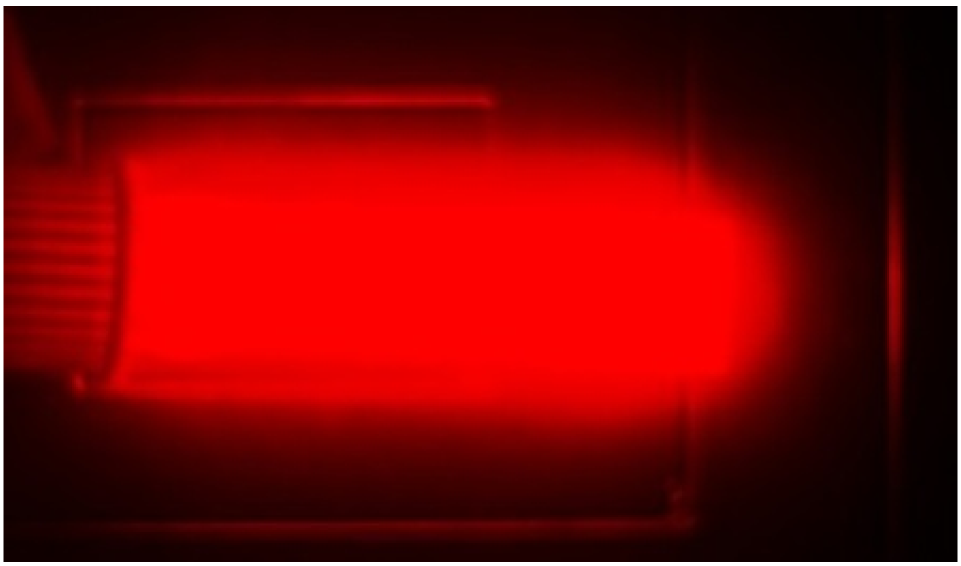
Tiny, brightly shining silicon crystals could be safe for deep-tissue imaging

July 31 2013, by Charlotte Hsu



Bright light emission from silicon quantum dots in a cuvette. The image is from a camera that captures the near-infrared light that the quantum dots emit. The light emission shown is a psuedo color, as near-infrared light does not fall in the visible spectrum. Credit: Folarin Erogbogbo

Tiny silicon crystals caused no health problems in monkeys three months after large doses were injected, marking a step forward in the quest to bring such materials into clinics as biomedical imaging agents, according to a new study.

The findings, published online July 10 in the journal *ACS Nano*, suggest that the silicon nanocrystals, known as quantum dots, may be a safe tool for diagnostic imaging in humans. The nanocrystals absorb and emit light in the near-infrared part of the spectrum, a quality that makes them ideal for seeing deeper into tissue than traditional fluorescence-based techniques.

"Quantum dots, or nanocrystals, are very, very promising for biomedical imaging applications, but everyone's worried about the toxicity and what will happen to them if they degrade," said co-lead author Folarin Erogbogbo, a University at Buffalo research assistant professor who has since accepted a new position as an assistant professor of biomedical engineering at San Jose State University. "Silicon nanocrystals can be the solution to that because they don't contain materials like cadmium that are found in other quantum dots, and are generally considered to be nontoxic."

The study was a collaboration between UB, Chinese PLA General Hospital in China, San Jose State University, Nanyang Technological University in Singapore and Korea University in South Korea. It's part of a larger body of research that many of the team members have been conducting to investigate the effect of various nanoparticles in animal models.

The researchers tested the silicon quantum dots in rhesus macaques and mice, injecting each animal with 200 milligrams of the particles per kilogram of the animal's weight.

Blood tests taken for three months afterward showed no signs of toxicity in either the mice or monkeys, and all of the animals appeared healthy over the course of the study. The subjects ate, drank, groomed, explored and urinated normally.

The silicon crystals did, however, gather and stay in the livers and spleens of the mice, resulting in side effects including inflammation and spotty death of liver cells.

Interestingly, the same thing did not happen with the rhesus macaques: The monkeys' organs appeared normal, without the damage seen in the mice.

This discrepancy raises the question of how useful toxicity studies on mice can be in determining a nanocrystal's potential effect on humans, said co-author Paras Prasad, SUNY Distinguished Professor in chemistry, physics, electrical engineering and medicine at UB, and executive director of UB's Institute for Lasers, Photonics and Biophotonics.

Quantum dots and other nanoparticles—because of their tiny size—can access parts of the body where larger particles just can't go. Due to this and other factors, the differences in anatomic scale between mice and primates may matter more in nanomedicine than in other pharmaceutical fields, Prasad said.

"Even at high doses, we didn't see any adverse side effects at all in monkeys despite the problems in mice," Prasad said. "This is the first test of these silicon quantum dots in primates, and the research results mark a step forward toward potential clinical applications."

The fact that the silicon did not biodegrade in the mice was very surprising, said co-author Mark Swihart, a UB professor of chemical and biological engineer and co-director of UB's New York State Center of Excellence in Materials Informatics.

"Generally, people assume that silicon quantum dots will biodegrade," Swihart said. "We didn't see that happen, and we think this might be due to the fact that we capped the surface with organic, FDA-approved molecules to keep the quantum dots from degrading too fast.

"We may have done too good of a job of protecting them," Swihart continued. "If you really kept your car beautifully waxed all the time, it would never rust. That's what we've done with these quantum dots."

More information: pubs.acs.org/doi/abs/10.1021/nn4029234

Provided by University at Buffalo

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