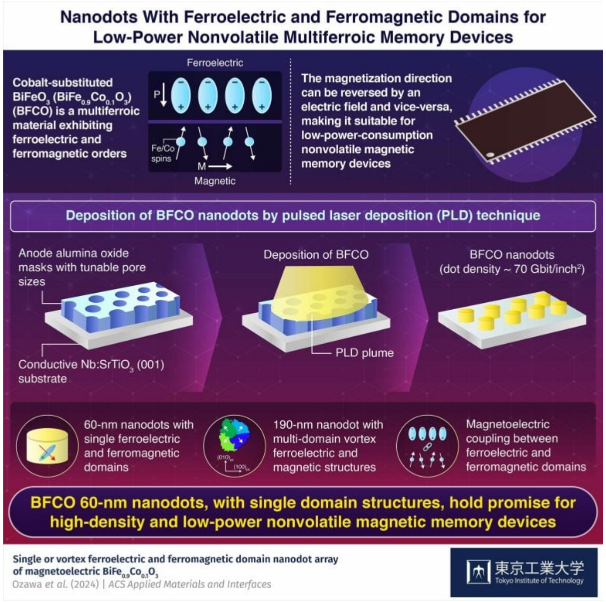
The Emergence of Multiferroic Nanodots with Low Power

Posted by Okachinepa 05/01/2024



Courtesy of SynEvol
Credit: Tokyo Tech

Current non-volatile memory devices store data using ferroelectric or ferromagnetic materials, while traditional memory devices are volatile. In ferromagnetic devices, data is recorded or stored by aligning magnetic moments, while in ferroelectric devices, data storage relies on the alignment of electric dipoles. However, ferroelectric memory devices require the memory cell to be rewritten since reading data destroys the polarized state, and creating and manipulating magnetic fields consumes a lot of energy.

Ferroelectric and ferromagnetic orders coexist in multiferroic materials, which present a possible avenue for more effective effective and adaptable memory technology. BiFe0.9Co0.1O3, also known as BFCO, is a multiferroic material that has significant magnetoelectric coupling, which means that variations in electric polarization have an impact on magnetism. Thus, instead of creating magnetic fields, which uses more energy, data can be written using electric fields, and read using magnetic fields, which eliminates the need for the destructive read-out procedure.

A group of scientists at the Tokyo Institute of Technology in Japan, lead by Professor Masaki Azuma and Assistant Professor Kei Shigematsu, have created nanodots with single ferroelectric and ferromagnetic domains, which is a major advancement for multiferroic memory systems.

The "Sumitomo Chemical Next-Generation Eco-Friendly Devices Collaborative Research Cluster" at the Tokyo Institute of Technology's Institute for Innovative Research is dedicated to studying multiferroic materials, which are based on strongly correlated electron systems and show cross-correlation responses between magnetic and electrical properties. According to Azuma, the center's objectives include creating materials and procedures for the next generation of low-power, non-volatile magnetic memory devices, as well as performing reliability tests and social implementation.

In this work, multiferroic BFCO was deposited over a conductive Nb:SrTiO3 (001) substrate by pulsed laser deposition, as reported in the April 9, 2024, journal ACS Applied Materials and Interfaces. Anodized aluminum oxide (AAO) masks with tunable pore widths were used to regulate the deposition process, producing nanodots with 60 and 190 nm diameters.

Given that an electric field may be used to reverse the magnetization direction of BFCO, it presents a viable option for low-power, nonvolatile magnetic memory systems. Upon utilizing piezoresponse force microscopy and magnetic force microscopy to observe the polarization and magnetization directions, respectively, the researchers discovered that the nanodots have associated ferroelectric and ferromagnetic domain structures.

It's interesting that they found notable variations between nanodots of various sizes. Using an oxalic acid AAO mask, the smaller 60-nm nanodot displayed single ferroelectric and ferromagnetic domains with consistent polarization and magnetization directions throughout. The larger 190-nm nanodot, on the other hand, showed multi-domain vortex ferroelectric and magnetic structures, indicating strong magnetoelectric interaction. It was created using a malonic acid AAO mask.

According to Shigematsu, "a multi-domain structure offers a playground for fundamental research, and such a single-domain structure of ferroelectricity and ferromagnetism would be an ideal platform for investigating BFCO as an electric-field writing magnetic read-out memory device."

Because nonvolatile magnetic memory systems keep their stored data even after the power is switched off, they are essential for a wide range of electronic applications. BFCO 60-nm nanodots have a lot of promise for magnetic memory systems that require little electrical power for recording and reading because of their special combination of single ferromagnetic and ferroelectric domains.