Tunable light emission from a boron nitride nanotube device

Scientists have worked hard in the last few decades to grow nanostructures free of defects. The near-perfect atomic arrangements obtained at the nanometre scale have been employed to create new, efficient devices such as light-emitters, transistors and sensors. However, while many applications benefit from using defect-free materials, the presence of certain defects can generate new and fascinating properties. In the study described here, we have shown that the structural defects that exist in Boron Nitride nanotubes can be put to maximum use as a variable wavelength light source. The outcome of this research is a patent for a light-emitting source that can easily be incorporated into current microelectronics technology.

Boron Nitride BN is a promising material in the field of nanotechnology, thanks to its excellent insulating properties, its high mechanical strength, and its two-dimensional crystal structure similar to graphene. And specifically, the properties of hexagonal boron nitride nanotubes, the focus of this research, appear far superior to those of other materials currently being used as light emitters, for example, in applications linked to optical storage (DVD's...) or communications.

Boron nitride is extremely efficient in ultraviolet light emission, one of the best materials currently available. However, boron nitride nanotubes emit light in a very limited range of the ultraviolet spectrum. This means they cannot be used in applications where the emission needs to be produced in a controlled way over a broad range of wavelengths (including in the visible spectrum).

We have found a solution to overcome this limitation, which opens the way to the use of hexagonal BN nanotubes in commercial applications. By means of numerical simulations, we have investigated light emission in BN nanotubes in the presence of defects. We have shown that, by applying an electric field perpendicular to a nanotube containing particular lattice defects (atomic vacancies, carbon impurity atoms), it will be possible to get the nanotubes to emit light across the whole spectrum from the infrared to the far ultraviolet and to control the wavelength in a simple way (see Fig. 1). This easy tuning by an electric field is only to be found with nanotubes. It is related to their cylindrical geometry (they are tubular structures with diameters of order nanometres, lengths of order microns). These predictions of the theory show the way to new devices based on BN nanotubes.

The generic configuration of the proposed device (see Fig. 2) comprises as-grown BN nanotubes deposited on an insulating surface that acts as a dielectric, to enable the application of the gated electric field that tunes the light emission. The configurations is very similar to that of a Field Effect Transistor (FET).

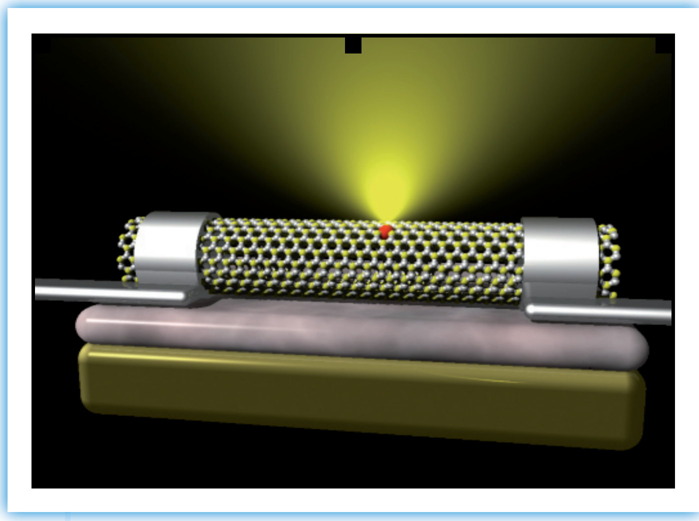

Fig. 2: Schematic set-up for the proposed method of activating an optoelectronic device based on Boron Nitride nanotubes with lattice defects (red dot). The method uses an ambipolar transistor configuration. BN nanotubes are deposited on an insulating surface that acts as a gate dielectric to enable application of the transverse electric field that controls the wavelength of the light emission.

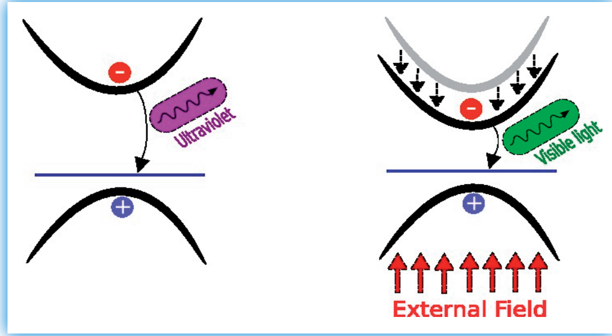

Fig. 1: Simplified band structure diagram for a BN nanotube with and without application of a perpendicular electric field. The electric field shifts the conduction band relative to the defect level (blue line), thus tuning the wavelength of the light emitted when an electron and a hole annihilate at the defect.

CONTACT

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FURTHER READING

Efficient Gate-tunable light-emitting device made of defective boron nitride nanotubes: from ultraviolet to the visible
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C. Attaccalite, M. Bockstedte, A. Marini, A. Rubio, L. Wirtz
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