Powering the Future: High Energy Efficiency Nanoelectronics for Advanced Neuromorphic Computing

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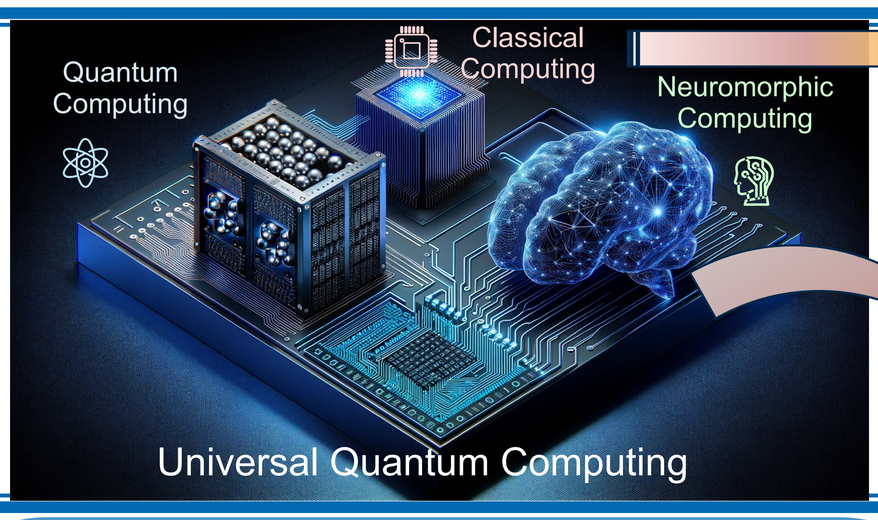
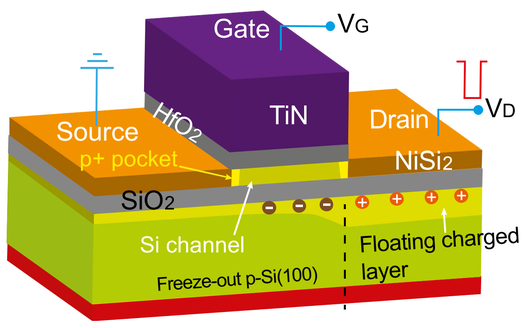
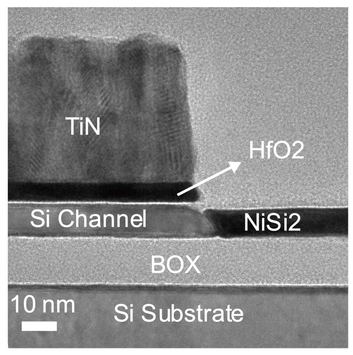
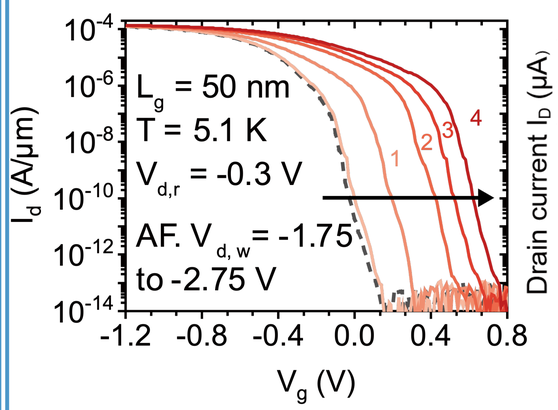
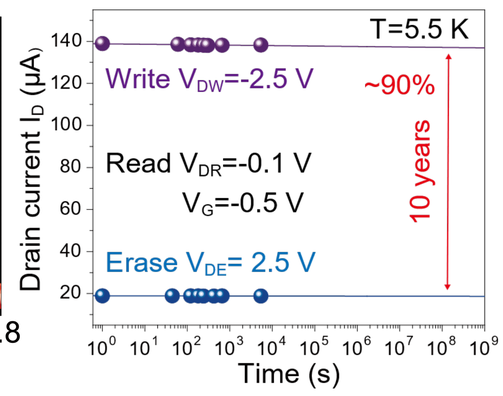


Cryogenic Memory









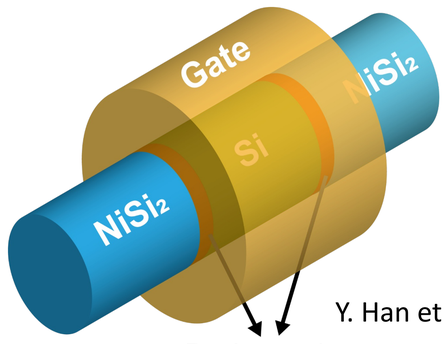
Yi. Han et al., Nature Electronics, under Review

- Multi-state, wide temperature range memory
- Non-volatile with retention:
  >10 years at 5K
  a few days at 300K
- High scalability
- Ultra-low writing energy: **100zJ**

