RRAM based analog synapse device for neuromorphic system

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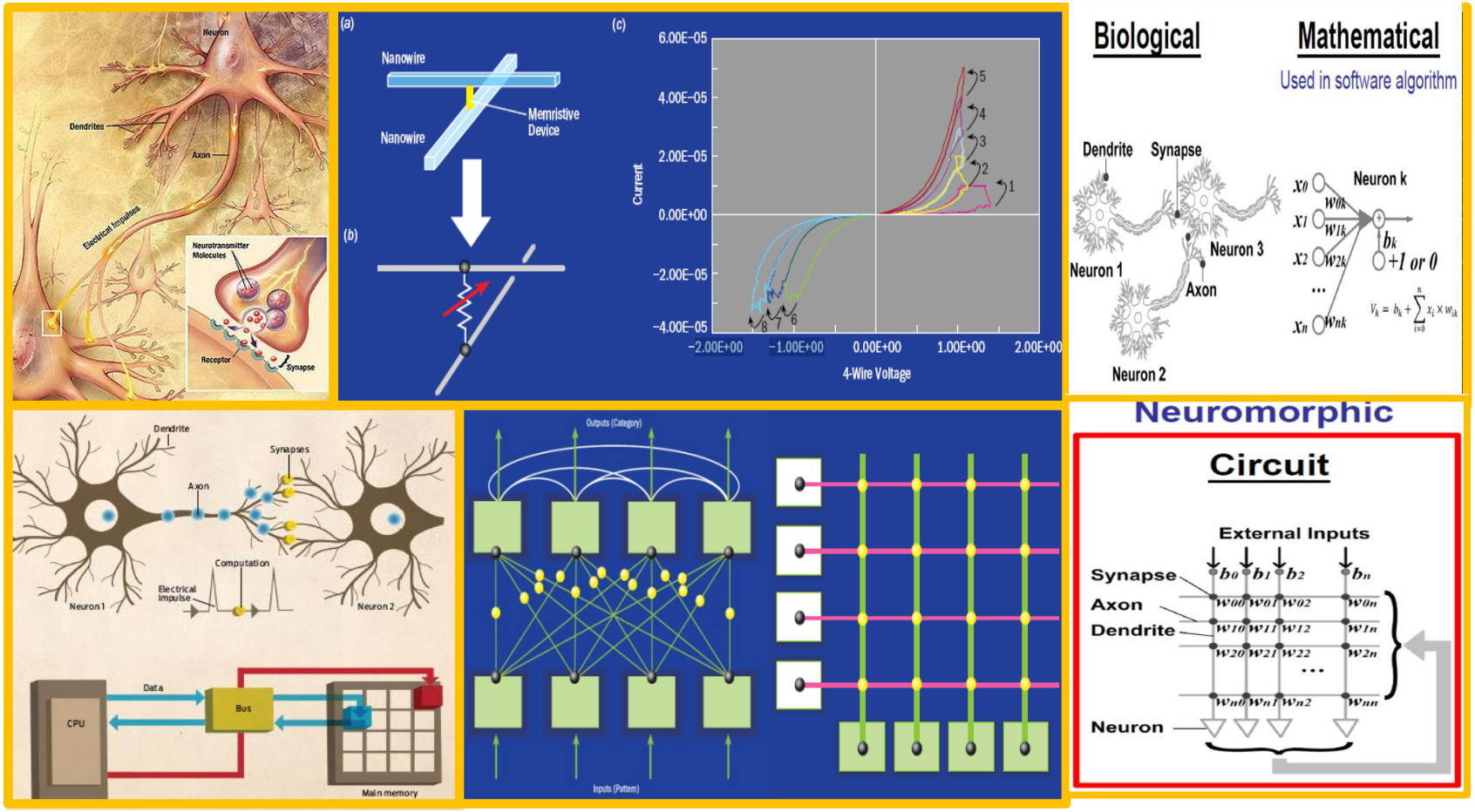
Outline

