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Infrared LEDs can be made cheaper, compatible with silicon

By Anne Ju

Light-emitting diodes at infrared wavelengths are the magic behind such things as night vision and optical communications, including the streaming data that comes through Netflix. Cornell researchers have advanced the process of making such LEDs cheaper and easier to fabricate, which could lead to ultra-thin LEDs painted onto silicon to replace computer wiring with light waves.

The research group led by Frank Wise, professor of applied and engineering physics, reported online May 6 in the journal Nature Nanotechnology that they have used solution chemistry to make infrared LEDs out of nanocrystals, commonly known as quantum dots, out of lead sulfide.

Their process, which involves tuning emitted wavelengths based on controlling the size of the nanocrystals, could rival the effective, but expensive, practice of growing semiconductor materials using the atom-by-atom process known as epitaxy. The Cornell nanocrystal LEDs are about as bright as epitaxially grown LEDs, but they were made using low-temperature, solution-based processing that is much cheaper.

Infrared LEDs are usually made of crystals of such materials as indium gallium arsenide, and they cannot be grown on silicon due to their different crystal structures, Wise explained. Thus far there has been no natural way to make light-emitting materials on silicon.

Getting electrons to flow through nanocrystals is a major challenge, Wise said. The Cornell team did it with some clever chemistry: They changed the distance between the nanocrystals by changing the molecules on their surfaces. Longer carbon chains produced bigger spacing, which dramatically affected the efficiency of light emission. Changing the distance between nanocrystals by half a nanometer made the devices 100 times more efficient, Wise said. The researchers found the optimum distances between nanocrystals to make the LEDs emit the brightest light. They measured those distances using X-ray scattering technology provided by the Cornell High Energy Synchrotron Source (CHESS).

Because the Cornell-developed LEDs were made through solution processing, they can be more easily integrated with other materials. They could lead to such breakthroughs as the ability to "paint" the LEDs onto silicon, for example. Such an application would hold sway in optical interconnects, replacing electrical wires that are now a bottleneck for speed of the modern computer chip. Communication between chips with a light wave, rather than a wire, is expected to revolutionize information processing.

The nanocrystals the researchers used have struck interest among people making photovoltaic cells, too. A solar cell absorbs light and emits electrons as electric current, which can supply power. Lead sulfide and lead selenide nanocrystals are leading candidates for replacing cadmium telluride and other materials found in commercial solar cells today.

The paper's co-authors are Tobias Hanrath, assistant professor of chemical and biomolecular engineering, and George Malliaras, formerly an associate professor of materials science and engineering at Cornell; as well as former postdoctoral associate Liangfeng Sun; graduate students Joshua J. Choi, David Stachnik and Adam Bartnik (now a staff member at Wilson Laboratory); and postdoctoral associate Byung-Ryool Hyun.

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