Nanocaps help scientists control magnetism reversal

March 3 2006

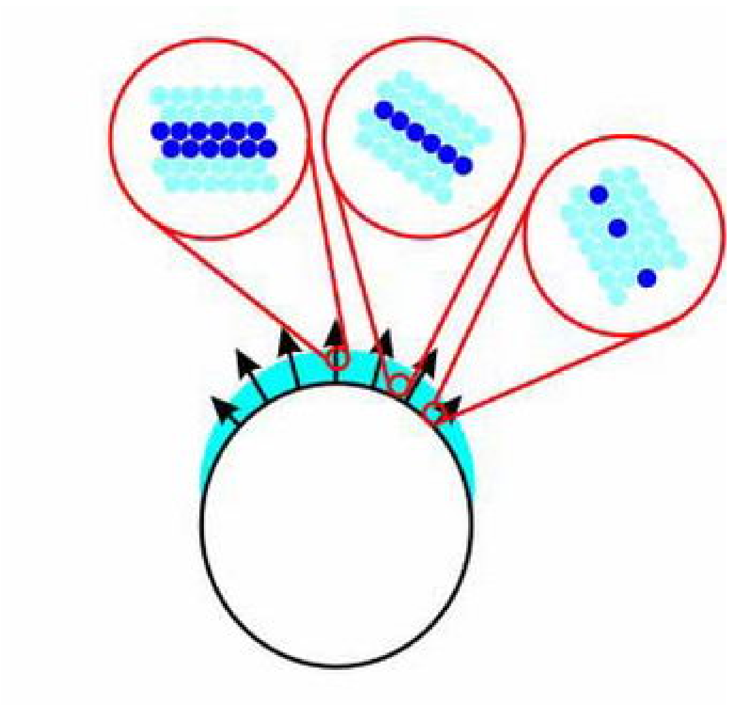

Figure 1: In this model of a multilayer cap on top of a nanosphere, the turquoise layer on the sphere shows different thickness levels, and the black arrows represent the radial symmetric anisotropy orientation across the cap. The radial orientation – as opposed to a parallel orientation in flat films – is caused by the different thickness levels, and is what alters the nanoparticle's magnetic reversal properties. Image source: T.C. Ulbrich, et al.

By fabricating curved "nanocaps" to study nanoscale magnetism, scientists have discovered how to partly control magnetism reversal, which could improve applications such as data storage, recording media and biomedical technology.

A link between the magnetic and geometric properties of nanoparticles has a significant effect on the magnetization reversal mechanism of these nanoparticles, report T.C. Ulbrich et al. in a recent report in *Physical Review Letters*. Using a new nanomaterial, which consists of a spherical particle covered with a thin film, the scientists studied how the thickness of the ferromagnetic film affects magnetization reversal. Ferromagnetic materials, which react to external magnetic fields to spontaneously form permanent magnets, can last for millions of years or until a different magnetic field is applied.

