Progressive and stable synaptic plasticity with femtojoule energy consumption by the interface engineering of a metal/ferroelectric

Sohwi Kim[1]
Chansoo Yoon[1], Gwangtaek Oh[1], Minjeong Shin[1], Eun Hee Kee[1], Jiyoung Kim[1], Seoyul Lim[1], Jungeun Oh[1], Ji Hye Lee[2, 3], Sanghyun Park[4], Bo Soo Kang[4], and Young Heon Kim[5], Bae Ho Park[1]*

[1]*Division of Quantum Phases & Devices, Department of Physics, Konkuk University, Seoul 05029, Republic of Korea*
[2]*Center for Correlated Electron Systems (CCES), Institute of Basic Science (IBS), Seoul, Republic of Korea*
[3]*Department of Physics and Astronomy, Seoul National University, Seoul 08826, Republic of Korea*
[4]*Department of Applied Physics, Hanyang University, Gyeonggi-do 15588, Republic of Korea*
[5]*Graduate School of Analytical Science and Technology, Chungnam National University, Daejoen 34134, Republic of Korea*

Contact: baehpark@konkuk.ac.kr

In the era of "big data", the cognitive system of the human brain is being mimicked through hardware implementation of highly accurate neuromorphic computing by progressive weight update in synaptic electronics. Low-energy synaptic operation requires both low reading current and short operation time to be applicable to large-scale neuromorphic computing systems. In this study, we implement an energy-efficient synaptic device comprising a Ni/Pb($Zr_{0.52}Ti_{0.48}$)O_3 (PZT)/0.5 wt% Nb-doped $SrTiO_3$ (Nb:STO) heterojunction with a low reading current of 10 nA and short operation time of 20–100 ns. Ultralow attojoule operation up to 5.5 aJ at a synaptic event, which is significantly lower than the energy required for synaptic events in the human brain (10 fJ), is achieved by adjusting the Schottky barrier between the top electrode and ferroelectric film. Moreover, progressive domain switching in ferroelectric PZT successfully induces both low nonlinearity/asymmetry and good stability of the weight update. The synaptic device developed here can facilitate the development of large-scale neuromorphic arrays for artificial neural networks with low energy consumption and high accuracy.

References

[1] Kim, S., Yoon, C., Oh, G., Lee, Y. W., Shin, M., Kee, E. H., ... & Kim, Y. H. Advanced Science, 2201502(2022)

Figures

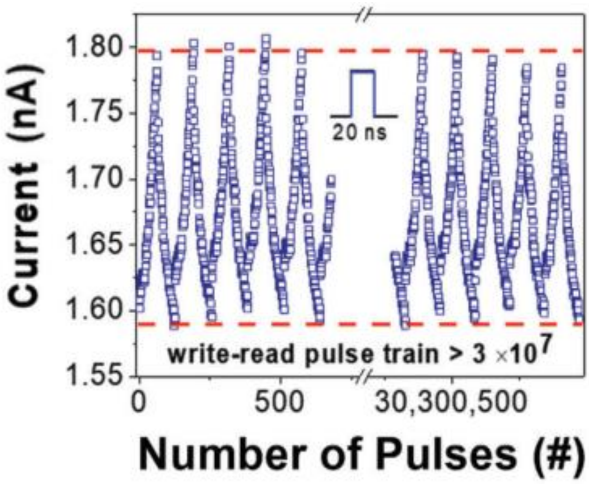

Figure 1: Femtojoule energy consumption with high endurance in Ni/PZT/Nb:STO synaptic device.