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

Introduction

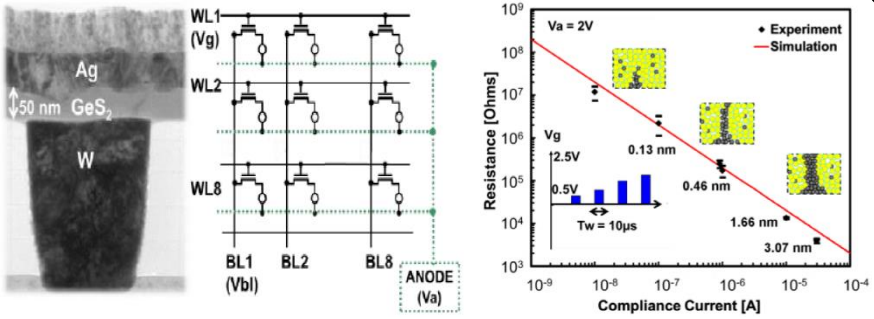


Source: HP

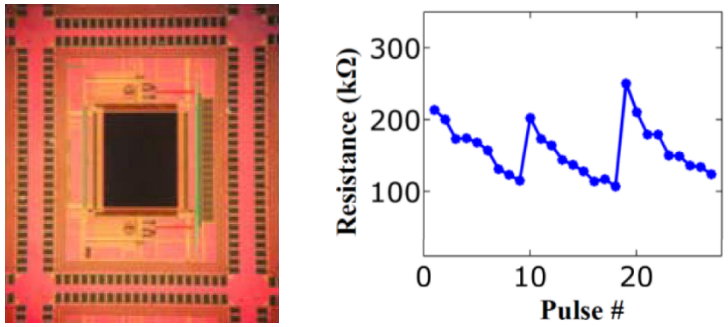
- ✓ Neuron (~10^{11}) + Synapse (~10^{15}) + Learning Rule
- ✓ Low energy (~10fJ) synapse and neuron devices