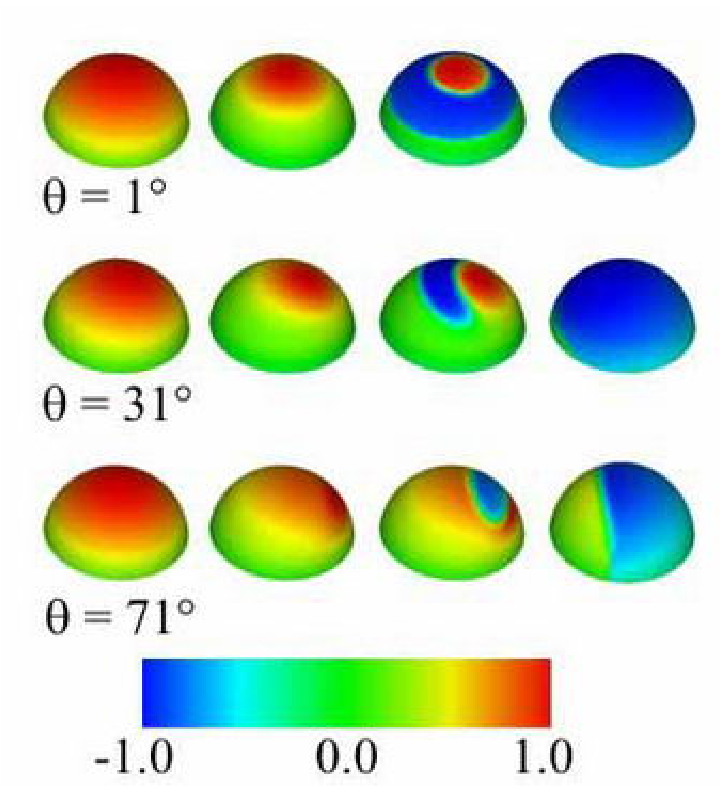

Figure 2: These sequences (which are micromagnetic simulations) show how the magnetization of these 310 nm caps changes depending on the angle of the direction of the applied magnetic field (1º, 31º or 71º). As the applied magnetic

field is increased (from left to right), the magnetization of the caps changes differently depending on the angle, which is due to the curvature/different thickness levels. Image source: T.C. Ulbrich, et al.

These new, curved multilayer films differ from previously studied materials, most of which were flat with constant thickness. By depositing thin layers (some less than one nanometer) of ferromagnetic cobalt and palladium on spherical nanoparticles, the scientists formed these films in the shape of caps. Analyzing different thickness levels across the sphere, the team could distinguish different degrees of thickness, discovering that this topological change altered the fundamental nanoscale magnetism of the individual particles.

In this case, the scientists applied a reverse magnetic field to the already magnetized nanocaps, and then analyzed how the magnetization reversal evolved in individual caps. In regions where the film is thick, the nanomaterial demonstrates radial magnetic anisotropy, which means the material's magnetism is directionally dependent and ferromagnetic (Figure 1). Where the film is thinner, the material's ferromagnetic properties and the magnetic anisotropy vanish.

“The evaporation of multilayer films on spherical particles leads to an anisotropy distribution in the caps,” said Ulbrich. “In contrast to a flat film, where the anisotropy is parallel throughout the film, here, the anisotropy points radially outward, leading to the altered magnetic reversal properties.”

Previous theories used to describe flat film layers don't describe the magnetism reversal for the different cases of curved film.

“To investigate the physical origin of this remarkable behavior in detail, micromagnetic simulations were performed, enabling us to distinguish the [different] influences," wrote the researchers (Figure 2).

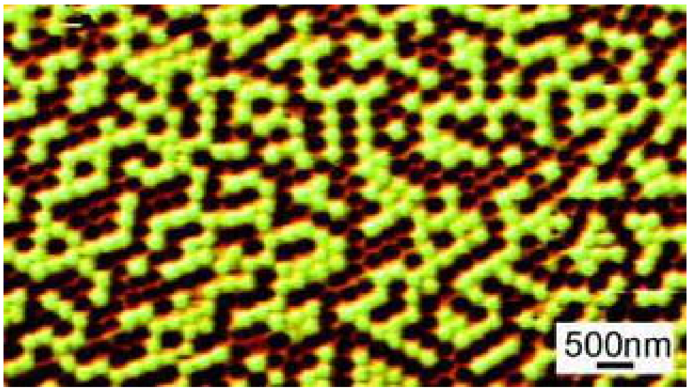

Figure 3: This image, taken with a magnetic force microscope, distinguishes oppositely charged magnetic multilayers on nanospheres. Image source: T.C. Ulbrich, et al.

In addition to investigating the topographic assembly of the nanoparticles, the physicists also looked at the morphology to determine the film structure. Using a scanning tunneling microscope, the team discovered that the film had a grainy nanostructure, which also played a role in affecting the film's magnetic anisotropy. Images from an atomic force microscope and a magnetic force microscope (Figure 3) showed that individual nanoparticles flipped after exposure to a reversed magnetic field.

Because the scientists have control over the film curvature – and subsequently over anisotropies and magnetic properties – the discovery has opened up doors to the possibilities of tailoring magnetism reversal for new nanoscale applications.

"Using these 'tilted' caps, we can combine easy writability and high thermal stability, which might lead to a higher storage density in magnetic recording applications," said Ulbrich.

Citation: Ulbrich, T.C., Makarov, D., Hu, G., Guhr, I.L., Suess, D., Schrefl, T.and Albrecht, M. Magnetization Reversal in a Novel Gradient Nanomaterial. *Physical Review Letters*. 96, 077202 (2006).

By Lisa Zyga, Copyright 2006 PhysOrg.com