ABSTRACT

Complementary-Metal Oxide Semiconductor (CMOS) technology based classical computing systems (i.e von-Neumann architecture) are energy in-efficient due to physically separated processing and computing units (referred as-memory wall bottleneck), leading to sequential data shuttling between processor and memory. Moreover, going beyond the More-than-Moore's era, deep-sub-micron (DSM) scaling with CMOS technology leads to various challenges such as thermal reliability, high leakage currents, non-uniform features etc. To overcome the aforementioned challenges, exploration of various novel devices and parallel computing principles are much needed.

In this thesis, we explore two emerging Non-Volatile Memory (NVM) technologies i.e Phase-Change Memory (PCM) and Resistive Memory (RRAM) for non-Von-Neumann architecture based Neuromorphic and computational memory applications. We demonstrate exhaustive brain-inspired computing applications through these NVM devices. We emulate the biological synaptic plasticity, dendritic functionality and neuronal activity through the CMOS-NVM based architectures. Moreover to demonstrate the machine learning (ML) based image classification application, we implement the spiking neural networks by incorporating the respective functionalities. Furthermore, through experimental characterizations and CMOS-NVM based circuit simulations, we successfully demonstrate the multi-valued logic and computational memory applications. Various reliability aspects of NVM devices such variability, retention and endurance impacting the proposed brain-mimicking sub-blocks (i.e synapses, dendrites and neurons) and digital logic/memory circuits, are illustrated in this thesis. A detailed benchmarking and comparison with existing studies is also shown to highlight the key advantages (such as area and power) of our proposed implementations.