Brain-Inspired Computing Using Magnetic Domain Wall Devices

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Neuromorphic computing or brain-inspired computing is considered as a potential solution to overcome the energy inefficiency of the von Neumann architecture for artificial intelligence applications [1-4]. To realize spin-based neuromorphic computing practically, it is essential to design and fabricate electronic analogues of neurons and synapses. An electronic analogue of a synaptic device should provide multiple resistance states. A neuron device should receive multiple inputs and should provide a pulse output when the summation of the multiple inputs exceeds a threshold.

Our group has been carrying out investigations on the design and development of various synaptic and neuron devices in our laboratory. Domain wall (DW) devices based on magnetic tunnel junctions (MTJs), where the DW can be moved by spin-orbit torque, are suitable candidates for the fabrication of synaptic and neuron devices [2]. Spin-orbit torque helps in achieving DW motion at low energies whereas the use of MTJs helps in translating DW position information into resistance levels (or voltage pulses) [3]. This talk will summarize various designs of synthetic neurons synaptic elements and materials [4]. The first half of the talk will be at an introductory level, aimed at first-year graduate students. The second half will provide details of the latest research.

[1] K Roy, A Jaiswal and P Panda, Naure 575 607-617 (2019)
[2] WLW Mah, JP Chan, KR Ganesh, VB Naik, SN Piramanayagam, Leakage function in magnetic domain wall based artificial neuron using stray field, Appl. Phys. Lett., 123 (9) 092401 (2023).
[3] D Kumar, HJ Chung, JP Chan, TL Jin, ST Lim, SSP Parkin, R Sbiaa and SN Piramanayagam, Ultralow Energy Domain Wall Device for Spin-Based Neuromorphic Computing ACS Nano 17(7) 6261-6274 (2023)
[4] R Maddu, D Kumar, S Bhatti and S.N. Piramanayagam, Spintronic Heterostructures for Artificial Intelligence: A Materials Perspective, Phys. Stat. Sol. RRL 17(6) 2200493 (2023).

S. N. (Prem) Piramanayagam got the Ph.D. from the Indian Institute of Technology, Bombay, India, in 1994. He carried out further research at Shinshu University, Japan (1995–1999) and worked at the Data Storage Institute (DSI), Singapore (A*STAR). He is currently an Associate Professor at Nanyang Technological University (NTU), Singapore. He has 30 years of experience in magnetism, with research topics including amorphous magnetic alloys, permanent magnetic materials, and thin films and nanostructures for recording and spintronics applications. His current interest lies in the interdisciplinary areas of magnetism, electronics, and nanotechnology.

Prem has received an award for teaching excellence from NTU Singapore and several awards for outstanding research from DSI Singapore. He is a Senior Member of IEEE and has been an active volunteer in the IEEE Magnetics Society, including chair of the Technical Committee, elected member of the Administrative Committee, chair of the Singapore Chapter, and co-chair of the 2018 Intermag Conference in Singapore. He has published over 200 journal articles and has filed several patent applications. He serves as an editor of *IEEE Transactions on Magnetics* and as editor-in-chief of *Nano* (World Scientific). He co-edited the book, *Developments in Data Storage: Materials Perspective* (Wiley-IEEE Press, 2011).

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