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Correlated Nickelates: Phase Transitions and Neuromorphic Electronics

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As the finest computing system in our planet, human brain outperforms IBM Blue Gene at many aspects. Inspired by biological neural systems, neuromorphic devices open up new computing paradigms to explore cognition, learning and limits of parallel computation. In our brains, synapse is believed to be responsible for the learning and memory behaviors. The success of synapse concept at software-level artificial neural networks in the applications of voice and image recognitions has been driving the search for their hardware counterpart – synaptic device/transistor. Here we emulate the synapse by using a strongly correlated oxide – $SmNiO_3$. The electronic properties of correlated oxides are exceptionally sensitive to the orbital occupancy of electrons. We show a new strategy – interstitial electron doping via chemical route - for realizing sharp phase transition in perovskite $SmNiO_3$. The electron configuration of e_g orbital of $Ni^{3+}t_{2g}^6e_g^1$ in metallic $SmNiO_3$ is modified by injecting and anchoring an extra electron, forming a strongly correlated $Ni^{2+}t_{2g}^6e_g^2$ structure leading to the emergence of a new insulating phase. By this means, a reversible resistivity modulation greater than eight orders of magnitude (along with large change in optical band gap) is demonstrated at room temperature. A solid state synaptic proton-gated phase-change transistor is demonstrated based on this principle. With ionic liquid-gating $SmNiO_3$ transistor as an example, synaptic Spike-Timing-Dependent Plasticity (a popular learning algorithm in many synapses) is realized. The extreme sensitivity of electronic properties to dopants in correlated oxides make them a particularly suitable class of materials to realize artificial biological circuits that can be operated at and above room temperature and seamlessly integrated into conventional electronic circuits. I will close with a vision of my future research.

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