Silicon nanoparticles replace expensive semiconductors

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An international team of researchers led by Russian scientists has developed a new method of using silicon nanoparticles instead of expensive semiconductor materials for certain types of displays and other optoelectronic devices.

Lomonosov MSU physicists found a way to "force" silicon nanoparticles to glow in response to radiation strongly enough to replace expensive semiconductors used in the display business. According to Maxim Shcherbakov, researcher at the Department of Quantum Electronics of Moscow State University and one of the authors of the study, the method considerably enhances the efficiency of nanoparticle photoluminescence.

The key to the technique is photoluminescence—the process by which materials irradiated by visible or ultraviolet radiation respond with their own light, but in a different spectral range. In the study, the material glows red.

In some modern displays, semiconductor nanoparticles, or so-called quantum dots, are used. In quantum dots, electrons behave completely unlike those in the bulk semiconductor, and it has long been known that quantum dots possess excellent luminescent properties. Today, for the purposes of quantum-dot based displays, expensive and toxic materials are used; therefore, researchers have explored the use of silicon, which is cheaper and well understood. It is suitable for such use in all respects except one—silicon nanoparticles weakly respond to radiation, which is not appealing for optoelectronic industry.

Scientists all over the world have sought to solve this problem since the beginning of the 1990s, but until now, no significant success has been achieved. The breakthrough idea about how to "tame" silicon originated in Sweden, at the Royal Institute of Technology, Kista. A post-doctoral researcher named Sergey Dyakov, a graduate of the MSU Faculty of Physics and the first author of the paper, suggested placing an array of silicon nanoparticles in a matrix with a non-homogeneous dielectric medium and covering it with golden nanostripes.

"The heterogeneity of the environment, as has been previously shown in other experiments, allows to increase the photoluminescence of silicon by several orders of magnitude due to the so-called quantum confinement," says Maxim Shcherbakov. "However, the efficiency of the light interaction with nanocrystals still remains insufficient. It has been proposed to enhance the efficiency by using plasmons (quasiparticle appearing from fluctuations of the electron gas in metals—ed). A plasmon lattice formed by gold nanostripes 'held' light on the nanoscale, and allowed a more effective interaction with nanoparticles located nearby, bringing its luminescence to an increase."

The MSU experiments with samples of a "gold-plated" matrix with silicon nanoparticles brilliantly confirmed the theoretical predictions—the UV irradiated silicon shone brightly enough to be used it in practice.

More information: Optical properties of silicon nanocrystals covered by periodic array of gold nanowires. *Physical Review B*. DOI: 10.1103/PhysRevB.93.205413

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