Reactions in tiny containers—towards the world's smallest coaxial cable

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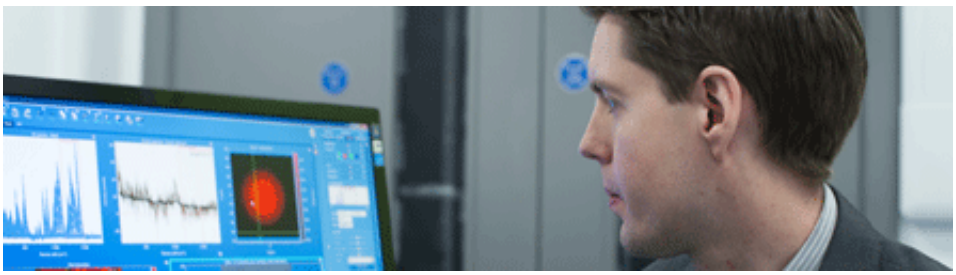

Credit: University of Nottingham

As electronic devices continue to shrink to meet the demand for pocket sized and wearable technology, scientists are working to develop the minute components that make them work and a team at the University of Nottingham have developed a new approach for the preparation of a coaxial cable around 50,000 times narrower than the width of a human hair.

This miniscule wire – comprising a carbon nanotube located inside a boron nitride nanotube – can be produced on a preparative scale and may represent an important step towards the miniaturisation of electronic devices.

The multi-national team of experts from the UK and Hungary, was jointly led by Andrei Khlobystov, a Professor of Nanomaterials and Director of the University of Nottingham's Nanoscale and Microscale

Research Centre (nmRC), and Graham Rance, a Research Fellow in Nanomaterials Characterisation at the nmRC, who possess complementary expertise in the synthesis and characterisation of carbon nanomaterials. The study entitled 'Growth of carbon nanotubes inside boron nitride nanotubes by coalescence of fullerenes: toward the world's smallest coaxial cable' has been published in *Small Methods*, a new journal focused on cutting-edge developments in experimental approaches to the production of nano- and microscale materials.

Coaxial cables – essential for the safe transport of electric current that power modern-day devices – are typically made up of an inner conductor (usually copper) surrounded by an insulating plastic jacket. However, as consumer demand for smaller electronic devices increases, the limit to which these current materials can be used is rapidly being reached. Copper, for instance, is known to lose its high conductivity when scaled down to very small sizes and thus new materials are becomingly increasingly important.

Miniature wires

Carbon nanotubes are strong, lightweight and, most importantly, highly electrically conducting miniature wires, typically 1-5 nanometres in diameter, but up to centimetres in length, and are ideal for the core of an insulated nanoscale cable. Boron nitride nanotubes, whilst structurally similar to carbon nanotubes, by comparison are electrically insulating, perfect for surrounding the conducting core. The challenge was to arrange these two nanoscale materials one inside the other in the required co-axial geometry. This research has shown that by placing small, football-shaped, carbon-rich molecules (C60-fullerenes) inside boron nitride nanotubes and heating the resultant materials to very high temperatures (above 1000 oC), the fullerenes spontaneously transform into carbon nanotubes, leading to the formation of an electrically conducting carbon nanotube inside an electrically insulating boron

nitride nanotube – the world's smallest coaxial cable.

Professor Khlobystov said: "Currently most modern technologies are heavily dependent on the use of metals, some of which are becoming increasingly rare and costly. Therefore, there is a need to work towards replacing metals with more abundant and sustainable elements, such as carbon and other light elements. Our study demonstrates the principle of how nanoscale cables with conducting cores and insulating shells can be fabricated from simple ingredients. The next challenge is to test their electrical and mechanical properties to determine the scope of these materials for technological applications."

Broad ranging applications

Dr Rance said: "Our approach for the preparation of a miniaturised coaxial cable further explores the ability of hollow nanoscale tubules to control the formation of new and interesting nanostructures inside the inner cavity, some that cannot be prepared in any other way. On a fundamental level, this research is helping us to understand the behaviour of molecules when confined to very small spaces; however, on a more practical level, we anticipate this strategy will lead to the production of novel materials, with potentially broad ranging applications, from nanoscale electronics, to catalytic materials and in sensing devices."

The research was carried out by experts in synthetic and analytical chemistry, materials science and electron microscopy and builds the concept of carbon nano test tubes developed by Prof. Khlobystov (World's tiniest test tubes, Guinness Book of World Records 2005), where the nanotube acts simultaneously as a container for molecules and a reaction vessel for chemical transformations. His pioneering work on carbon nano-containers and nano-reactors continues to lead to new ways of directing molecular assembly and studying chemical reactions.

Professor Katalin Kamaras, Research Professor and expert in vibrational spectroscopy collaborated on the research, with her team working at the Wigner Research Centre for Physics of the Hungarian Academy of Sciences in Budapest. Professor Kamaras said: "My research group has been working on the spectroscopy of carbon nanostructures for a long time. Spectroscopy yields knowledge on the internal dynamics of the encapsulated molecules and can follow their transformations based on their physical properties. Through our collaboration with Prof. Khlobystov it became possible to "see" the structures we had only indirect information on. This joint research has the potential of opening new possibilities in both fundamental and applied materials science."

The UK research was performed at the state of the art Nanoscale and Microscale Research Centre (nmRC). The vision of the centre is to become a world-leading facility for the characterisation and analysis of molecular materials at the nano and microscale. With a unique suite of 20 major instruments the centre is staffed by experts with medical, scientific and engineering backgrounds. They are currently working on a wide range of research from cancer cells and 3-D printed medical implants to semiconductors and solar cells.

More information: Kate E. Walker et al. Growth of Carbon Nanotubes inside Boron Nitride Nanotubes by Coalescence of Fullerenes: Toward the World's Smallest Coaxial Cable, *Small Methods* (2017). DOI: 10.1002/smtd.201700184

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