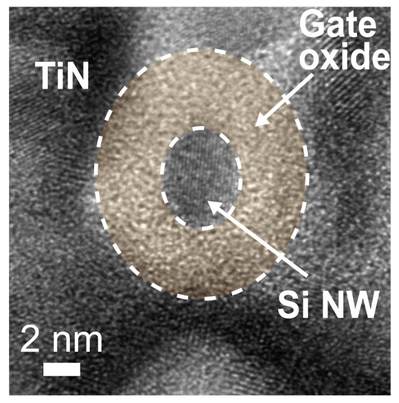
Ultra-low Power Cryogenic CMOS

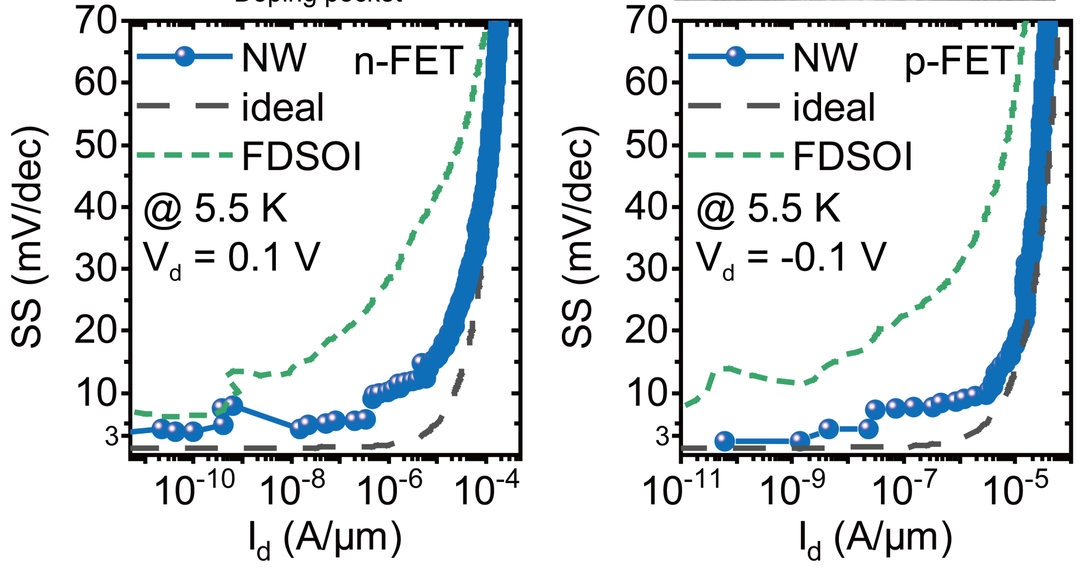
Challenges:

- Band-tail causes subthreshold swing saturation;
- localized states cause inflection



Y. Han et al., VLSI 2023

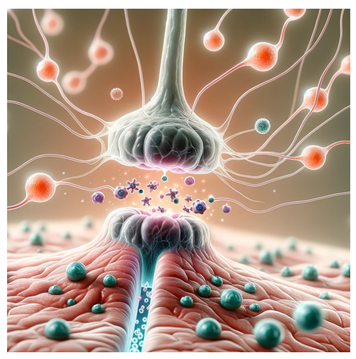


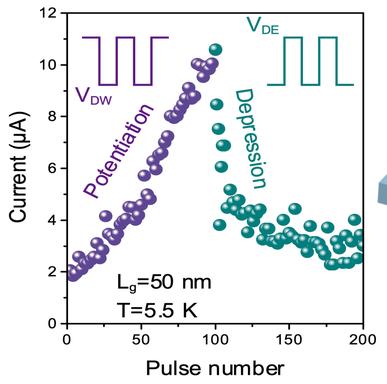


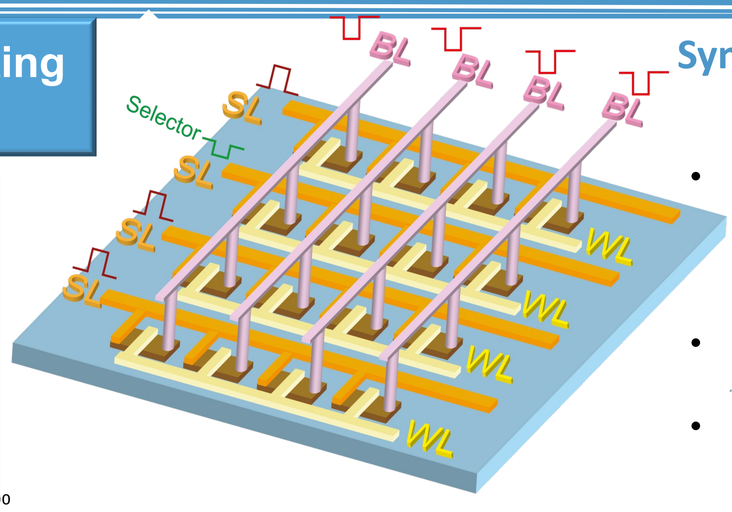
- Very scaled GAA Nanowire MOSFETs: 5 nm diameter Si nanowire
- Lowest subthreshold swing: 2.3 mV/dec at 5 K
- Suppressed inflection phenomenon
- High potential for ultra-low power quantum computing application

Cryogenic Neuromorphic Computing

for machine learning of Qubits.



