in the biomedical field to shy away. The Marie Curie-funded Carbio project has however turned a corner, making the nanotubes biocompatible and opening up a world of biomedical possibilities.

Delivering the goods: carbon nanotubes

The potential of carbon nanotubes (CNTs) as drug-carrier systems and sensors for diagnosis and therapy at a cellular level is what the Carbio team set out to explore. The idea: the hollow tubes, which can be constructed with one, two or more walls, could be filled with drugs, sensors or even heating elements and then transport their load directly to where they are needed in the human body.

A dangerous but precious cargo

Project coordinator Dr Rüdiger Klingeler of the Leibniz Institute for Solid State and Materials Research (IFW) in Dresden, Germany, is enthusiastic about the project and its results. 'Studies of CNT interaction with biological environments provide the basis for applying the tubes for imaging, sensing and cancer treatment,' he says. 'Our work packages focus on the synthesis of CNTs, biocompatibility and bioactivity, imaging and sensing, as well as hyperthermia and medical studies.'

Carbio focuses on targeted anti-tumour therapy. Current cancer therapies are not targeted, which means that they often affect healthy tissues and cause side effects for patients. Employing biocompatible CNTs could effectively change that: scientists would wrap the tubes around their miniature cargo and the wrapping would stay in place until the whole package reaches its destination. The contents of the package would then be released and allowed to get to work where they are needed, there and only there.

But how can doctors stop the nanotubes from poisoning the patient? The Carbio researchers solved that particular problem by adding another layer to the wrap – a layer of DNA and ribonucleic acid (RNA) around the CNTs to make them biocompatible.

It's a wrap!

The use of carbon-wrapped nanocontainers has numerous advantages for medical applications. First, there are a number of materials that might be toxic but which will help bring a tumour under control or destroy it. The protective carbon shell would mean that this kind of material could be used more effectively in therapy. Second, the outer shell of CNTs can be chemically modified to further enhance effectiveness. For instance, it can be made more – or less – soluble, so that a drug contained could be released rapidly or slowly, at the same time maintaining the initial physical and chemical properties of the encapsulated material.

Advances in production methods are making carbon nanotubes more viable every day. Some of these advances have been made in the framework of the Carbio project, improving the production process as well as reaching an unprecedented degree of purity in the tubes. The team has also already tested the containers with various 'fillings'. Results so far are encouraging: no significant toxic effects have been identified.

The Carbio researchers specifically studied the all-important transfer of CNTs into cells and the release of drugs in cell culture experiments. They attained one particularly significant milestone when they developed a method to use CNTs for the transport and release of the anti-cancer drugs carboplatin and doxorubicin. Both are used in chemotherapy for a wide range of cancers and commonly cause nausea, vomiting and heart arrhythmias.

But Carbio's ambitions go further: the Fellows are also looking into the potential of Magnetic Resonance Imaging (MRI) and CNTs in cancer treatment. And they have developed a nanothermometer. This ingenious device can help monitor the temperature in tumour cells during hyperthermia therapy, a therapeutic method that aims to weaken or destroy the malignant cells with intense heat. The team is already working on enhancing it further, and additional investigations will improve the accuracy of the temperature sensors.

Laying the foundations

As work on the project itself continues, the fruitful Carbio collaboration has already led to over 10 related project proposals, both on a national and European level. And the original partners are hoping to receive further funding under the EU's Seventh Framework Programme in order to keep up the momentum of this ground-breaking research. Several patents are also pending, on *Particles for determining the local temperature*, for example.

Perhaps even more important, though, is the impact that the Marie Curie project has had on the relatively young field of CNT research. The Fellows' mobility has enabled them to spread their knowledge elsewhere and to fortify collaborations within the field. All Fellows have visited partner institutions several times and have conducted research together with their co-Fellow hosts. In addition, periodic Carbio meetings provide a fruitful platform for scientific discussions within the network, while workshops and summer schools bring the researchers together. An impressive 74 publications are already in print, bearing testament to Carbio's scientific success.

Dr Klingeler is convinced that part of this success is due to the consortium's truly interdisciplinary nature. Biologists, engineers and physicists from Germany, France, the Netherlands, Austria, Poland and the UK have joined forces on the Carbio project, which 'provides an excellent example of a multidisciplinary training network', Dr Klingeler says. *'No one lab in this consortium can work without the input of several of the partners and, as a result, the early-stage researchers have an extremely good overview of the work of the Carbio network as a whole. The laboratory leaders come from chemistry, clinical, biochemical and physics backgrounds, and the fact that they can communicate from such a diverse base is a triumph,'* he concludes.

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Lead partner ■ Leibniz Institute for Solid State and Materials Research (IFW) Dresden
Helmholtzstr. 20
DE-01069 Dresden
Tel. +49 351 4659 666 // Fax +49 351 4659 9666
E-mail: R.Klingeler@ifw-dresden.de

Other partners ■ Université Paul Sabatier, France - Zachodniopomorski Uniwersytet Technologczny (West Pomeranian University of Technology), Poland - University of Surrey, United Kingdom - The Chancellor, Masters and Scholars of the University of Oxford, United Kingdom - Johannes Kepler Universität Linz, Austria - Universteit Twente, Netherlands - Technische Universität Dresden, Germany