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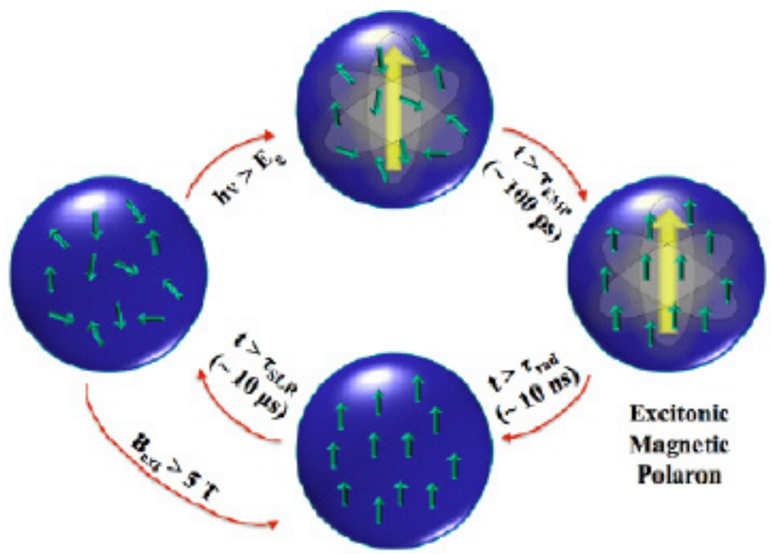
Light magnetizes nanoscale semiconductors

Light has been used to magnetize colloidal semiconductor quantum dots for the first time. The result is an important advance for the field of spintronics – in which devices exploit the spins of electrons as well as their charge.



Dopant-exciton magnetic exchange coupling

Until now, semiconductors could only be made magnetic at extremely low temperatures. This is because the magnetic interactions of the charge carriers – or excitons – used to magnetize semiconducting nanoparticles were not strong enough to overcome the thermal effects occurring at around 30 K.

Now, Daniel Gamelin of the University of Washington, Seattle, and colleagues have made doped nanocrystals in which quantum confinement allows the excitons to have greater magnetic interactions, as well as lifetimes as long as 100 ns – as opposed to just 200 picoseconds previously. Using light, the researchers injected excitons within the quantum-confined colloidal nanocrystals, which led to strong light-induced magnetization.

The team achieved its result using semiconductor nanocrystals made of cadmium selenide with some of the non-magnetic cadmium ions replaced with magnetic manganese ions. The crystals, which are less than 10 nm across, were then suspended in a colloidal solution.

EMPs

Exposing these nanocrystals to beams of light produces a very large internal magnetic field within the nanocrystal that completely aligns all of the Mn(II) spins in the same direction. This alignment happens very fast and the effect is strongest at low temperatures but remains strong up to room temperature, says Gamelin. It comes thanks to the presence of high-temperature excitonic magnetic polarons (EMPs), observed for the first time in this study.

“Despite theoretical predictions, these high-temperature EMPs have so far remained a low-temperature novelty because strong enough dopant-carrier interactions could not be engineered,” explained Gamelin.

The order-of-magnitude advance described by the University of Washington team was achieved by switching from conventional molecular beam epitaxy (MBE) growth to a new direct chemical synthesis of magnetic semiconductor quantum dots. This has enhanced EMP stability by up to 100 times over that in previous semiconductor nanostructures so that the magnetization effects can now be observed at 300 K.

Another added bonus is that the free-standing colloidal quantum dots produced are compatible with common processing techniques, such as soft lithography and ink-jet printing, while previously EMP materials were not. The colloids could thus be considered as new tools in the nanotech toolbox for a variety of device applications, says Gamelin.

“Our work will hopefully stimulate more fundamental and applied research into the development of new magnetic semiconductor materials for future spintronics/spin-photonics technologies,” he told *nanotechweb.org*. “These materials and observations might also impact research in fields as diverse as quantum optics, high-temperature ferromagnetism and single-molecule magnetism."

The results were published in *Science*.

About the author

Belle Dumé is contributing editor at *nanotechweb.org*