Researchers develop novel multiferroic materials and devices integrated with silicon chips

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A research team led by North Carolina State University has made two advances in multiferroic materials, including the ability to integrate them on a silicon chip, which will allow the development of new electronic memory devices. The researchers have already created prototypes of the devices and are in the process of testing them.

Multiferroic materials have both ferroelectric and ferromagnetic properties.

"These multiferroic materials offer the possibility of switching a material's magnetism with an electric field, or switching its electric polarity with a magnetic field – making them very attractive for use in next-generation, low-power, nonvolatile memory storage devices," says Dr. Jay Narayan, John C. Fan Distinguished Chair Professor of Materials Science and Engineering at NC State and senior author of two papers describing the work.

Researchers had previously known that you could create a multiferroic material by layering barium titanate (BTO), which is ferroelectric, and lanthanum strontium magnese oxide (LSMO), which is ferromagnetic. But these "bilayer" thin films weren't feasible for large-scale use because they could not be integrated on a silicon chip – the constituent elements of the thin films would diffuse into the silicon.

But Narayan's team has advanced the work in two ways. First, by developing a technique to give BTO ferromagnetic properties, making it multiferroic without the need for LSMO; second, by developing buffer layers that can be used to integrate either the multiferroic BTO or the multiferroic BTO/LSMO bilayer film onto a silicon chip.

To make BTO multiferroic, the researchers used a high-power nanosecond pulse laser to create oxygen vacancy-related defects into the material. These defects create ferromagnetic properties in the BTO.

The buffer layers are titanium nitride (TiN) and magnesium oxide (MgO). The TiN is grown as a single crystal on the silicon substrate. The MgO is then grown as a single crystal on the TiN. The BTO, or BTO/LSMO bilayer film, is then deposited on the MgO. The resulting buffer layers allow the multiferroic material to function efficiently without diffusing into the silicon and destroying silicon transistors.

"We've already fabricated prototype memory devices using these integrated, multiferroic materials, and are testing them now," Narayan says. "Then we will begin looking for industry partners to make the transition to manufacturing."

More information: "Magnetic properties of $BaTiO_3/La_{0.7}Sr_{0.3}MnO_3$ thin films integrated on Si(100)." *J. Appl. Phys.* 116, 224104 (2014); dx.doi.org/10.1063/1.4903322

"Ferroelectric and ferromagnetic properties in $BaTiO_3$ thin films on Si (100)" *J. Appl. Phys.* 116, 094103 (2014); dx.doi.org/10.1063/1.4894508

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