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Emergent resistance network suggests mechanism for colossal magnetoresistance

Research by scientists at Stanford University and RIKEN has revealed new clues on the microscopic processes by which resistance in certain materials is dramatically altered by the presence of magnetic fields. Reported in *Science*, the discovery provides fundamental insights toward the development of radically new memory and switching devices.

Colossal magnetoresistance (CMR), a phenomenon in which enormous variations in resistance are produced by small magnetic field changes, has attracted attention as a means to develop low-power, more compact alternatives to conventional circuits. Unlike semiconductors such as silicon, electrons in the manganites and other transition metal oxides in which CMR occurs interact strongly with each other, held in place by a lattice that constrains their movement. CMR is triggered when a strong magnetic field induces such materials to tip from a charge-ordered insulating phase into a ferromagnetic metallic phase, drastically altering the material's properties.

An earlier technique developed by the team was successful in producing manganite films only a few dozen nanometers thick capable of undergoing this transition from insulating to metallic phase. To explore the mechanisms underlying this transition, the researchers adapted a microwave impedance microscope to withstand cryogenic temperatures and extreme magnetic fields. Using this microscope, they discovered that under a powerful 9 tesla magnetic field, filamentary metallic domains emerge in the manganite films, forming an interconnected network aligned along the axes of the film substrate.

The first ever evidence of a microscopic mechanism for CMR, the discovery of this network greatly enhances our understanding of microscopic phase transitions in thin film manganites. It also marks a major advance in the race toward new memory and switching devices, whose impact promises to revolutionize computing technology.

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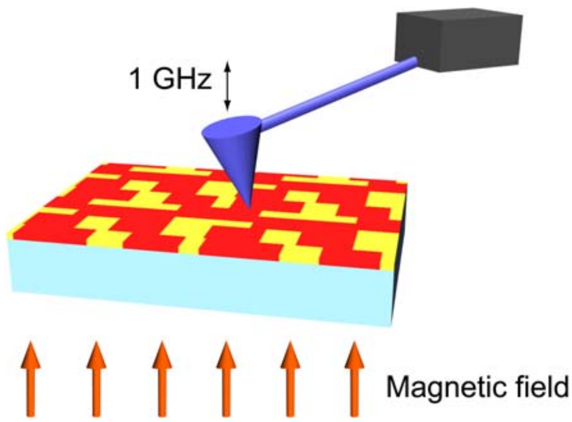

Figure 1: Schematic picture of scanning microwave impedance microscope.

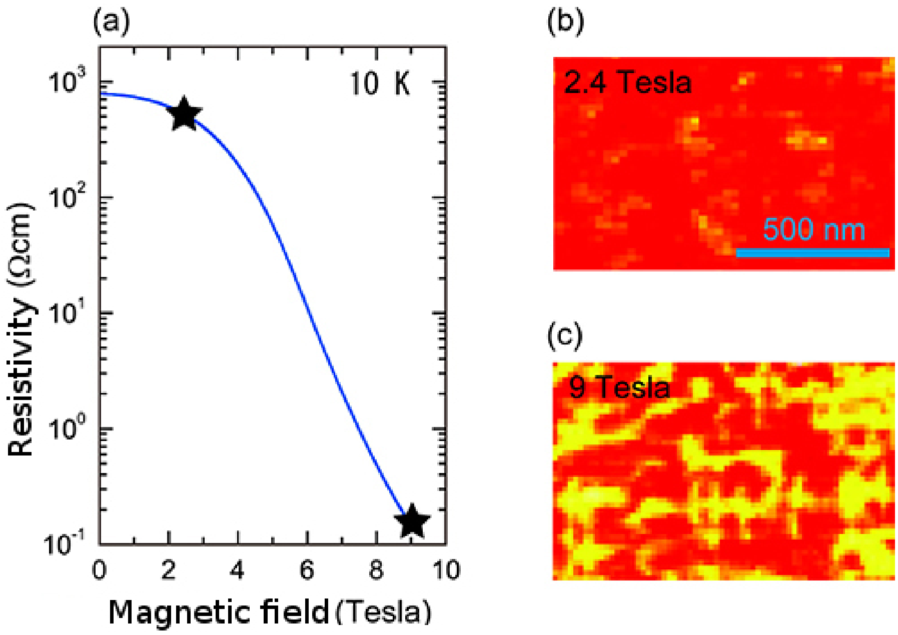

Figure 2 : Magnetic-field dependence of the resistivity of $Nd_{0.5}Sr_{0.5}MnO_3$ thin film and its microwave impedance microscope images.

a : Magnetic-field dependence of the resistivity at 10 K.

b,c : Images of microwave impedance microscope taken in the magnetic field of 2.4 and 9.0 tesla. The red region indicates insulating state and the yellow region indicates metallic state.