Applying pressure reaps material rewards

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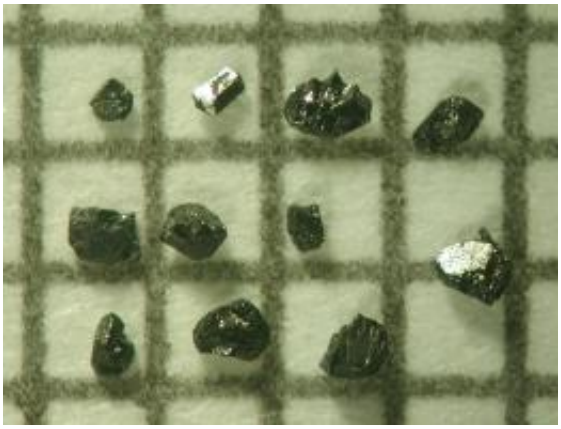

Figure 1: Large crystals of the multiferroic yttrium manganite, a material with important implications for future memory devices, created from a high-pressure growth technique. Credit: Reproduced from Ref. 1 © 2011 S. Ishiwata et al.

Researchers in Japan have succeeded in growing single crystals of yttrium manganite ($YMnO_3$) using a high-pressure material-growth technique1. Developed by Shintaro Ishiwata and his colleagues from the RIKEN Advanced Science Institute and the University of Tokyo, the technique reveals how this material's atomic structure gives it multiferroic properties, which hold promise as a route to low-power-consumption electronic memories.

Multiferroic materials have both ferromagnetic and ferroelectric properties that make them ideal for an improved class of memory devices. Ferromagnetic materials are essential for most electronic

memory devices because they can retain long-lasting magnetic properties after exposure to a magnetic field. The electrical properties of ferroelectric materials are controllable using an electric field. The combination of these properties means that it is possible to control magnetic memories with an electrical field while reducing heat loss.

Ishiwata and colleagues created an initial sample of $YMnO_3$ by mixing the compounds Y_2O_3 and Mn_2O_3 at 1,300 °C. "This ambient-pressure phase of YMnO3 is a kind of multiferroic, but … its electronic properties cannot be controlled by magnetic fields," explains Ishiwata. Moreover, the sample was polycrystalline; that is, made up of many tiny crystals. The researchers created larger crystals (Fig. 1) by mixing this precursor with potassium chloride and water and subjecting it to a pressure almost 55,000 times that of atmospheric pressure and temperatures in excess of 1,000 °C for two hours. "The crystal growth of multiferroic $YMnO_3$ is normally hampered by damage caused in the high-pressure cell," explains Ishiwata. "By adding water, we drastically lowered the melting point of $YMnO_3$ and therefore reduced the reaction time."

To provide clear evidence of the strong magneto-electric effects, Ishiwata and colleagues investigated their sample at various temperatures and under an applied magnetic field. A change in atomic structure transformed the precursor $YMnO_3$ into a useful multiferroic material. The precursor had a hexagonal lattice arrangement. The high pressure converted this to a type of crystal known as an orthorhombic perovskite—so named because it has a similar, but slightly tilted, atomic structure to the natural mineral perovskite.

Now that they are able to reliably grow large single $YMnO_3$ crystals, the researchers can thoroughly investigate the properties of this useful material. "It has been predicted that perovskite-type YMnO3 should have a large polarization; that is, a strong atomic-level response to

electric fields," says Ishiwata. "The observed polarization is not as large as predicted yet, but it is still the largest of any magnetic-order-driven multiferroic."

More information: Ishiwata, S., et al. High-pressure hydrothermal crystal growth and multiferroic properties of a perovskite YMnO3. Journal of the American Chemical Society 133, 13818–13820 (2011).

Provided by RIKEN