Electric field driven transition in magnetite\textsuperscript{1}
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Magnetite, Fe\textsubscript{3}O\textsubscript{4}, is a strongly electronically correlated system and thus exhibits remarkable electrical and magnetic properties, including the Verwey transition at $T_V \sim 122$ K, which has attracted much attention since its 1939 discovery. Fe\textsubscript{3}O\textsubscript{4} has recently revealed a new effect. By performing experiments at the nanoscale, we have discovered a novel electric-field driven transition (EFT) in magnetite below $T_V$, from high- to low-resistance states driven by high electric field. The EFT is detected both in Fe\textsubscript{3}O\textsubscript{4} nanoparticles and thin films, is hysteretic in voltage under continuous biasing, and is not caused by self- heating (S. Lee et. al., Nature Mater. 7, 130 (2008)). In this work we report on a thorough investigation of this new EFT. First, we unveil the origin of hysteresis observed in $I-V$ curves. By applying voltage in a \textit{pulsed} manner with controlled parameters we unambiguously demonstrate that while the transition is field-driven, hysteresis results from Joule heating in the low-resistance state. A simple relaxation-time thermal model captures the essentials of the hysteresis mechanism (A. Fursina et al., Phys. Rev. B 79, 245131 (2009)). Second, by doing multilead electrical measurements, we quantitatively separate the contributions of the Fe\textsubscript{3}O\textsubscript{4} channel and each electrode interfaces and explore the contact effects upon testing several different contact metals. On the onset of the transition, contact resistances at \textit{both} source and drain electrodes and the resistance of Fe\textsubscript{3}O\textsubscript{4} channel decrease abruptly. This behavior is consistent with a theoretically predicted transition mechanism of charge gap closure by electric field. Finally, we report recent measurements of the distribution of switching voltages and its evolution with temperature. These studies demonstrate that nanoscale, nonequilibrium probes can reveal much about the underlying physics of strongly correlated materials.

\textsuperscript{1}Recent work done primarily by A. Fursina, in collaboration with D. Natelson, R. G. S. Sofin, and I. V. Shvets. Financial support includes US Dept. of Energy Grant No. DE-FG02-06ER46337, the David and Lucille Packard Foundation, and the Research Corp.