Using Magnetic Field Chaining in multiferroic Janus nanofibers to extract the Magnetoelectric coupling

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Composite multiferroics couple piezoelectricity and magnetostriction, allowing electrical control of magnetism and vice-versa. At the nanoscale the magnetoelectric coupling is theorized to be an order of magnitude larger than the bulk due to connectivity and the surface to volume ratio [1]. Even though multiferroics have been created in thin film, nanoparticle, and nanofiber form, metrology to quantitatively measure the multiferroic coupling is limited, especially for composite nanomaterials. Our previous work showed that multiferroic Janus nanofibers chain end-to-end in a magnetic field, and that the scaling parameters (z', z) are magnetic field dependent [2]. Here, by simultaneously applying an electric field perpendicular to the magnetic field, we observe changes in the length of the fiber chains, as well as increases in dispersion of chain length across a multi-chain sample.

Our Janus nanofibers consist of two hemi-cylinders and are produced by electrospinning with a combination of $BaTiO_3$(62% weight) and $CoFe_2O_4$(38%) [3]. We grind the fibers to produce random distribution of lengths with an average diameter of 1 μm. The nanofibers are then suspended in polyvinyl alcohol using citric acid and sodium hydroxide to enable colloidal stability. Before magnetic assembly, the suspended fibers are sonicated and deposited into a Hele-Shaw cell created with ITO coated cover slides to allow application of a perpendicular electric field while imaging the chaining process in a microscope.

We use video imaging to monitor the chaining process in a 200 Oe magnetic field alone and together with electric fields of 44.44 and 111.1 kV/m respectively. Figure 1 shows typical chaining dynamics, the chaining scaling parameters, and the corresponding increase in standard deviation as the electric field is applied. We performed a two sample t-test which shows that we do not have sufficient data to claim a statistically significant change in chaining. However, the variation in chain length when electric field is applied suggests the electric field does modify the assembly dynamics. However, we cannot put a bound on the strength of the magnetoelectric coupling coefficient, but expect to with additional data. Importantly, we have to rule out other electrochemical or geometrical effects that might also affect the chaining process.

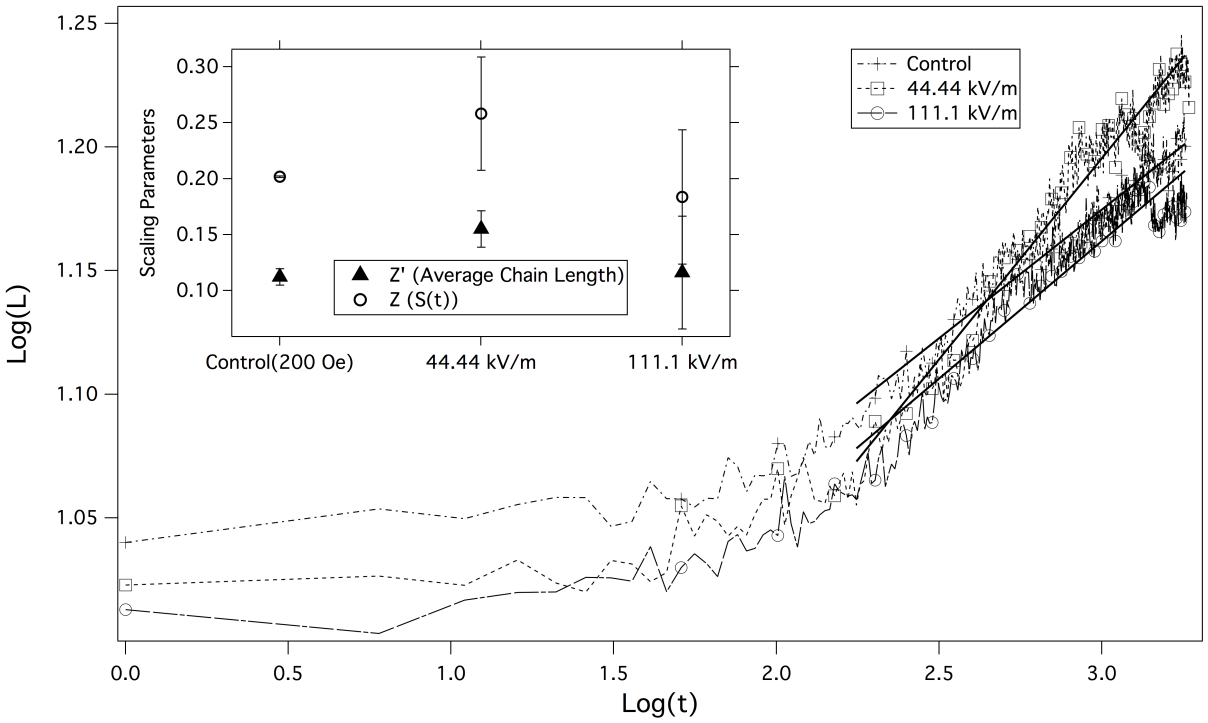

Figure 1: Log-Log graph of Average Chain Length vs Time, with inset Scaling parameters graph.

References

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