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Coupling of magnetic and ferroelectric hysteresis by a multi-component magnetic structure in Mn2GeO4

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The family of magnetically-induced multiferroic materials that exhibit coupled magnetic and electric order offer great promise for future applications. A detailed understanding of the coupling mechanism between magnetism and ferroelectricity facilitates the development of new materials that may allow controllable multiferroic properties to emerge at room temperature. Here, we will focus on our study of the insulator Mn2GeO4. Bulk measurement and neutron diffraction experiments on single crystal samples have revealed that, in zero applied magnetic field, three different magnetic structure phases exist as a function of decreasing temperature. The lowest temperature magnetic phase is found to be multiferroic. Here, both a macroscopic ferroelectric polarization and finite magnetization emerge. Both of these orders are spontaneous and point along the crystal c-axis. To understand these macroscopic properties, neutron diffraction has been employed as a microscopic probe of the multiferroic phase. We find that the magnetic structure is composed of coupled commensurate and incommensurate components. A symmetry analysis reveals that the finite magnetization can be associated with the commensurate component, while the incommensurate component is responsible for the emergence of ferroelectricity. The coupling between the two components of the magnetic structure is inferred by the neutron diffraction results, and demonstrated by hysteretic behaviour in both magnetization and the electric polarization. Our results suggest that multi-component magnetic structures such as that found in Mn2GeO4 may provide a new route towards functional materials that exhibit both ferromagnetic and ferroelectric orders.

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