Introduction

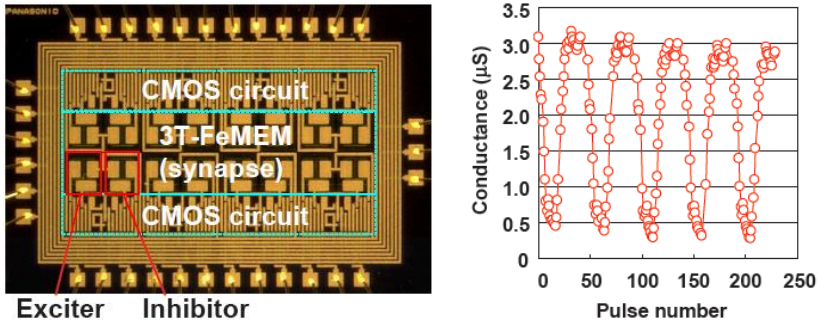
CEA-LETI, IEDM 2012



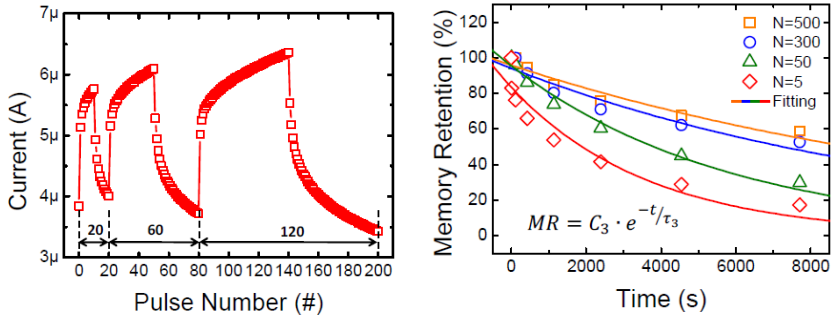
Stanford Univ., IEDM 2013



Panasonic, VLSI 2013



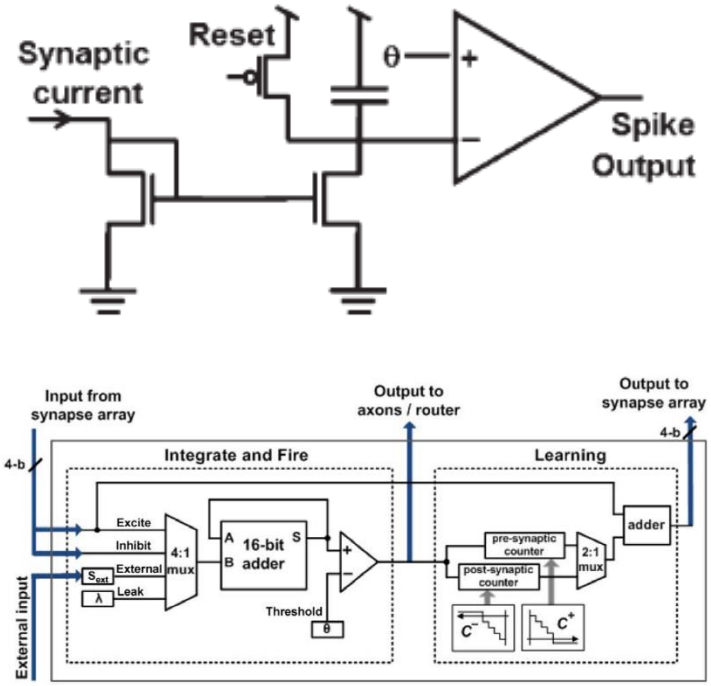
Univ. of Nat. Chiao Tung, IEDM 2014



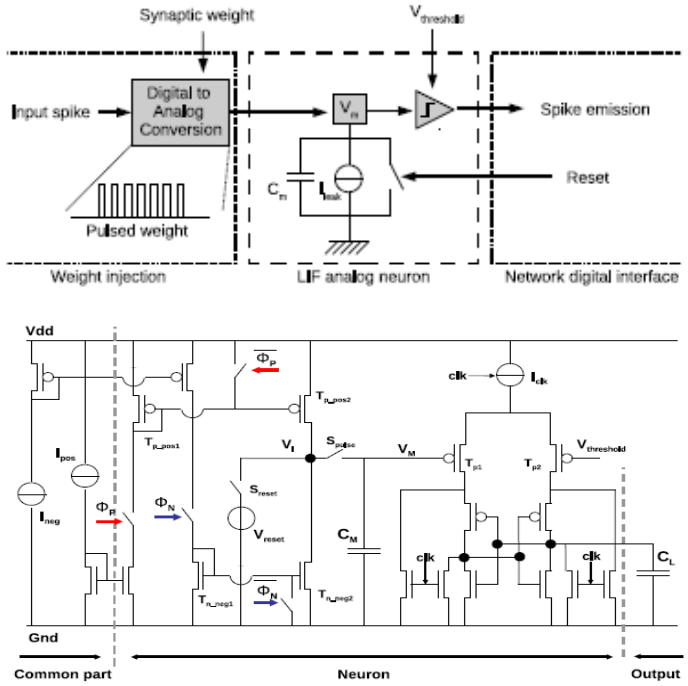
- ✓ Various new synapse devices were proposed (CBRAM, PCM, 3T-FeMEM, and RRAM)

Introduction

IBM, TED 2013



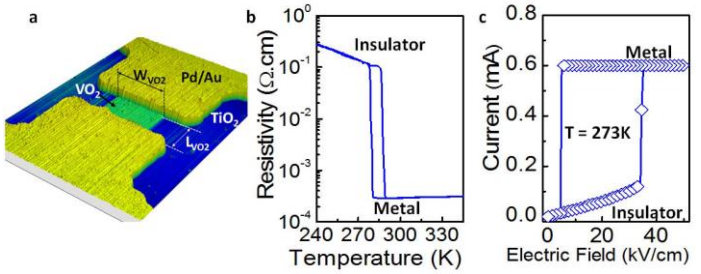
CEA-LETI, NEWCAS 2011

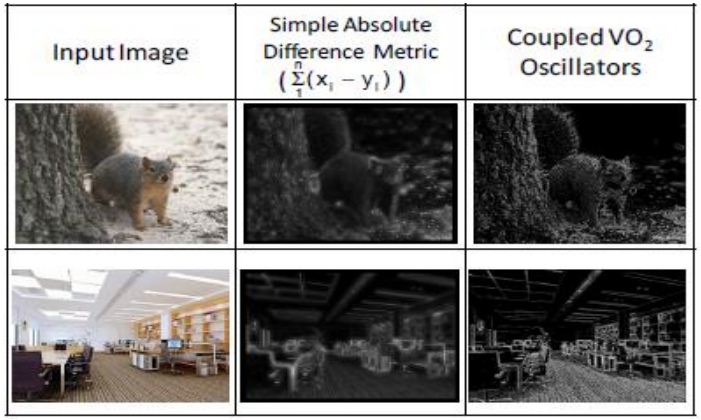


✓ Problems : Large device area, power consumption, circuit complexity etc..

