



Multiferroic Metal Organic Frameworks

Prashant Jain,^{a,b,c} Vasanth Ramachandran,^a Ronald J. Clark,^a Hai Dong Zhou,^c Christopher Wiebe,^c
Brian H. Toby,^d Naresh S. Dalal,^{a,c} Harold W. Kroto,^a and Anthony K. Cheetham^b

^aDepartment of Chemistry and Biochemistry, Florida State University, Tallahassee, Florida 32306-4390

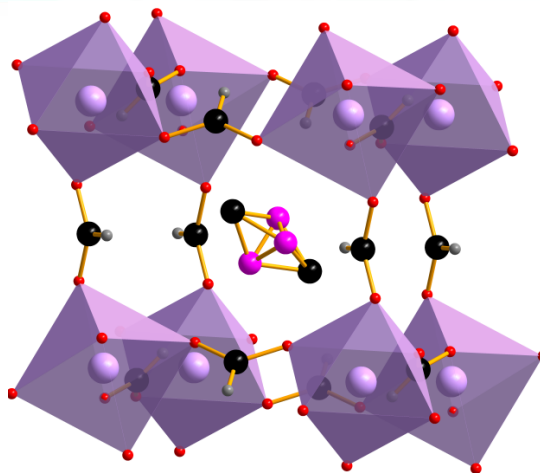
^bDepartment of Materials Science and Metallurgy, University of Cambridge, Cambridge CB2 3QZ, U.K.

^cNational High Magnetic Field Laboratory, Tallahassee, Florida 32310-3706

^dAdvanced Photon Source, Argonne National Laboratory, Argonne, Illinois 60439

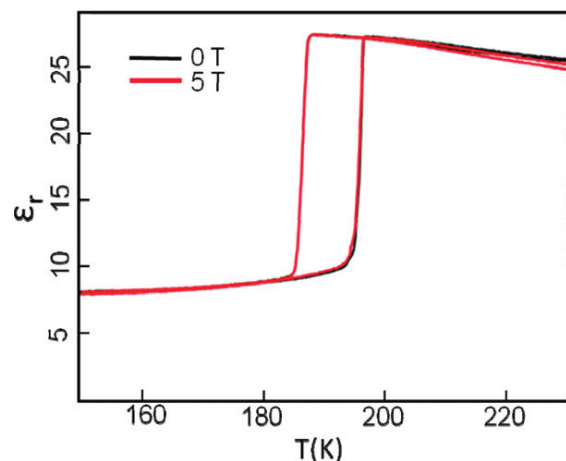


Multiferroics exhibit more than one primary ferroic order parameters like ferromagnetism and ferroelectricity simultaneously. Competition between the underlying mechanisms in the case of magnetic and electrical ordering makes multiferroic compounds rare. Most of the known multiferroics belong to the family of transition metal oxide perovskite. In recent years, there has been tremendous interest in multiferroics in order to manipulate magnetic properties using an electric field and vice-versa which could have deep impact on data storage, sensors etc .



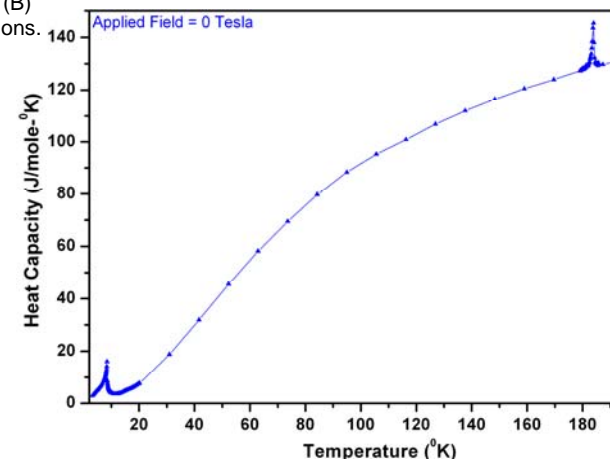
Building block of $[(\text{CH}_3)_2\text{NH}_2]\text{M}(\text{HCOO})_3$. The DMA cation (A) is at the center of a ReO_3 type cavity, formed by transition metal (B) and formate (X) ions. Nitrogen is disordered over three positions.

Metal organic framework (MOFs) are extended organic - inorganic crystalline polymers with strong bonding providing robustness and a geometrically well defined structure. They constitute an important class of materials that have been studied extensively over the last few years due to their potential applications in catalysis, gas separation and storage. Other properties which draw attention to these materials include magnetic, optical and electronic properties.



Dielectric constant of DMMnF as a function of temperature with no magnetic field and with that of 5 T.

MOFs, dimethylammonium metal (Mn, Ni, Co, Fe) formates, have the same topology as that of oxide perovskites. Metal atoms sit at the corner of cube and are connected to each other by a formate ligand. Cavity of the cube is occupied by dimethylammonium cation; nitrogen of which is disordered over three different positions due to the hydrogen bonding of the amine hydrogens with the oxygen of the framework. Upon cooling the compounds go under a phase transition, due to the ordering of nitrogen, leading to ferroelectric ordering. They also order ferromagnetically at 40 K below which both the order parameter coexist.



Heat capacity of DMMnF as a function of temperature. The anomalies relating to electrical ordering and magnetic ordering are clearly visible.

1. Jain, P.; Dalal, N. S.; Toby, B. H.; Kroto, H. W.; Cheetham, A. K. *J. Am. Chem. Soc.* 2008, *130*, 10450.

2. Jain, P.; Ramachandran, V.; Clark, R. J.; Zhou, H. D.; Toby, B. H.; Dalal, N. S.; Kroto, H. W.; Cheetham, A. K. *J. Am. Chem. Soc.* 2009, *131*, 13625.

Contact: Prashant Jain (pj267@cam.ac.uk) Prof. Harry Kroto (kroto@chem.fsu.edu), Prof. Naresh Dalal (dalal@chem.fsu.edu) & Prof. Tony Cheetham (akc30@cam.ac.uk)