Tailored carbon could help treating neurological diseases

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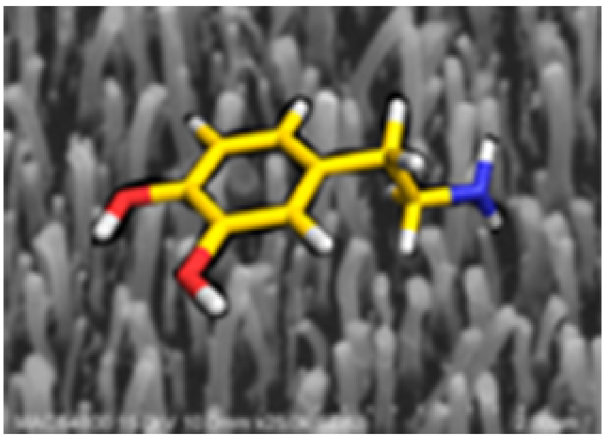

Image of carbon nanofibre surface with a modelled dopamine molecule on top, taken with a scanning electronic microscope. Credit: University of Helsinki

Tomi Laurila's research topic has many quirky names.

"Nanodiamond, nanohorn, nano-onion...," lists off the Aalto University Professor, recounting the many nano-shapes of carbon. Laurila is using these shapes to build new materials: tiny sensors, only a few hundred nanometres across, that can achieve great things due to their special characteristics.

For one, the sensors can be used to enhance the treatment of neurological conditions. That is why Laurila, University of Helsinki Professor Tomi Taira and experts from HUS (the Hospital District of

Helsinki and Uusimaa) are looking for ways to use the sensors for taking electrochemical measurements of biomolecules. Biomolecules are e.g. neurotransmitters such as glutamate, dopamine and opioids, which are used by nerve cells to communicate with each other.

"Most of the drugs meant for treating neurological diseases change the communication between nerve cells that is based on neurotransmitters. If we had real time and individual information on the operation of the neurotransmitter system, it would make it much easier to for example plan precise treatments," explains Taira.

Due to their small size, carbon sensors can be taken directly next to a nerve cell, where the sensors will report what kind of neurotransmitter the cell is emitting and what kind of reaction it is inducing in other cells.

"In practice, we are measuring the electrons that are moving in oxidation and reduction reactions," Laurila explains the operating principle of the sensors.

"The advantage of the sensors developed by Tomi and the others is their speed and small size. The probes used in current measurement methods can be compared to logs on a cellular scale – it's impossible to use them and get an idea of the brain's dynamic," summarizes Taira.

Feedback system and memory traces

For the sensors, the journey from in vitro tests conducted in glass dishes and test tubes to in vivo tests and clinical use is long. However, the researchers are highly motivated.

"About 165 million people are suffering from various neurological diseases in Europe alone. And because they are so expensive to treat, neurological diseases make up as much as 80 per cent of health care costs," tells Taira.

Tomi Laurila believes that carbon sensors will have applications in fields such as optogenetics. Optogenetics is a recently developed method where a light-sensitive molecule is brought into a nerve cell so that the cell's electric operation can then be turned on or off by stimulating it with light. A few years ago, a group of scientists proved in the scientific journal *Nature* that they had managed to use optogenetics to activate a memory trace that had been created previously due to learning. Using the same technique, researchers were able to demonstrate that with a certain type of Alzheimer's, the problem is not that there are no memory traces being created, but that the brain cannot read the traces.

"So the traces exist, and they can be activated by boosting them with light stimuli," explains Taira but stresses that a clinical application is not yet a reality. However, clinical applications for other conditions may be closer by. One example is Parkinson's disease. In Parkinson's disease, the amount of dopamine starts to decrease in the cells of a particular brain section, which causes the typical symptoms such as tremors, rigidity and slowness of movement. With the sensors, the level of dopamine could be monitored in real time.

"A sort of feedback system could be connected to it, so that it would react by giving an electric or optical stimulus to the cells, which would in turn release more dopamine," envisions Taira.

"Another application that would have an immediate clinical use is monitoring unconscious and comatose patients. With these patients, the level of glutamate fluctuates very much, and too much glutamate damages the nerve cell – online monitoring would therefore improve their treatment significantly.

Atom by atom

Manufacturing carbon sensors is definitely not a mass production process; it is slow and meticulous handiwork.

"At this stage, the sensors are practically being built atom by atom," summarises Tomi Laurila.

"Luckily, we have many experts on carbon materials of our own. For example, the nanobuds of Professor Esko Kauppinen and the carbon films of Professor Jari Koskinen help with the manufacturing of the sensors. Carbon-based materials are mainly very compatible with the human body, but there is still little information about them. That's why a big part of the work is to go through the electrochemical characterisation that has been done on different forms of carbon."

The sensors are being developed and tested by experts from various fields, such as chemistry, materials science, modelling, medicine and imaging. Twenty or so articles have been published on the basic properties of the materials. Now, the challenge is to build them into geometries that are functional in a physiological environment. And taking measurements is not simple, either.

"Brain tissue is delicate and doesn't appreciate having objects being inserted in it. But if this were easy, someone would've already done it," conclude the two.

Provided by University of Helsinki

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