Session 6 - Emerging Device and Compute Technology - Neuromorphic Session I-Device Focus
Monday, December 9, 1:30 p.m.
Continental Ballroom 5
Co-Chairs: U. Avci, Intel Corp.
Q. Liu, Chinese Academy of Sciences

1:35 PM **6.1** Reducing the Impact of Phase-Change Memory Conductance Drift on the Inference of large-scale Hardware Neural Networks
Stefano Ambrogio, Mathieu Gallot, Katherine Spoon, Hsinyu Tsai, Charles Mackin, Marie Wesson, Sanjay Kariyappa, Pritish Narayanan, Chi-Chun Liu, Arvind Kumar, An Chen, Geoffrey W Burr, IBM Research, IBM TJ Watson Research Center

We analyze the impact of conductance drift and noise in Deep Neural Networks (DNNs) inference. We provide PCM array partial-set states experimental characterization, describe the impact of drift on Fully-Connected DNN on MNIST, ResNet on CIFAR-10 and LSTM on Alice-in-Wonderland, and we consider 1/f and Random Telegraph Noise sources.

2:00 PM **6.2** Performance Maximization of In-Memory Reinforcement Learning with Variability-Controlled $Hf_{1-x}ZrxO_2$ Ferroelectric Tunnel Junctions,
Kensuke Ota, Marina Yamaguchi, Radu Berdan, Takao Marukame, Yoshifumi Nishi, Kazuhiro Matsuo, Kota Takahashi, Yuta Kamiya, Shinji Miyano, Jun Deguchi, Shosuke Fujii, Masumi Saitoh, Toshiba Corporation, Kioxia Corporation

We develop strategies to maximize performance and reliability of in-memory reinforcement learning with $Hf_{1-x}ZrxO_2$ ferroelectric tunnel junction. Small cycle-to-cycle variability and large voltage tuning window is desirable. $Hf_{1-x}ZrxO_2$ thinning reduces variability, while voltage margin is larger with lower Zr concentration. Device size scaling enables low-power, high-density, and high-reliability reinforcement learning.

2:25 PM **6.3** Sub-nA Low-Current HZO Ferroelectric Tunnel Junction for High-Performance and Accurate Deep Learning Acceleration
Tzu-Yun Wu, Hsin-Hui Huang, Yueh-Hua Chu, Chih-Cheng Chang, Ming-Hung Wu, Chien-Hua Hsu, Chien-Ting Wu, Min-Ci Wu, Wen-Wei Wu, Tian-Sheuan Chang, Heng-Yuan Lee, Shyh-Shyuan Sheu, Wei-Chung Lo, Tuo-Hung Hou, National Chiao Tung University, Industrial Technology Research Institute, Taiwan Semiconductor Research Institute

A HZO FTJ operates at sub-nA current while achieving 50-ns switching, $>10^7$ endurance, >10-yr retention, and analog state modulation. We analyze an FTJ-based BNN. It achieves better accuracy and 702, 101, and 7×10^4 times improvements in power, area, and energy-area-product efficiency compared with those using NVMs with typical mA current.

2:50 PM **6.4** Capacitor-less Stochastic Leaky-FeFET Neuron of Both Excitatory and Inhibitory Connections for SNN with Reduced Hardware Cost
Jin Luo, Liutao Yu, Tianyi Liu, Mengxuan Yang, Zhiyuan Fu, Zhongxin Liang, Liang Chen, Shuhan Liu, Cheng Chen, Si Wu, Qianqian Huang, Ru Huang, Peking University

A capacitor-less L-FeFET neuron enabling both excitatory and inhibitory input connections with two transistors and one resistor is experimentally demonstrated to emulate biological neuronal dynamics. The new neuron with dramatically-reduced hardware cost is applied to unsupervised SNN with the implementation of clustering and high-accuracy inference, showing great potentials for neuromorphic computing.

3:15 PM COFFEE BREAK

3:40 PM 6.5 Complementary Graphene-Ferroelectric Transistors (C-GFTs) as Synapses with Modulatable Plasticity for Supervised Learning
Yue Zhou, Nuo Xu, Bin Gao, Yangyang Chen, Boyi Dong, Yi Li, Yuhui He, Xiangshui Miao, Tsinghua University, Huazhong University of Science and Technology, University of California, Berkeley, Tsinghua University

The complementary graphene-ferroelectric transistors (GFT) have been developed as synapses for the first time, which can be dynamically reconfigured between potentiative and depressive modes. Both modes demonstrate excellent linearity, small cycle-to-cycle variation of 2%, over 5-bit levels and power consumption of 8 pJ/per operation in MNIST learning task.

4:05 PM 6.6 A Novel Scalable Energy-Efficient Synaptic Device: Crossbar Ferroelectric Semiconductor Junction
Mengwei Si, Yandong Luo, Wonil Chung, Hagyoul Bae, Dongqi Zheng, Junkang Li, Jingkai Qin, Gang Qiu, Shimeng Yu, Peide Ye, Purdue University, Georgia Institute of Technology

A ferroelectric semiconductor α-In_2 Se_3 based crossbar ferroelectric semiconductor junction as a synaptic device is demonstrated. A metal-ferroelectric semiconductor-metal crossbar structure is used instead conventional ferroelectric tunnel junction. The crossbar ferroelectric semiconductor junction shows good on-line learning accuracy, low latency and energy consumption as a promising and competitive synaptic device.

4:30 PM 6.7 Experimental Demonstration of Conversion-Based SNNs with 1T1R Mott Neurons for Neuromorphic Inference
Xumeng Zhang, Zhongrui Wang, Wenhao Song, Rivu Midya, Ye Zhuo, Rui Wang, Mingyi Rao, Navnidhi Upadhyay, Qiangfei Xia, J. Joshua Yang, Qi Liu, Ming Liu, Chinese Academy of Sciences, University of Massachusetts, Amherst, University of Chinese Academy of Sciences

We experimentally demonstrated a one-layer SNN (320 ×10) based on fully memristive devices for the first time. Experimental results show 95.7% converting accuracy of the neurons and − 85.7% − recognition accuracy in − MNIST − data sets. At last, a neuron X-bar architecture is proposed for parallel multi-tasking and better system integration.