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Preisach-percolation dynamics of multilevel resistive switching in phase-separated LPCMO

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We investigate the complex interplay of competing phases in bulk $La_{5/8-x}Pr_xCa_3/8MnO_3$ (LPCMO) to demonstrate the coexistence of volatile and non-volatile multilevel resistive switching (RS) within a single device. In this system, ferromagnetic metallic (FM-M) and charge-ordered insulating (COI) phases spatially coexist across a broad ~160 K temperature window. While volatile RS is driven by a reversible, electrically induced metal-insulator transition, the non-volatile RS is governed by the thermal history of the FM volume fraction. Specifically, voltage pulses that heat the device into a critical 90–210 K window permanently alter the phase fraction, modulating the resistance by up to seven orders of magnitude (~300 Ω to ~109 Ω). The metallic state is fully recoverable by cycling the temperature above the charge-ordering threshold (~210 K). To quantitatively capture this phase-fraction control, we implement a Preisach–percolation framework. Calibrated directly from experimental R–T hysteresis loops without free parameters, the model extracts domain switching distributions and utilizes a percolation threshold of $p_c = 0.65$ to successfully predict both macroscopic resistance at 2 K and magnetization at 5 K following specific thermal pathways. Ultimately, we demonstrate the stabilization of three distinct, highly reproducible resistance states over 25 cycles with ratios exceeding 10^3, showcasing phase-fraction engineering as a robust mechanism for multilevel memory in correlated oxides.

Keywords: resistive switching, phase separation, Preisach model, percolation theory, LPCMO, neuromorphic computing.

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