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Stochastic Nature of Voltage-Controlled Charge Dynamics in AlOx Magnetic Tunnel Junctions

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Abstract-

Spintronic memristors based on ferromagnetic metal/oxide heterostructures have recently enabled reversible manipulation of both magnetic properties and resistive switching (RS), offering promising prospects for multibit memory and neuromorphic computing. In this study, we investigate the stochastic nature and relaxation processes of charge dynamics induced by localized oxygen vacancy (VO) in AlOx-based magnetic tunnel junctions (MTJs). We observe that random telegraph noise (RTN) exhibits charge stochasticity at specific bias voltages in the low resistance state (LRS), reflecting the competition and transition between charge capture and emission states against the thermal energy. This behavior reveals that the thermally unstable charge stochasticity originates from localized traps in the AlOx barrier. In contrast, the high resistance state (HRS) favors the RTN emission states, indicating the dominance of direct tunneling effects. Through numerical calculations based on the tight-binding (TB) model and experimental results, we demonstrate that voltage-driven shifts in the VO position within the AlOx barrier, associated with RS, govern the charge dynamics of the MTJs investigated. These findings provide valuable insights and practical implications for the development of next-generation devices leveraging charge stochasticity in AlOx-based MTJs.

Index Terms- magnetic tunnel junction; memristor; resistive switching; random telegraph noise; oxygen vacancy

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