Memristors : Artificial Synapses

J. Grollier, Unité Mixte de Physique CNRS/Thales, Palaiseau, France

Imitation using artificial tools of some of the incredible human brain capacities for cognitive processes will certainly be the next big challenge in the revolution of information technology. A few days-old baby is able to interpret and analyze sequences of images in a fraction of second whereas such apparently simple tasks are still out of the reach of the most powerful digital computers.

In order to solve some problems of artificial intelligence, complex computational models called Artificial Neural Networks (ANNs) have been proposed based on the brain architecture. Even if ANNs with multiple neural layers are extremely powerful, they loose the speed, fault tolerance and low power consumption provided by their originally analog and parallel architecture when they are implemented as software simulations. Thus the development of new hardware devices having a brain-inspired massively parallel, dynamical architecture and radically different from contemporary IT technology is today a top objective for computer scientists, neuro-scientists and hardware designers.

Since the number of synapses is order of magnitudes larger than the number of neurons, the development of neuromorphic circuits for complex operations relies on the ability to build nano-scale synapses. Improvement of the performances of existing hardware ANNs are limited by their need of a large number of electronic components for the implementation of each synapse, including SRAMs blocks to store the weights.

Recently, a Hewlett-Packard (HP) team has suggested that memristor devices could intrinsically behave as artificial nano-synapses [1,2]. A memristor is an ultrasmall non-linear dynamical and non-volatile electrical resistance. Its memory effect provides a straight implementation of the synaptic plasticity. Although the HP devices are based on electromigration effects in a TiO_x thin oxide layer, many other physical phenomena can give rise to memristive effects.

During this talk, I will show that spintronic nano-devices have a strong potential as artificial synapses. I will introduce the spin transfer effect [3], that allows to manipulate the magnetization of a nano-magnet by a simple transfusion of spin from the conduction electrons to the local magnetization. I will explain how, by using this physical phenomena through its different forms, it is possible not only to implement spintronic memristors [4], but also another exciting type of binary magnetic artificial synapse based on stochastic effects.

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[4] Chanthbouala, A. *et al.*, "Vertical current induced domain wall motion in MgO-based magnetic tunnel junction with low current densities", *Nature Physics*, 7, pp. 626-630, 2011