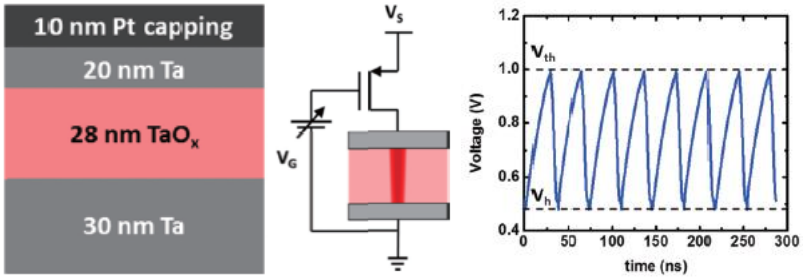
Introduction

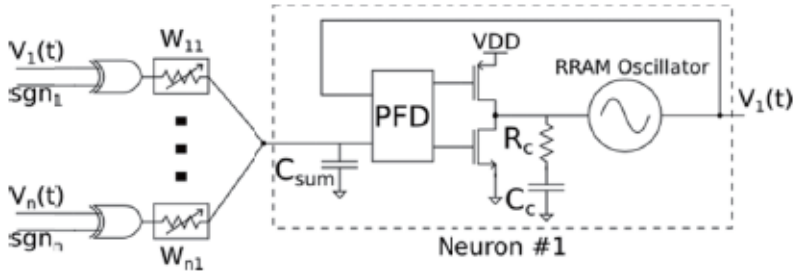
Pennsylvania Univ., IEDM 2014





Carnegie Mellon Univ., VLSI 2015

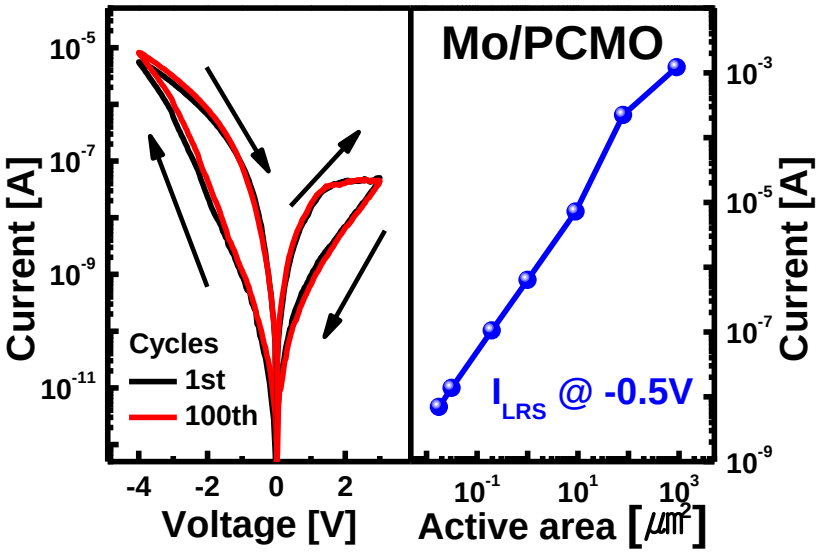


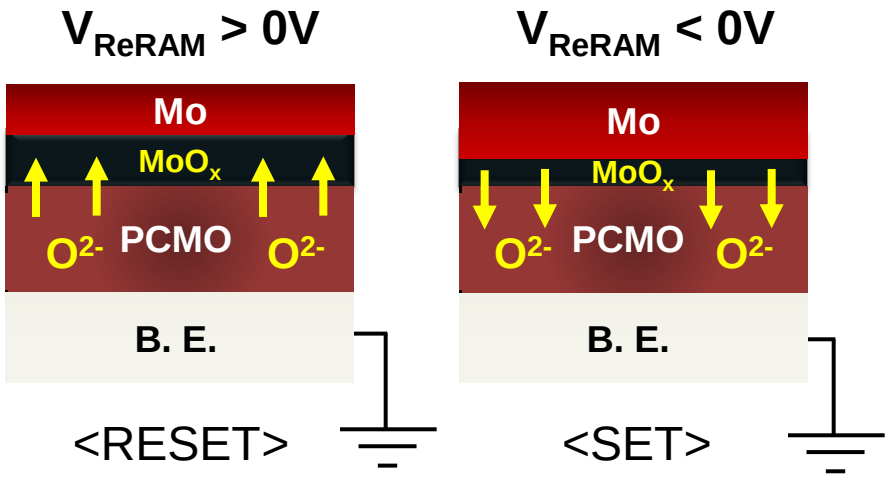


- ✓ VO_2 Insulator-Metal-Transition temperature ~ 67°C

: Not practical for device application

