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Semiconductor quantum dots: Ferromagnetism without magnets

Published online 24 June 2008

Materials exhibiting room temperature ferromagnetism (RTFM) are of interest for the fabrication of spintronic devices. Now, researchers from the Academia Sinica in Taiwan working in collaboration with colleagues in India and United States have demonstrated the synthesis of nanocrystals of a nominally non magnetic semiconductor that exhibit ferromagnetism at several degrees above room temperature[1].

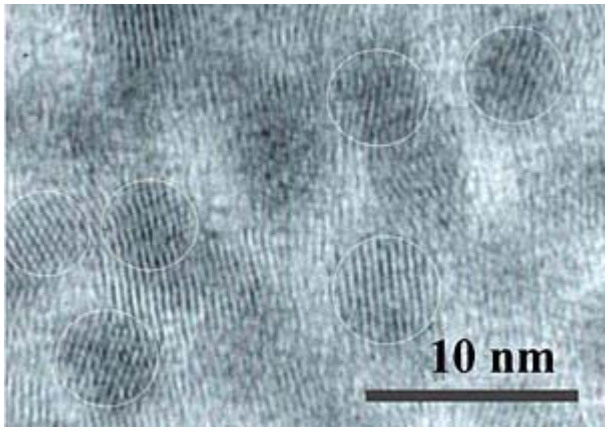

Fig. 1: Transmission electron microscope image of ferromagnetic CdSe quantum dots.

RTFM has been observed in several materials before, usually semiconductors or oxides. In spite of a lack of consensus on the mechanism responsible for this phenomenon, it is thought that magnetic signals originate from magnetic impurities present in the material rather than the intrinsic properties of the materials themselves

Yang-Yuan Chen and colleagues believe that in the case of their CdSe nanocrystals the ferromagnetism is definitely an intrinsic property. The nanocrystals were capped with TOPO (Tri-n-octylphosphine)—which is also nonmagnetic—and no clusters of magnetic impurities were used. The researchers speculate that the RTFM arises from electronic effects at the crystal surfaces due to the presence of the TOPO.

"Since the electronegativity of oxygen is much larger than that of Cd, then the charge transfer from Cd to TOPO depletes the $4d^{10}$ full band of Cd, creating holes and producing a net magnetic moment for Cd atoms bonded to TOPO," says Chen.

The saturation magnetization decreases with increasing nanocrystal size, which is in full agreement with the model proposed by Chen and colleagues. Indeed, surface-related effects are expected to be stronger for small sized crystals. Furthermore, dedicated chemical analysis prevented the inclusion of Fe impurities that could give ris to the observed magnetic signals.

The ferromagnetism in the nanocrystals is the first of its kind. "The importance of the work is that with appropriate surface modification, i.e., capping with TOPO in our case

semiconductor quantum dots exhibit RTFM with no need of magnetic dopants," says Chen. "Our next step is to look for other surfactants which could replace TOPO. We also plan to perform Cd L3-edge XANES to directly measure the unoccupied states of 4d orbital in Cd sites for further confirmation of the result."

Reference

1. Seehra, M.S. et al. Size-controlled Ex-nihilo ferromagnetism in capped CdSe quantum dots. *Adv. Mater.* **20**, 1656 – 1660 (2008). | article |

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This research highlight has been approved by the author of the original article and all empirical data contained within has been provided by said author.

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