Magnetic nanoparticle assembly in extreme force gradients

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Keywords: MADE IN SC, Hierarchical Structures, Magnetic Properties

Abstract:

Thrust 1 of the MADE in SC program focuses on novel methods to hierarchically assemble material building blocks to create advanced materials with unique optical, electronic, and magnetic properties. By combining nanoparticle self-assembly with magnetic-field-gradient driven assembly, we demonstrate the ability to create 2-dimensional features as small as 75 nm, i.e. resolution comparable to Electron Beam Lithography, using single nanoparticles as blocks. Critical to this patterning technology is the use of perpendicular magnetic recording media as a programmable template for assembly. Importantly, such a recording medium generates highly localized magnetic field gradients within nanometers of its surface that exceed 10 MegaTesla/meter! This field gradient creates a force that itself changes rapidly with height above the medium. Such an extreme force gradient can accelerate magnetic nanoparticles toward the medium surface. Balancing such attractive force gradients is the repulsive colloidal force that keeps the nanoparticles from aggregating in fluid. By tuning this balance between magnetic and colloidal stabilizing forces, for example by modifying the suspending fluid, we can trigger self-assembly of magnetic nanoparticles. We use real-time optical diffraction to monitor this triggering as the nanoparticles assemble into parallel lines on a magnetic recording medium. Triggered self-assembly depends strongly on the ionic properties of the colloidal fluid, but at a level too small to cause bulk colloidal aggregation. To date simulations are able to predict the triggering, but not the dynamics observed as a function of ionic strength. Beyond driving self-assembly via tuning nanoscale forces, this approach offers a metrology with sufficient sensitivity to identify subtle effects that could affect nanoparticle behaviour in a clinical setting. Future efforts will include adding photoluminescent or semiconducting shells to the magnetic nanoparticle blocks to create precision 2D patterned materials with novel optical or semiconducting properties.

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Biography:
Dr. Mefford graduate in 2003 with an honors degree in Textile and Polymer Chemistry and minor in Philosophy from Clemson University. He then attended Virginia Tech, where he earned his PhD in Macromolecular Science and Engineering in 2007. For his PhD, he worked on the development of treatments for retinal detachment using hydrophobic ferrofluids. Before returning back to Clemson, Dr. Mefford developed methods for the fabrication and functionalization of microfluidic devices as a Post-doctoral Researcher for The Ohio State University Department of Chemistry. Mefford joined the faculty of the School of Material Science and Engineering at Clemson in the Fall of 2008. His research focuses on developing stable, polymer-iron oxide nanoparticle complexes and composites for biomedical applications. These applications include: developing materials for magnetically modulated energy delivery, MRI contrast agents, and drug delivery systems. He is also currently involved in collaborations with the Biology, Bioengineering, Chemical Engineering, and the Chemistry departments. In his free time, Dr. Mefford is found running, cycling, sailing, backpacking, and homebrewing.

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Biography:
Dr. Crawford graduated in 1992 with a B.S. in Physics from Haverford College. He received his M.S. (1995) and Ph.D. (1997) in Physics from the University of Colorado at Boulder. For his Ph.D. research, Crawford employed nonlinear optics to study interfaces and dynamics in multilayered magnetic thin films. While at CU-Boulder, he was supported by a Professional Research Experience fellowship from the National Institute of Standards and Technology (NIST). After completing his Ph.D., Crawford joined NIST as a National Research Council (NRC) Postdoctoral Fellow. In 1999, he was one of the first scientists hired by Seagate Technology's new research division. While at Seagate Research Crawford received two Outstanding Technical Contribution Awards and was granted 9 patents. Dr. Crawford joined the USC Department of Physics as an Associate Professor in 2005, received tenure in 2010, and was promoted to Professor in 2015. His research focuses on novel measurements of magnetic materials and devices, and since 2008 he has studied templated self-assembly of magnetic nanomaterials. His research lead to the formation of USC startup MagAssemble LLC in 2013. He has helped lead the Smart State Center for Experimental Nanoscale Physics as its Deputy Director since 2013.