Mo/PCMO synapse device

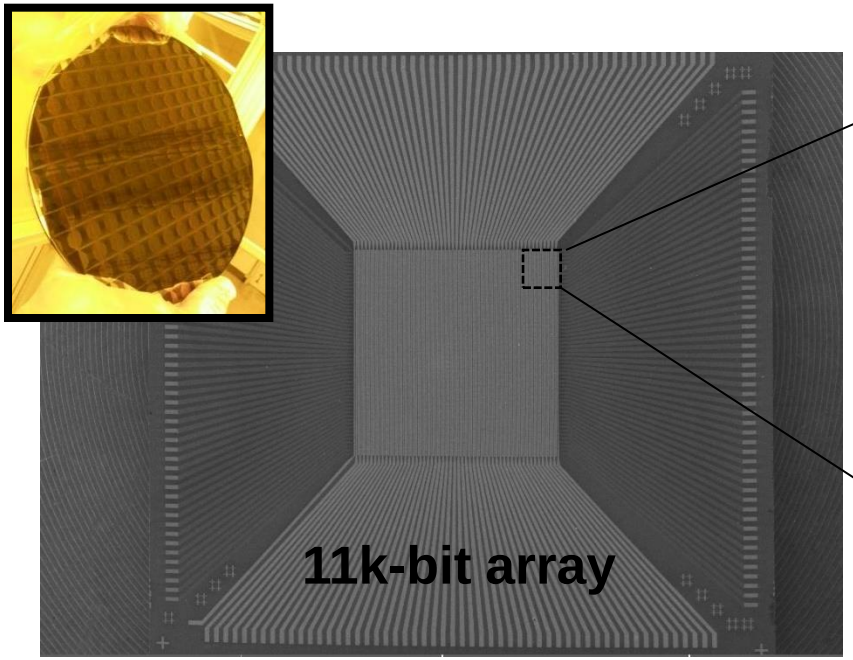


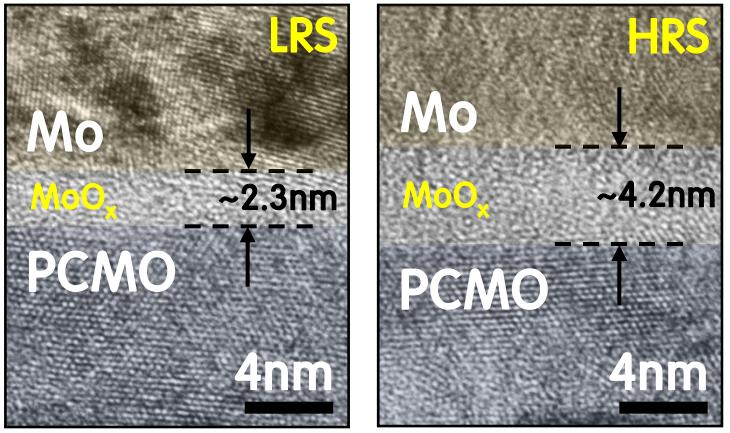


✓ Current level ∝ Active area

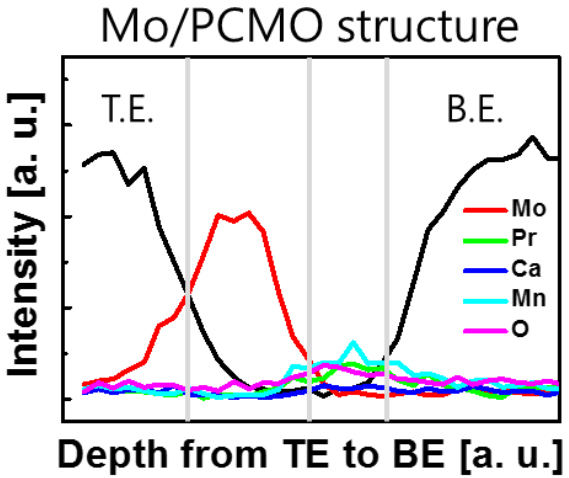
✓ Field-induce oxygen migration & redox reaction at the interface
: Control thickness of interface oxide and device resistivity

