Faster colloidal fluorescence emitters: Nanoplatelets

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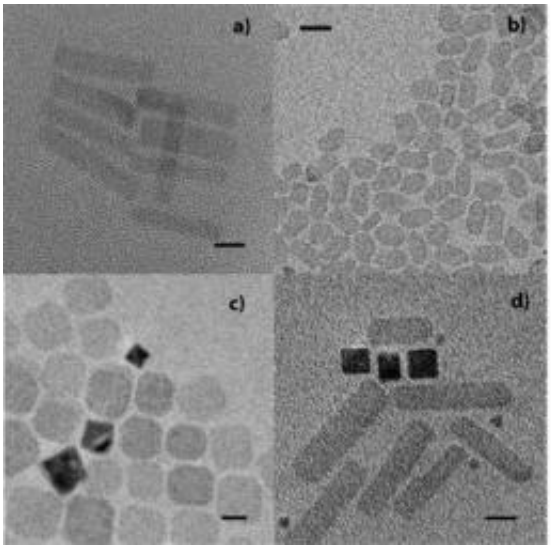

Transmission electron microscope images of CdSe colloidal nanoplatelets. Different lateral shapes (a-d) can be obtained using different precursors. Scale bars: b) 20nm, others, 10nm. Credit: Benoit Dubertret

(PhysOrg.com) -- Significant advances in the application of colloidal structures as light emitters and lasers may soon be realized following the discovery of very fast fluorescence emission rates in colloidal nanoplatelets. These nanoplatelets combine the best characteristics of two domains: the wide tunability of the absorption and photoluminescence of nanocrystals and the short decay time of excitons in quantum wells. This discovery, which was announced by scientists at the Naval Research Laboratory and Laboratoire de Physique et d'Etude

des Matéiaux, UMR8213 du CNRS, ESPCI, suggests that the nanoplatelets are an important, novel material for constructing tunable light-emitting diodes, low-threshold lasers, and photo-voltaic solar cells. The complete findings of the study are published on line in the October 23, 2011, issue of the journal *Nature Materials*.

Nanoplatelets are a new class of optical materials that are essentially atomically flat, quasi- two- dimensional colloidal CdSe, CdS, and CdTe layers with well-defined thicknesses ranging from 4 to 11 monolayers. These nanoplatelets have electronic properties of two-dimensional quantum wells formed by molecular beam epitaxy, and their thickness-dependent absorption and emission spectra are completely controlled by the layer thickness. The very high spatial confinement of carriers in these colloidal structures, practically inaccessible in epitaxial quantum wells, combined with opportunities to create very thin, flat layers (down to 1.5 nm) of the semiconductors makes the band gap of this material tunable over a 1.4 eV range. The widely tunable absorption band edge, which is controlled primarily by the nanoplatelet thickness, results in widely tunable emission spectra.

Strong enhancement of electron-hole Coulomb interaction due to the small dielectric constant of the surrounding media is another property of colloidal nanoplatelets that exists in neither spherical colloidal nanocrystals nor in epitaxial quantum wells. This phenomenon significantly decreases the radius of excitons and shortens their radiative decay time. In addition, nanoplatelet shape affects the strength of the exciton coupling with emitted photons because the tangential component of the photon electric field does not change its value when it penetrates through the surface of the flat nanoplatelets. This also shortens the fluorescent decay time in these structures.

Finally, the ground exciton states in quasi-two-dimensional nanoplatelets can have a giant oscillator strength transition connected with the exciton

center of mass coherent motion. The giant oscillator strength transition is a quantum mechanical phenomenon that may be described as coherent excitation of the volume, which is significantly larger than the volume of the exciton. The phenomenon was predicted 50 years ago by Rashba. The giant oscillator strength transition of the ground exciton state enhances the absorption cross-section and shortens significantly the exciton radiative decay time. In the case of two-dimensional structures, the enhancement is proportional to the ratio of the area of the exciton coherent motion to the square of the exciton Bohr radius.

The research teams at Laboratoire de Physique et d'Etude des Matéiaux and NRL found that at room temperatures, the fluorescence lifetime of CdSe nanoplatelets is shorter than that of CdSe nanocrystals with similar quantum yield and emission wavelength. Importantly, the fluorescence lifetime of nanoplatelets decreases with temperature, whereas their emission intensity increases. Such a temperature dependence of the fluorescence lifetime is a unique signature of the giant oscillator strength transition, which previously was observed only in quantum wells at helium temperatures. At 6K the radiative decay time becomes shorter than 1 ns, which is two orders of magnitude less than for spherical CdSe nanocrystals. This makes the nanoplatelets the fastest colloidal fuorescent emitters known and strongly suggests that they show a giant oscillator strength transition.

Future efforts will be focused on optimization of these nanoplatelet structures with a goal to eliminate the nonradiative processes connected with the surface. The growth of core-shell nanoplatelets would further extend the properties and applications of the materials presented here and would pave the way for the synthesis of colloidal, multiple-quantum-well structures. Such structures should enable researchers to take full advantage of the observed shortening of the radiative decay time and tunability, and point the way to future breakthroughs in photonics, lasers, and other optical applications of nanoplatelets.

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