RRAM based analog synapse device for neuromorphic system

Kibong Moon, Euijun Cha, and Hyunsang Hwang

Pohang University of Science and Technology (POSTECH), Korea

The 13th Korea-U.S. Forum on Nanotechnology, Sep. 26-27, Seoul, Korea
Outline

• Introduction and Motivation
• Mo/PCMO synapse device
• Pattern recalling system
• Summary
Introduction

- Neuron ($\sim 10^{11}$) + Synapse ($\sim 10^{15}$) + Learning Rule
- Low energy ($\sim 10\text{f}J$) synapse and neuron devices
Various new synapse devices were proposed (CBRAM, PCM, 3T-FeMEM, and RRAM)
Problems: Large device area, power consumption, circuit complexity etc.
VO₂ Insulator-Metal-Transition temperature ~ 67°C
: Not practical for device application
Mo/PCMO synapse device

- Current level ∝ Active area

- Field-induce oxygen migration & redox reaction at the interface:
  Control thickness of interface oxide and device resistivity

![Diagram showing current-voltage characteristics and field-induced oxygen migration.](image)
Mo/PCMO synapse device

- Well fabricated without mixing (Mo/PCMO)
- Direct evidence of redox reaction at the interface
Mo/PCMO synapse device

✓ DC property
✓ AC property

✓ Potentiation (-V):
  - Increase conductance
  - Strengthen synaptic weight

✓ Depression (+V):
  - Decrease conductance
  - Weaken synaptic weight
NbO$_2$ neuron device

- NbO$_2$ based oscillation characteristics with synapse device
- Above critical threshold voltage $\Rightarrow$ Oscillation behavior
Pattern recalling system

Operation of Hopfield network on 11k-bit array

- Neuromorphic application using 11k-bit array Mo/PCMO synapse device and NbO$_2$ IMT oscillator neuron devices
Pattern recalling system

- Synapse weight mapping: **Binary and Analog synapse** based Hopfield neural network

- Analog synapse shows much better pattern recognition accuracy
Summary

✓ Mo/PCMO analog synapse device
  - Field-induced oxygen migration for switching of Mo/PCMO device
  - Fabrication of large scale synapse array device on 8-inch wafer
  - Evaluating synapse characteristics for an artificial synapse

✓ Hardware implementation of neuromorphic application
  - NbO$_2$ oscillator as an artificial neuron
  - Integrating Mo/PCMO synapse array and NbO$_2$ neuron
  - Improved pattern recalling accuracy using analog synapse
Thank you for your attention...!

This research was supported by the Pioneer Research Center Program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning (2012-0009460)