Perovskite nickelate device reconfigurable for different functions

In a recent report published in *Science* (https://doi.org/10.1126/science.abj7943), Shriram Ramanathan, a professor of materials engineering at Purdue University, and his research group described the development of a perovskite neodymium nickelate ($NdNiO_3$) device that can switch between multiple electronic functions such as neurons, synapses, capacitors, and resistors, which are essential for brain-inspired computers. This simple yet powerful perovskite nickelate device can be reconfigured for a specific purpose by applying a single electric pulse. Their simulated dynamic networks (mimicking the dynamic functions of the brain neural network) outperformed static networks for incremental learning scenarios.

Perovskite nickelates are a class of quantum materials that possess exotic physical properties such as a metal-to-insulator transition governed by strong electron correlations. The nickelate devices were fabricated using atomic layer deposition, an industry standard thin-film deposition technique that offers exceptional conformal coating capabilities, tunable film composition, and highly precise thickness control. The researchers discovered that the electrical resistance of the material can be modulated by many orders of magnitude when hydrogen ions are introduced into the material.

"The sensitivity of electronic properties of perovskite nickelates and the local distribution of the dopant ions have enabled these results," says Ramanathan.

Michael Park from Purdue University, one of the lead researchers of this study, confirmed the subtle differences in the dopant concentrations after reconfiguring the different functions of the device. Analytical techniques such as Raman spectroscopy were used to show the change in the chemical nature for different functions.

Ramanathan says, "This material is very sensitive to the location and the concentration of hydrogen ions. The physics behind this finding is electronic phase transition upon hydrogen (or electron) doping. The positively charged hydrogen ions in the material can be moved very efficiently by applying electric fields."

At the same time, electrons from hydrogen modify electron occupation of this material, creating a strongly correlated insulating phase. In other words, the electrical resistance or the effective bandgap can be tuned by perturbing local proton distribution under the electric fields. By exploiting the material's physical property, the neuromorphic functions or brain-inspired hardware functions can be realized.

Ho Nyung Lee, Corporate Fellow and Director of the Materials Sciences and Engineering Program at Oak Ridge National Laboratory, commended this finding: "The innovative approach to program electronic circuits on demand with a perovskite system and its excellent performance can serve as the baseline foundation for developing and advancing the concepts that neuromorphic computing requires."

Correlated oxide materials such as these perovskite nickelates are complex systems that exhibit a wide variety of materials properties. With the ability to reconfigure artificial synapses and neurons, memory capacitors, and resistors in a single device, novel neuromorphic computing systems with the efficiency and robustness of the brain may open new avenues for future artificial intelligence.

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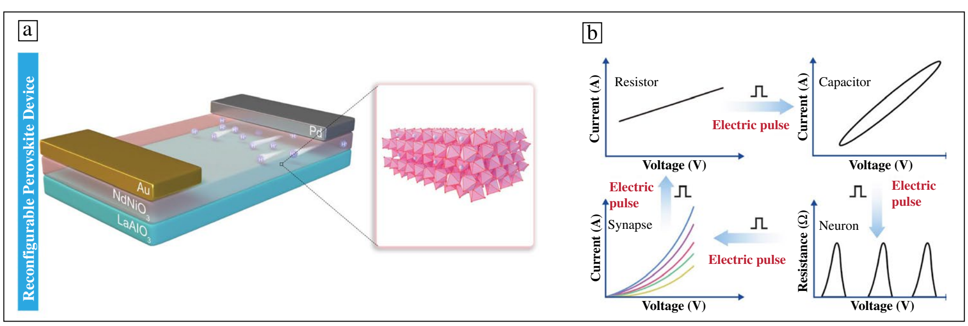

(a) Schematic of reconfigurable nickelate electronic devices that can be switched between resistor, capacitor, neuron, and synapse to enable adaptive brain-inspired computing. (b) Schematic of *I–V* behaviors of the nickelate device electrically reconfigured to different functions. Credit: *Science*.