Defective nanotubes turned into light emitters

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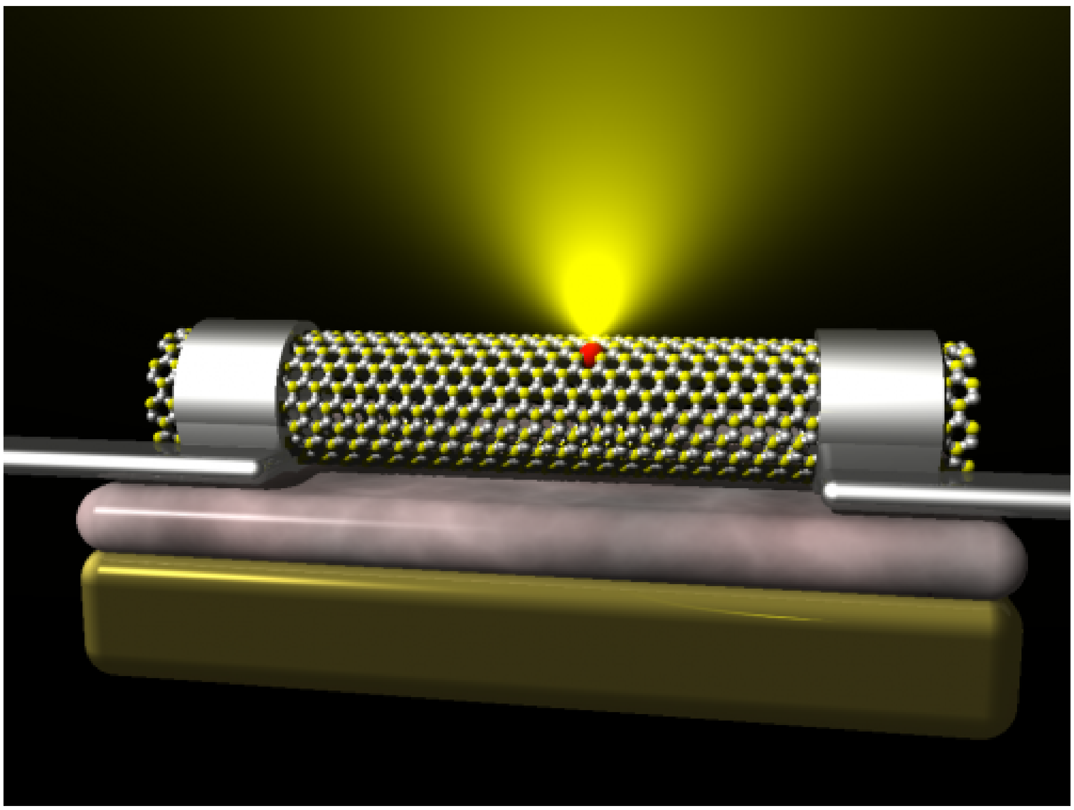

This is a diagram of the device proposed by the UPV/EHU's NanoBio Spectroscopy Group. The result has led to the patent for a new source of light emission; its main feature is that it emits across the whole of the visible and ultraviolet spectrum at ambient temperature, and can be produced using standard manufacturing methods. Credit: UPV/EHU

Scientists are usually after defect-free nano-structures. Yet in this case the UPV/EHU researcher Angel Rubio and his collaborators have put the structural defects in boron nitride nanotubes to maximum use. The outcome of his research is a new light-emitting source that can easily be incorporated into current microelectronics technology. The research has also resulted in a patent.

Boron nitride is a promising material in the field of nanotechnology, thanks to its excellent insulating properties, resistance and two-dimensional structure similar to graphene. And specifically, the properties of hexagonal boron nitride, the focus of this research, are far superior to those of other metals and semiconductors currently being used as light emitters, for example, in applications linked to optical storage (DVD) or communications. "It is extremely efficient in ultraviolet light emission, one of the best currently available on the market," remarked the UPV/EHU researcher Angel Rubio.

However, the light emission of boron nitride nanotubes takes place within a very limited range of the ultraviolet spectrum, which means they cannot be used in applications in which the emission needs to be produced within a broader range of frequencies and in a controlled way (for example in applications using visible light).

The research carried out by the UPV/EHU's NanoBio Spectroscopy Group has come up with a solution to overcome this limitation, and open up the door to the use of hexagonal boron nitride nanotubes in commercial applications.

They have shown that by applying an electric field perpendicular to the nanotube, it is possible to get the latter to emit light across the whole spectrum from the infrared to the far ultraviolet and to control it in a simple way. This ease of control is only to be found in nanotubes due to their cylindrical geometry (these are tubular structures with lengths in the order of micrometres, and diameters in the order of nanometres).

Rubio has been working with boron nitride nanotubes for nearly 20 years. "We proposed them theoretically, and then they were found experimentally. So far, all our theoretical predictions have been confirmed, and that is very gratifying," he explained. Once the properties of layered hexagonal boron nitride and its extremely high efficiency in light emission were known, this research sought to show that these properties are not lost in nanotubes. "We knew that when a sheet was rolled up and a tube was formed, a strong coupling was produced with the electric field and that would enable us to change the light emission. We wanted to show," and they did in fact show, "that light emission efficiency was not being lost due to the fact that the nanotube was formed, and that it is also controllable."

Boron absences

The device functions on the basis of the use of natural (or induced) defects in boron nitride nanotubes. In particular, the defects enabling controlled emission are the gaps that appear in the wall of the nanotube due to the absence of a boron atom, which is the most common defect in its manufacture. "All nanotubes are very similar, but the fact that you have these defects makes the system operational and efficient, and what is more, the more defects you have, the better it functions."

Rubio highlighted "the simplicity" of the device proposed. "It's a device that functions with defects, it does not have to be pure, and it's very easy to build and control." Nanotubes can be synthesised using standard methods in the scientific community for producing inorganic nanotubes; the structures synthesised as a result have natural defects, and it is possible to incorporate more if you want by means of simple, post-synthesis irradiation processes. "It has a traditional transistor configuration, and what we are proposing would work with current electronic devices," he stressed. The "less attractive" part, as specified by Rubio, is that boron nitride nanotubes are still only produced in very small quantities, and as yet there is no economically viable synthesis process on a commercial scale.

Beyond graphene

Rubio is in no doubt about the potential of the new materials based on two-dimensional systems, and specifically, of compounds that offer an alternative to graphene, like, for example, hexagonal boron nitride. Without prejudice to graphene, Rubio believes that the alternative field could have greater potential in the long term and needs to be explored: "It's a field that has been active for over the last fifteen years, even though it has been less visible. We have been working with hexagonal boron nitride since 1994, it's like our child, and I believe that it has opened up an attractive field of research, which more and more groups are joining."

More information: Claudio Attaccalite, Ludger Wirtz, Andrea Marini, Angel Rubio. Efficient Gate-tunable light-emitting device made of defective boron nitride nanotubes: from ultraviolet to the visible. *Scientific Reports* 3, 2698 (2013) (Nature Publishing Group) dx.doi.org/10.1038/srep02698

Provided by Elhuyar Fundazioa

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