Mo/PCMO synapse device



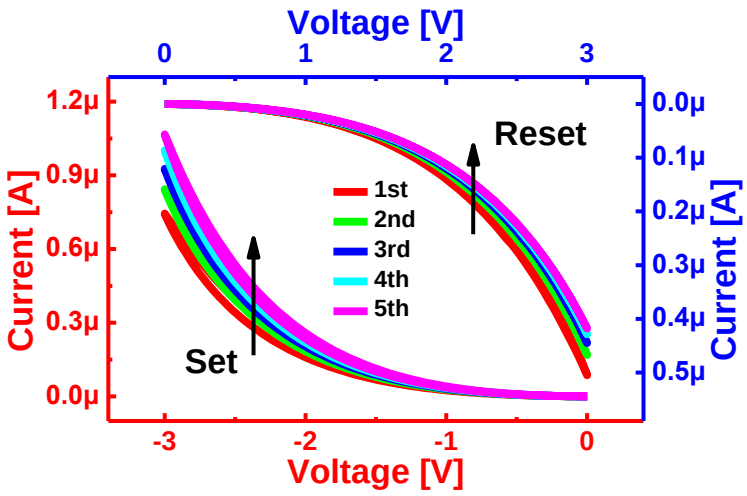


- ✓ Well fabricated without mixing (Mo/PCMO)
- ✓ Direct evidence of redox reaction at the interface

