Synaptic Weight Modulation and Logic Function Learning with Electro-grafted Nano Organic Memristors

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Abstract:
Neuromorphic computing has gained important attention since it is an efficient way to handle advanced cognitive tasks such as image recognition and classification. Hardware implementation of an artificial neural network (ANN) requires arrays of scalable memory elements to act as artificial synapses. Memristors, which are two-terminal analog memory devices, are excellent candidates for this application as their tunable resistance could be used to code and store synaptic weights with, in principle, low power consumption. In this work, we studied metal-organic-metal memristors in which the organic layer is a dense and robust electro-grafted thin film of redox complexes. The process allows fabricating planar and vertical junctions, as well as small crossbar arrays. The unipolar devices display non-volatile multi-level conductivity states with high R_{MAX}/R_{MIN} ratio and two distinct thresholds. The characteristics of individual memristors were characterized in depth with respect to the targeted synaptic function. We notably showed that they possess the Spike Timing-Dependent Plasticity (STDP) property (their conductivity evolves as a function of the time-delay between incoming pulses at both terminals), which is critical for future applications in neuromorphic circuits based on unsupervised learning. In parallel, we implemented a series of memristors as synapses in a simple prototype: a mixed circuit with the neuron implemented with conventional electronics. This ANN is able to learn linearly separable 3-input logic functions through an iterative supervised learning algorithm inspired by the Widrow-Hoff rule.

Keywords: spike timing-dependent plasticity, electro-grafting, organic memristors, supervised learning, neuromorphic circuit.

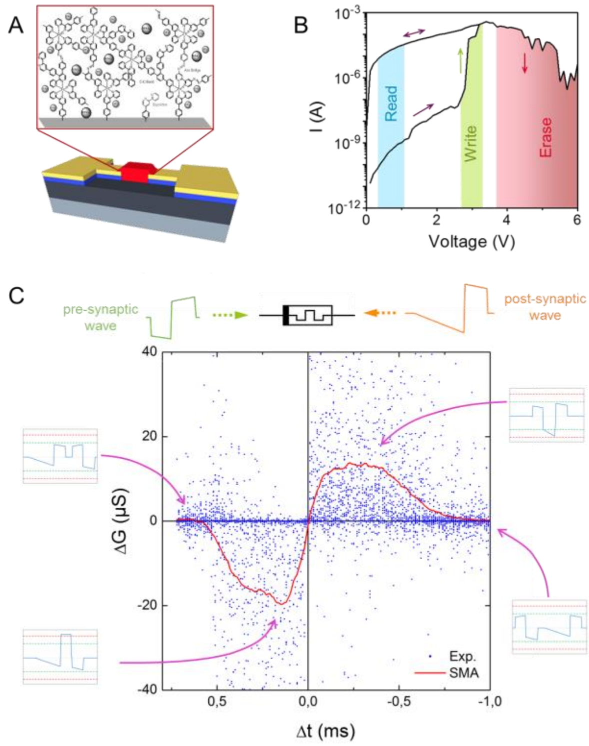

Figure 1: A) Planar structure of the organic memristor and schematic of the electro-grafted thin film of redox complexes. B) Unipolar switching behavior of single memristor. C) Cumulative STDP property of single organic memristor during ~4300 sequentially-applied voltage pulses with random time-delay of pre-/post-synaptic input.

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