# Novel hybrid material may inspire highly efficient next-gen displays

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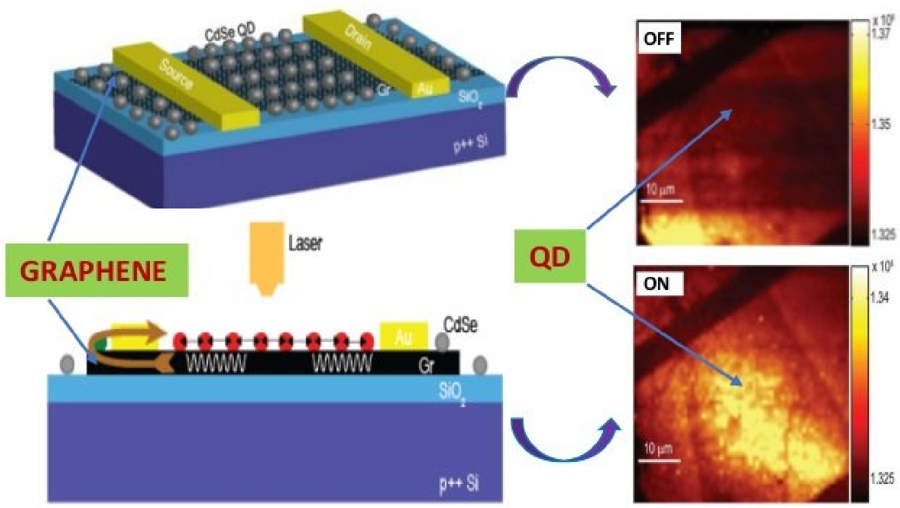


Credit: Basu et al.

Researchers at the Indian Institute of Science (IISc) have created a novel hybrid of graphene and quantum dots, a breakthrough that may inspire highly efficient and controllable next-generation displays and LEDs.

Quantum dots are semiconductor nanocrystals with the potential to revolutionize diverse technologies,including photovoltaics, medical imaging and quantum computing. They can absorb UV light and produce sharp, bright colours, making them especially attractive for next-generation TVs, smartphones and LEDs. However, they are poor electrical conductors, and therefore inefficient to use in devices on their own. To improve their efficiency, researchers have tried combining them with graphene, an excellent conductor. Adding graphene would also confer the ability to tinker with the output even after fabrication, or turn the device on and off at will.

Although the combination works well for photo-detectors and sensors, it is practically useless for displays and LEDs, because quantum dots lose their ability to emit light when fused with graphene. By modifying some experimental conditions, IISc scientists have found a way to eliminate this effect and create a highly efficient and tunable hybrid material. The results, published in *ACS Photonics*, open up possibilities for a new generation of state-of-the-art displays and LEDs.

Quantum dots are extremely tiny particles with properties vastly superior to conventional semiconductors. When activated by UV light, they can produce visible light in different colours depending on their size. Small dots produce blue light, for example, while large ones radiate red.

They absorb light very well, but they are poor electrical conductors; quantum dot-based devices that convert light to electricity are therefore not very efficient. Graphene, on the other hand, is almost transparent to light, but it is an excellent electrical conductor. When the two are combined, graphene could, in principle, quickly pull the absorbed energy away from quantum dots, cutting down energy loss, and convert it to an electrical signal, for example. This makes it possible to create devices such as photo detectors with extremely high efficiency.

"You get the best of both," says senior author Jaydeep Kumar Basu, professor, Department of Physics, IISc.

On the flip slide, the energy transfer to graphene leaves quantum dots with almost no energy left to emit light, making it impossible to use them in displays or LEDs.

"That is one area where the application of these hybrid materials has not taken off because of this effect," says Basu. "Graphene acts like a sponge, as far as the quantum dots are concerned. It does not allow any emission."

Basu's team tried to overcome this "quenching" effect by bringing into play a phenomenon called superradiance. When individual atoms or emitters (such as quantum dots) in a layer are excited, each one emits light independently. Under certain conditions, all the atoms or emitters can be made to emit light cooperatively. This produces a very bright light, with an intensity significantly greater than the sum total of individual emissions.

In a previous study, Basu's team was able to bring about superradiance in a thin layer of quantum dots by combining it with metal nanoparticles under certain experimental conditions. They recreated those conditions in the new quantum dot-graphene hybrid devices to produce superradiance, which was strong enough to compensate for the quenching. Using models, they found that this happens when individual quantum dots are 5 nm or less apart, and the quantum dot layer and graphene are separated by a distance of 3 nm or less.

"We have shown for the first time that we are able to get away from this 'sponge' effect, and keep the emitters alive," says Basu.

When superradiance dominated, the intensity of light emitted in the presence of graphene was also found to be three times higher than what could have been achieved using quantum dots alone.

"The advantage with graphene is that you can also tune it electrically," says Basu. "You can vary the intensity by simply changing the voltage or the current."

The study also opens up new avenues for research on understanding how light and matter interact at the nanoscale, the authors say.

**More information:** Electrically Tunable Enhanced Photoluminescence of Semiconductor Quantum Dots on Graphene, published in *ACS Photonics*, June 2017.
pubs.acs.org/doi/abs/10.1021/acsphotonics.7b00266

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