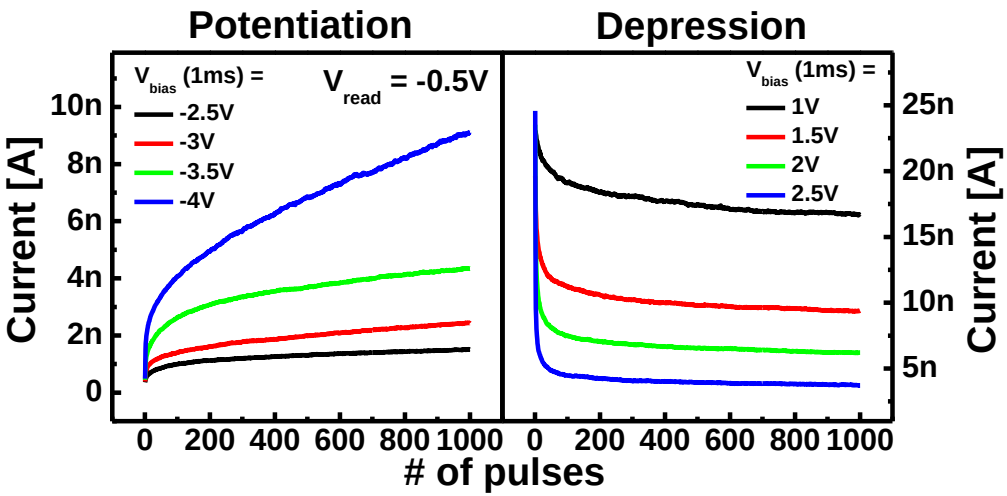


Mo/PCMO synapse device

✓ DC property



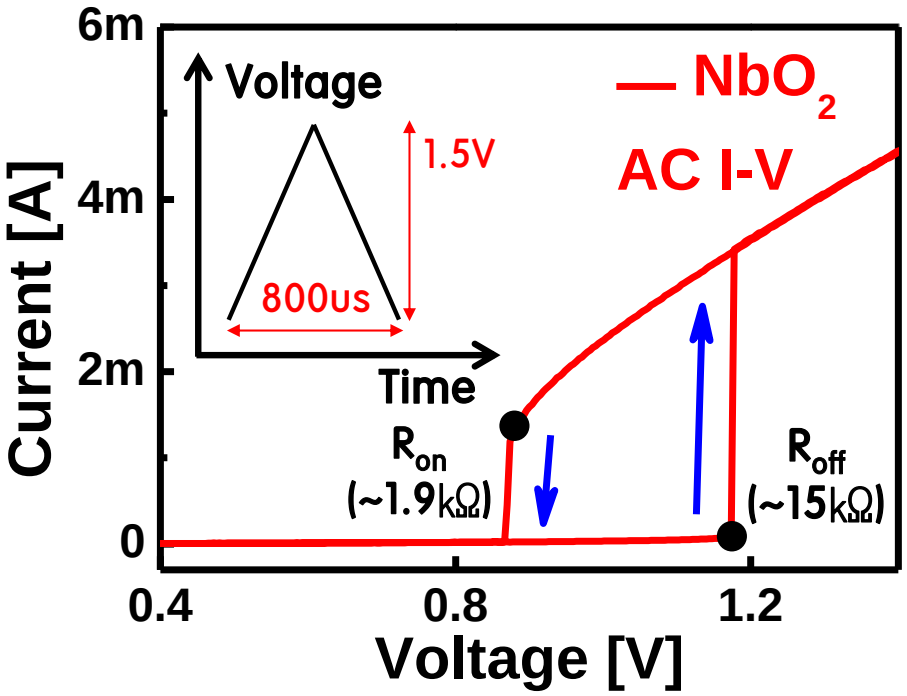
✓ AC property

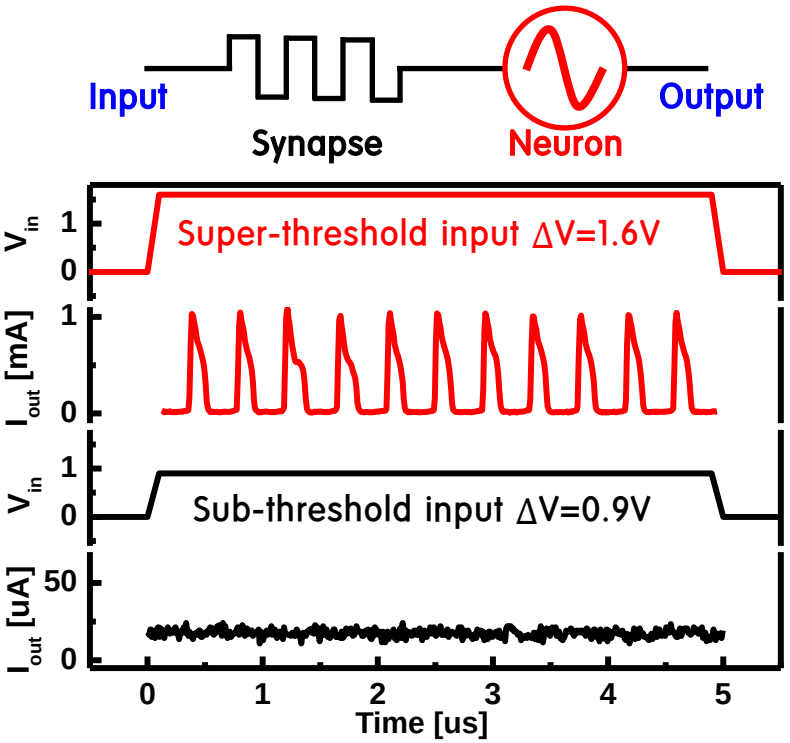


✓ Potentiation (-V)
: Increase conductance
: Strengthen synaptic weight

✓ Depression (+V)
: Decrease conductance
: Weaken synaptic weight

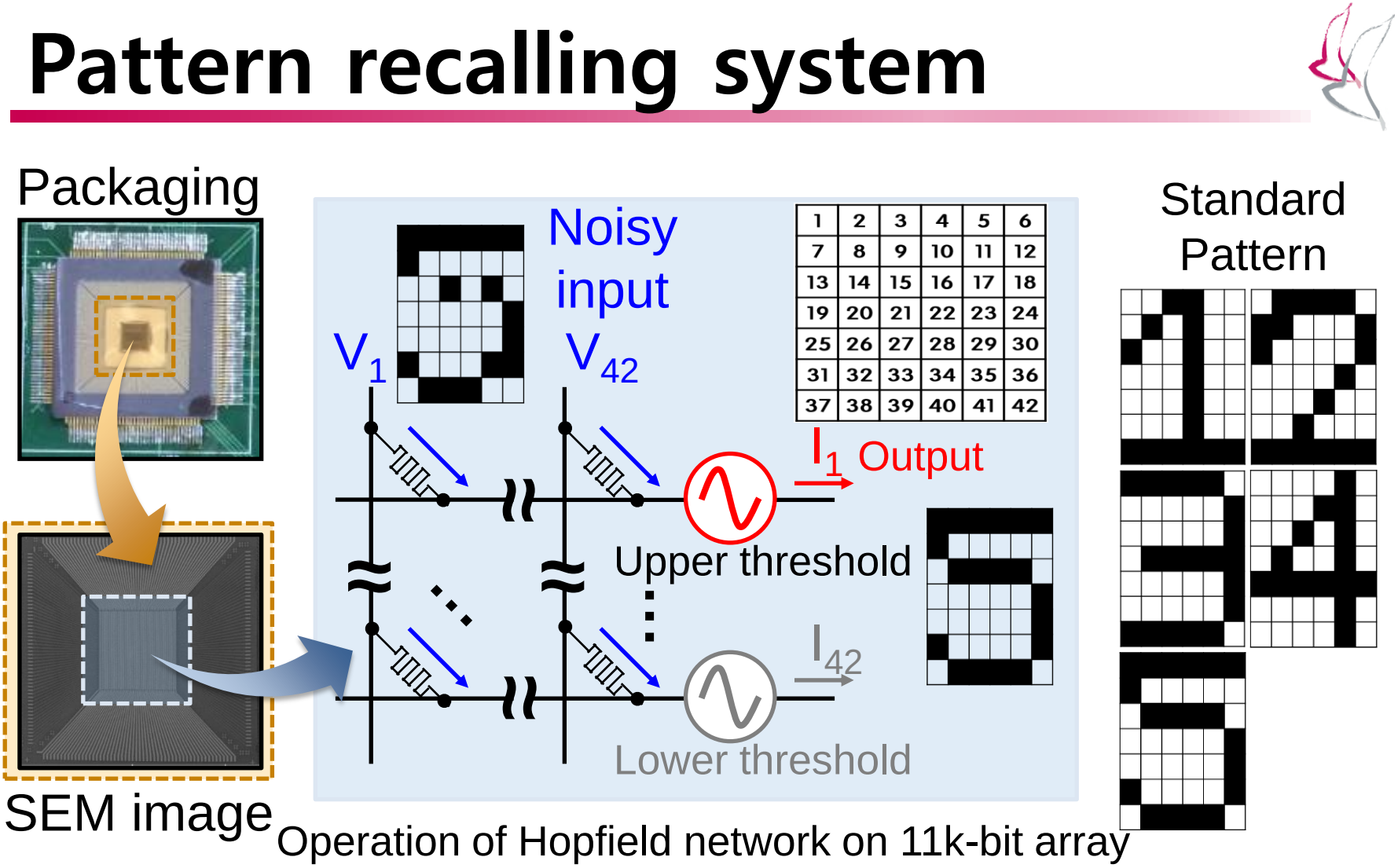
NbO_2 neuron device





- ✓ NbO_2 based oscillation characteristics with synapse device
- ✓ Above critical threshold voltage ➔ Oscillation behavior

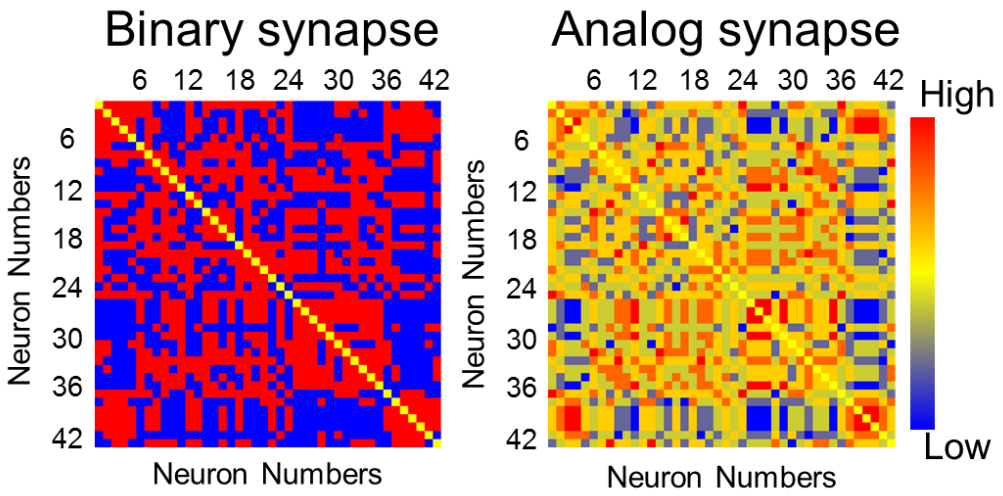
Pattern recalling system

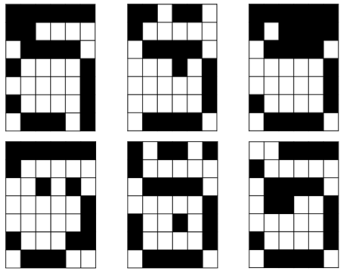
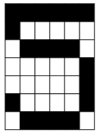


Operation of Hopfield network on 11k-bit array

✓ Neuromorphic application using 11k-bit array Mo/PCMO synapse device and NbO_2 IMT oscillator neuron devices

Pattern recalling system



	Binary	Analog
Input		
Output	Error	

✓ Synapse weight mapping : Binary and Analog synapse based Hop-field 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 implmenetation 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…!

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