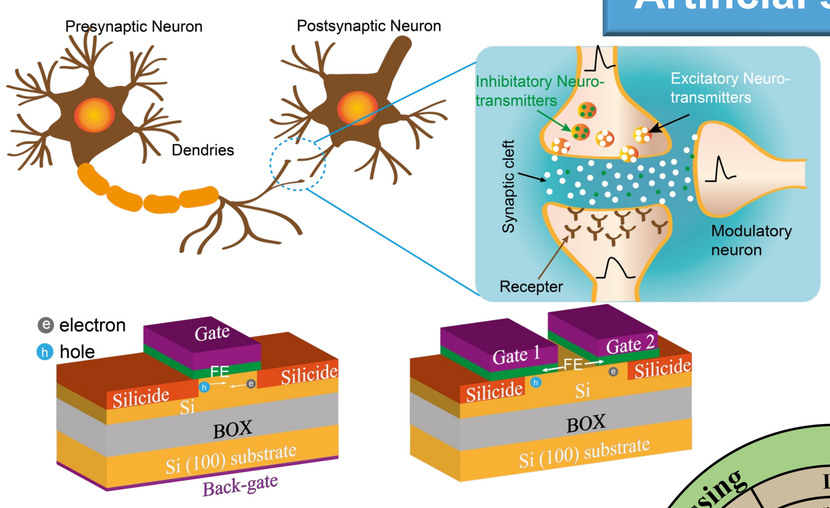


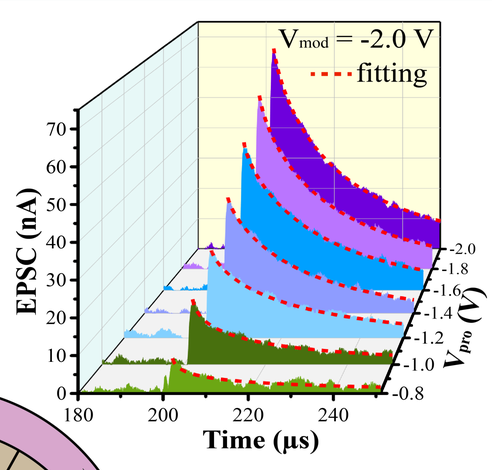


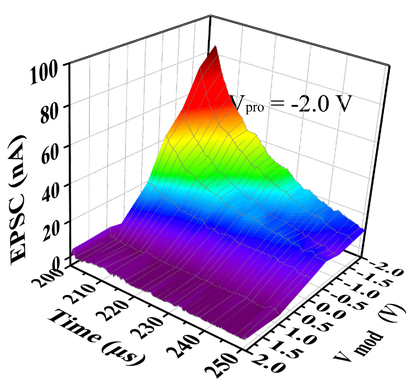
Synapses Array

- Artificial synapses at a wide temperature range 300 - <4 K
- Low power consumption
- Self-selecting synapse arrays

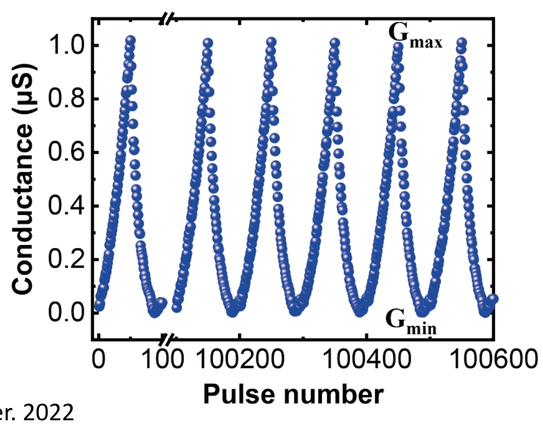
Artificial synapses fabricated with ferroelectric transistors

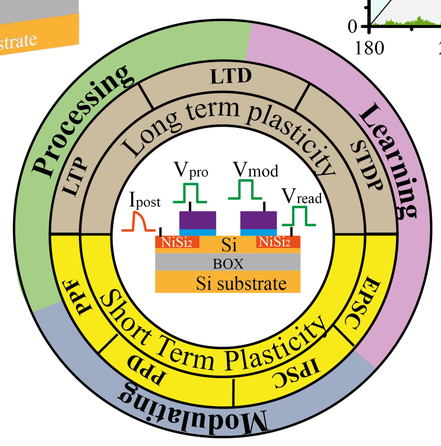






F. Xi et al., Adv. Elctron Mater. 2022





- Multi-functionalities: learning, processing and modulating
- Very low power: 1fJ/spike
- High speed: 20 ns
- Very small CTC variation
- High on/off ratio
- High learning accuracy

- **Synapse arrays**
- **Integration of synapses and neurons**
- **In sensor computing**
- **Flexible neuromorphic computing devices**

Collaboration with South Korea: Prof. Sanghyeon Kim (KAIST), Dr. Jae-Hoon Han (KIST), Dr. Choonghyun Lee (Pebble Square)

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https://www.fz-juelich.de/en/pgi/pgi-9/

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