Magneto-ionics for Low-power Memory, Data Security and Advanced Computing

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Abstract

Magneto-ionics, which refers to voltage-driven modification of the magnetic properties of materials as a result of electric-field-induced ion transport, offers a compelling route toward low-power, analog magnetic memories and computing devices. Just as spintronics revolutionized electronics by integrating spin, merging magnetism with voltage-driven ion motion (iontronics) opens exciting prospects for the development of analog low-power magnetic data storage and their application in emerging research areas such as synaptic devices, data security and in-memory computing. While most magneto-ionic systems rely on oxygen, hydrogen, or lithium ions, this work introduces nitrogen magneto-ionics: the voltage-driven transport of nitrogen ions in transition metal nitride films (e.g., CoN, FeN, CoMnN, FeCoN) at room temperature using solid or liquid electrolytes [1-7]. These nitrides exhibit a tunable coexistence of ferromagnetic, paramagnetic, and antiferromagnetic phases, dictated by alloy composition and nitrogen content [4].

Remarkably, and in contrast to oxygen magneto-ionics, nitrogen transport tends to occur uniformly through a plane-wave-like migration front, an effect particularly interesting for the implementation of multilayer memory devices. We discuss methods to enhance switching speed and cyclability, and demonstrate neuromorphic traits such as potentiation, depression, spike-timing-dependent plasticity, and multilevel memory, amongst others [5]. Notably, some effects can be induced wirelessly via bipolar electrochemistry [3]. New phenomena in nanoscale patterned devices, such as FeCoN sub-micron disks, reveal a voltage-controlled transition between paramagnetic, coherent rotation, and magneto-ionic vortex states. These are driven by precise control of the planar N^{3-} ion front, which modulates local magnetic layer thickness [7]. Miniaturization of nitrogen magneto-ionic systems offers future prospects for brain-inspired devices and data security, where multiple synapses can be interconnected to perform in-memory computing.

References

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