Emerging Resistive Memory Technologies For Low Power Embedded Applications and Neuromorphic Systems

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The significant challenges to future of traditional memories (Flash and DRAM) at 1X nm regime has resulted in increased quest for new physical state variables (other than charge or voltage), new devices and architectures offering memory and logic functions beyond traditional transistors. Research in the memory field has generally converged in the approach of a two terminal memory resistive device (ReRAM) located in the back-end-of-line, as phase change memory (PCM), metal oxide resistive switching memory (OxRAM), conductive-bridge memory (CBRAM) or magnetic memories (MRAM). Significant advances in new materials, device technologies and circuits have made emerging memories good candidates to address the huge business opportunities for next generation high density memories [1, 2].

Nevertheless, the application potential of these new memories is not limited to standalone technologies. Resistive memories offer potential for exciting new applications and markets, as new functionality coupled with logic circuits to enable block power-down, or use as synapses in neuromorphic circuits. In this work, we will focus on the role that different emerging non-volatile resistive memory technologies can play in these new emerging fields of applications. Concerning the introduction of non-volatile functionality at the logic level we will demonstrate hybrid (CMOS logic + ReRAM devices, specifically CBRAM and OxRAM) circuits for Ultra Low Power (ULP) FPGA and fixed-logic IC design (as Non Volatile Flip-Flops) [3-5]. Concerning neuromorphic circuits, we will focus on the emulation of synaptic plasticity effects with resistive memories synapses (specifically, PCM or CBRAM). We will show the implementation of large-scale energy efficient neuromorphic systems with deterministic multi-level synapses or stochastic-binary synapses. Prototype applications such as complex visual- and auditory- pattern extraction will be also shown using feed-forward spiking neural networks [6, 7].

References

Fig. 1. (a) TEM cross section of a CBRAM device with GeS$_2$ electrolyte and HfO$_2$ (2nm) interface. (b) Typical I-V characteristics of GeS$_2$ CBRAM with different interface layers [3].

Fig. 2. (a) Picture of the uncoiled human cochlea. (b) Our single layer spiking neural network simulated for auditory processing. [7].