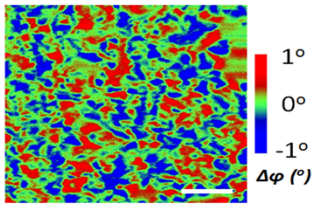
Tiny changes have huge impact – switching a material's magnetic strength with a voltage



Magnetic force microscopy mapping of the coexistence of the two different magnetic phases (ferromagnetic and antiferromagnetic) in FeRh.

Work was performed as User Project at the Center for Nanophase Materials Sciences.

Scientific Achievement

By applying a tiny electric field at room temperature to an oxide crystal, the magnetic properties of a coating (FeRh film) on this crystal can be switched, demonstrating a new, giant electro-resistance effect.

Significance and Impact

The long-lived and reversible resistance changes realized in these materials consisting of intermetallic alloy films on oxide crystals shows great potential for a new types of memory devices and switches.

Research Details

- Epitaxial intermetallic FeRh films were epitaxially grown on ferroelectric oxide substrates (PMN-PT) by both sputtering (at CNMS and Berkeley) and molecular beam epitaxy (at Cornell).
- Dynamic strain generated by applying an electric field to the ferroelectric PMN-PT substrate leads to changes of structural and magnetic phases of the FeRh films.
- The resulting phase change leads to unprecedented large changes in electrical resistance in an metallic system.

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Narrative highlight text: The effects of strain on intermetallic systems, or the effect of a voltage applied to a composite consisting of an intermetallic and an oxide, have received much less attention than the carrier-doped, strongly correlated complex oxides, typified by the emergence of high-temperature superconductivity in doped antiferromagnetic cuprates and colossal magnetoresistance in doped manganites. Reversible resistance switching induced by external electric fields on various manganites shows large electroresistance (ER) response and provides a great potential as an emerging nonvolatile memory technology. This work breaks away from the studies of such effects in purely oxydic materials: An intermetallic FeRh system undergoes a first-order antiferromagnetic to ferromagnetic transition above room temperature and shows two-phase coexistence near the transition. Here we have investigated the effect of an electric field to FeRh/PMN-PT heterostructures and report 8% change in the electrical resistivity of FeRh films. Such a 'giant' electroresistance (GER) response is striking in metallic systems, in which external electric fields are screened, and thus only weakly influence the carrier concentrations and mobilities. We show that our FeRh films comprise coexisting ferromagnetic and antiferromagnetic phases with different resistivities and the origin of the GER effect is the strain-mediated change in their relative proportions. The observed behavior is reminiscent of colossal magnetoresistance in perovskite manganites and illustrates the role of mixed-phase coexistence in achieving large changes in physical properties with low-energy external perturbation.

Reference

"Large resistivity modulation in mixed-phase metallic systems"
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