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Electric field control of magnetism and ferroelectricity in single crystals of multiferroic $BiFeO_3$

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$BiFeO_3$ is a room-temperature multiferroic combining large electric polarization (P) with long-wavelength spiral magnetic order. Significant efforts have been devoted to studies of thin- film $BiFeO_3$ model multiferroic devices, and local control of magnetization by an electric field has been demonstrated recently. However, the extant thin films consist of a poorly controlled patchwork of ferroelastic domains severely impeding experimental work. We report growth of mm-sized single crystals consisting of a single ferroelectric (FE) domain. Switching between two (out of 8) unique directions of P by an electric field is demonstrated. Magnetic moments are strongly coupled to the lattice, and rotate together with P when the field is applied. Electric field can be used to control the populations of the 3 equivalent magnetic domains with different directions of the spiral wave vector. In particular, a FE monodomain with a single-wave-vector magnetic spiral can be prepared. The spiral has the same helicity in the entire sample. All these effects are reversible. Thus, electric field can be used to control the ferroelectric and magnetic states, and even the magnetic helicity of the sample. This level of control, so far unachievable in thin films, makes single- crystal $BiFeO_3$ a promising object for investigation of physics of magnetoelectric coupling in multiferroics, as well as for model multiferroic device research.