MATERIALS ENGINEERING
SEMINAR

"Neuromorphic electronics with Mott insulators"

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ABSTRACT

The traditional semiconductor device scaling based on Moore's law is reaching its physical limits. New materials hosting rich physical phenomena such as correlated electronic behavior may be essential to identify novel approaches for information processing. The tunable band structures in such systems enables the design of hardware for neuromorphic computing. Strongly correlated perovskite nickelates ($ReNiO_3$) represent a class of quantum materials that possess exotic electronic properties such as metal-to-insulator transitions. In this thesis, detailed studies of $NdNiO_3$ thin films from wafer-scale synthesis to structure characterization and to electronic device demonstration will be discussed.

Atomic layer deposition (ALD) of correlated oxide thin films is essential for emerging electronic technologies and industry. We reported the scalable ALD growth of neodymium nickelate ($NdNiO_3$) with high crystal quality using $Nd(iPrCp)_3$, $Ni(tBu_2\text{-amd})_2$ and ozone (O_3) as precursors. By controlling various growth parameters such as precursor dose time and reactor temperature, we have optimized ALD condition for perovskite phase of $NdNiO_3$. We studied the structure and electrical properties of ALD $NdNiO_3$ films epitaxially grown on $LaAlO_3$ and confirmed their properties were comparable to those synthesized by physical vapor deposition methods.

$ReNiO_3$ undergoes a dramatic phase transition by hydrogen doping with catalytic electrodes independent of temperature. The electrons from hydrogen occupy Ni 3*d* orbitals and create strongly correlated insulating state with resistance changes up to eight orders of magnitudes. At room temperature, protons remain in the lattice locally near catalytic electrodes and can move by electrical fields due to its charge. The effect of high-speed voltage pulses on the migration of protons in $NdNiO_3$ devices is discussed. After voltage pulses were applied with changing the voltage magnitude in nanosecond time scale, the resistance changes of the nickelate device were investigated.

Reconfigurable perovskite nickelate devices were demonstrated and a single device can switch between multiple electronic functions such as neuron, synapse, resistor, and capacitor controlled by a single electrical pulse. Raman spectroscopy showed that differences in local proton distributions near the Pd electrode leads to different functions. This body of results motivates the search for novel materials where subtle compositional or structural differences can enable different gaps that can host neuromorphic functions.

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