Energy-Efficient Hardware and Materials for Brain-inspired Computing: Artificial Synapses Based on Proton and Oxygen Motion

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Deep learning is a powerful algorithm for machine learning applications such as computer vision and natural language processing. However, the training of these neural networks is limited by the traditional von Neumann architecture of our current CPUs and GPUs. Shuttling data back and forth between the separate memory and computation units in such architecture results in significant energy consumption; many orders of magnitude greater than the energy consumption in human brain.

Our projects focus on designing materials and devices that can instead perform data storage and computation in a single architecture using ions, inspired by the human brain. In one project, we have designed a protonic electrochemical synapse that changes conductivity deterministically by current-controlled shuffling of dopant protons across the active device layer; resulting in energy consumption on par with biological synapses in the brain. In our second project, we demonstrate controlled conducting oxygen vacancy filament formation in resistive memory devices via dopant and microstructure engineering. Through these strategies, we exhibit a path towards neuromorphic hardware that has high yield and consistency, performs data storage and computation in a single device, and uses significantly lesser energy as compared to current systems.