GaN microrods on graphene substrates enable bendable optoelectronics devices

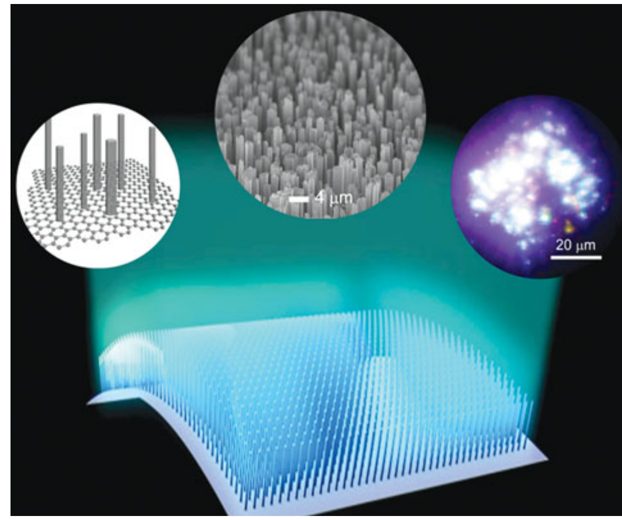
"Bendy" light-emitting diode (LED) displays and solar cells crafted with inorganic compound semiconductor microrods are moving one step closer to reality, thanks to graphene and the work of a team of researchers at Seoul National University (SNU).

While most flexible electronics and optoelectronics devices are fabricated using organic materials, inorganic compound semiconductors such as GaN can provide further advantages, including superior optical, electrical, and mechanical properties. One major obstacle to their use, however, is the difficulty of growing them on flexible substrates.

In the September issue of *APL Materials* (DOI: 10.1063/1.4894780), Gyu-Chul Yi and colleagues describe their work growing GaN microrods on graphene to create transferable LEDs and enable the fabrication of bendable and stretchable devices.

"GaN microstructures and nanostructures are garnering attention within the research community as light-emitting devices because of their variable-color light emission and high-density integration properties," says Yi. "When combined with graphene substrates, these microstructures also show excellent tolerance for mechanical deformation."

Ultrathin graphene films consist of weakly bonded layers of hexagonally arranged carbon atoms held together by strong covalent bonds. This makes graphene an ideal substrate "because it provides the desired flexibility with excellent mechanical strength—and it's also chemically and physically stable at temperatures in excess of 1000°C," says Yi.



Rendering of the microrod growth process. Credit: Seoul National University.

For the GaN microrod growth, the very stable and inactive surface of graphene offers a small number of nucleation sites for GaN growth, which would enhance three-dimensional island growth of GaN microrods on graphene. The team uses a catalyst-free metal–organic chemical vapor deposition (MOCVD) process.

"Among the technique's key criteria, it's necessary to maintain high crystallinity, control over doping, formation of heterostructures and quantum structures, and vertically aligned growth onto underlying substrates," Yi says.

When the team put the microrod LEDs to the test, they found that "the resulting flexible LEDs showed intense electroluminescence (EL) and were reliable—there was no significant degradation in optical performance after 1000 bending cycles," says Kunook Chung, the article's lead author and graduate student at SNU.

"By taking advantage of larger-sized graphene films, hybrid heterostructures can be used to fabricate various electronics and optoelectronics devices such as flexible and wearable LED displays for commercial use," says Yi.

Hybrid device functions as self-recovering electrochromic window and self-charging battery

Smart windows are finding many uses in architectural and vehicle applications. Their ability to reversibly switch from transparent to opaque provides important functionality, like reducing solar heat gain and glare, without sacrificing the benefits of broad views and natural lighting. However, one practical challenge for using them in buildings is the need for an external bias voltage, which means that electricians must run extra electrical wiring, increasing installation and maintenance costs. Now, X.W. Sun and colleagues at Nanyang Technological University and Shanghai Second Polytechnic University have developed a hybrid device that functions as a spontaneously reversible electrochromic window that does not need an external bias, and also as a self-recharging battery. They reported their results in the September 23 issue of *Nature Communications* (DOI: 10.1038/ncomms5921).

The widespread use of smart windows in buildings could save large amounts of energy, particularly in heat-dominated climates through reduced air conditioning. While their market penetration today is small, a recent analysis by IDTechEx predicts that the smart glass market will grow to $700 million over the next 10 years. The most mature smart window technology uses the electrochromic properties of thin-film tungsten oxide (WO_3), which is normally transparent. Under an external bias, charge-balancing ions (typically Li^+ from a nickel oxide counter electrode) are intercalated into the film, increasing the optical density and making the film opaque. In pursuit of lower costs, researchers have looked to other materials that display electrochromism. One

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