Colossal magnetocapacitance and scale-invariant dielectric response in phase-separated manganites

AMLAN BISWAS, RYAN P. RAIRIGH, GUNEETA SINGH-BHALLA, SEFAATIN TONGAY, TARA DHAKAL, AND ARTHUR F. HEBARD

What is scale-invariance?

Usually when one looks at an object under a microscope, its appearance depends on the magnification factor. However, if an object is **scale-invariant** it will look the same at all magnification factors. While it is mathematically possible to study such objects; real objects can only be approximately scale-invariant due to the atomic structure of materials.

Scale-invariance in magnetic materials

Most of our digital data are currently stored as small magnetic bits on devices such as hard drives. Due to our insatiable appetite for even higher density data storage, **magnetic materials** which display such scale invariance could have significant technological impact. A few years ago research groups obtained evidence that a class of magnetic materials known as **manganites** (more precisely, perovskite manganese oxides) can exist in **phase-separated state**, i.e. a mixture of magnetic and non-magnetic phases. The size of the magnetic regions was measured to be about a few micrometers, using transmission electron microscopes and magnetic force microscopes [Fig. 1, Ref. 1]. However, it is possible that these magnetic regions are even smaller than what the microscopes show us. A different way probing the length scale of magnetic metallic and non-magnetic insulating regions in mixed phase materials is to measure polarization response to a time varying electric field. Higher frequency electric fields, can detect the presence of smaller insulating and metallic regions. To measure this polarization response in phase separated manganites, we fabricated a capacitor structure in which a manganite thin film and an aluminum film form the two capacitor plates separated by a high quality aluminum oxide dielectric layer [Fig. 2, Ref. 2]. A sinusoidal electric field applied to such a capacitor yields a “complex” value of the capacitance with “real” (C′) and “imaginary” (C′′) components, which when plotted on a logarithmic scale fall on a single straight line as frequency, temperature or magnetic field are varied [Fig. 3, Ref. 2]. Such universal behavior with frequency, temperature and magnetic field indicates a **scale invariant phase-separation in manganites.**

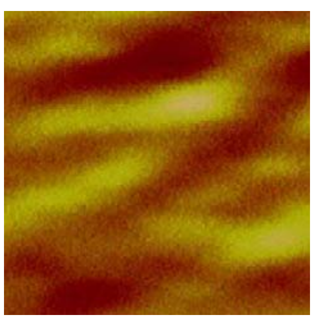

Figure 1. 6 μm × 6 μm magnetic force microscope image of a manganite showing the phase separation into magnetic and non-magnetic regions. (Reference 1).

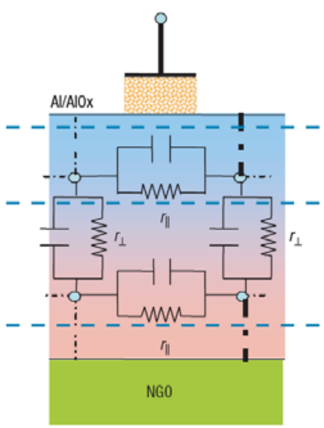

Figure 2. The capacitor structure showing the manganite thin film as a network of resistors and capacitors. (Reference 2).

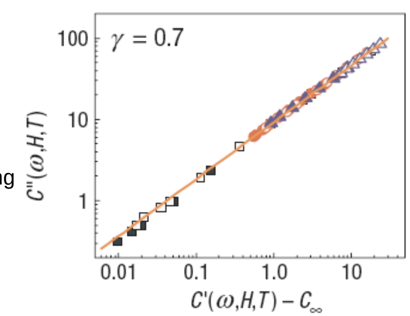

Figure 3. A plot of C′′ vs. C′ showing the data collapsing on a universal curve for different frequencies magnetic fields and temperatures. (Reference 2).

References:

[1] Direct Observation of Percolation in a Manganite Thin Film, Liuwan Zhang, Casey Israel, Amlan Biswas, R. L. Greene, and Alex de Lozanne, Science **298**, 805 (2002)

[2] Colossal magnetocapacitance and scale-invariant dielectric response in phase-separated manganites, Ryan P. Rairigh, Guneeta Singh-Bhalla, Sefaatin Tongay, Tara Dhakal, Amlan Biswas, Arthur F. Hebard, Nature Physics **3**, 551 (2007)

PIs:

Amlan Biswas (IHRP)

Arthur F. Hebard (NSF DMR: 0704240)