The emergence of Mottronics for hardware neuromorphic computing

E. N. Sirjita(1), K. Troger(1), M. Haydoura(1), L. Berthelot(1), B. Corraze(1), E. Janod(1), J. Tranchant(1), and L. Cario(1)

(1) Institut des matériaux de Nantes Jean Rouxel, UMR 6502 CNRS, Nantes University, France

The rapid growth of AI has increased the search for energy-efficient computing paradigms, with neuromorphic hardware, designed to mimic the efficiency of biological neural circuits, offering a compelling path forward. Currently, the main competitors of CMOS-based modern technologies consist in memristor-based neuromorphic designs. Indeed, non-volatile memory technologies like RRAM, FeRAM, PCM or MRAM have gained increasing attention in the last decade. They offer higher density of components, and a reduced power consumption compared to the standard CMOS technology, as well as the possibility to be implemented into CMOS nodes, providing a combination of benefits. However, all of these technologies have drawbacks which limit their broad adoption in neuromorphic hardware.

The Mott-based electronics (Mottronics) memristor family, which exploits the metal-insulator transition of strongly correlated Mott insulators, remains comparatively underexplored, despite offering competitive advantages over established memristive technologies. These materials display indeed an absence of a forming step, unipolar switching, sub-nanosecond compatible switching speeds, and writing energies below the picojoule [1]. Within this family of materials, attention has been mostly given to volatile switching VO_2 and NbO_2 devices. However, the chromium-doped V_2O_3 system [2], depending on fabrication and programming conditions, has been shown to exhibit both volatile (suited for threshold switching and leaky-integrate and fire neurons [3]), and non-volatile capabilities, with a large tunable memory window [2] and high cycling endurance. This flexibility can simplify material integration towards fully Mott-based neural networks exploiting an original mechanism of Insulator-to-Metal transition rooted in Mott physics [4].

Using both previous works, and novel research, this work aims to argue for the power, versatility, and competitiveness of Mott devices as elements for implementation into hardware-based neuromorphic networks, and highlights the broader potential of Mottronics.

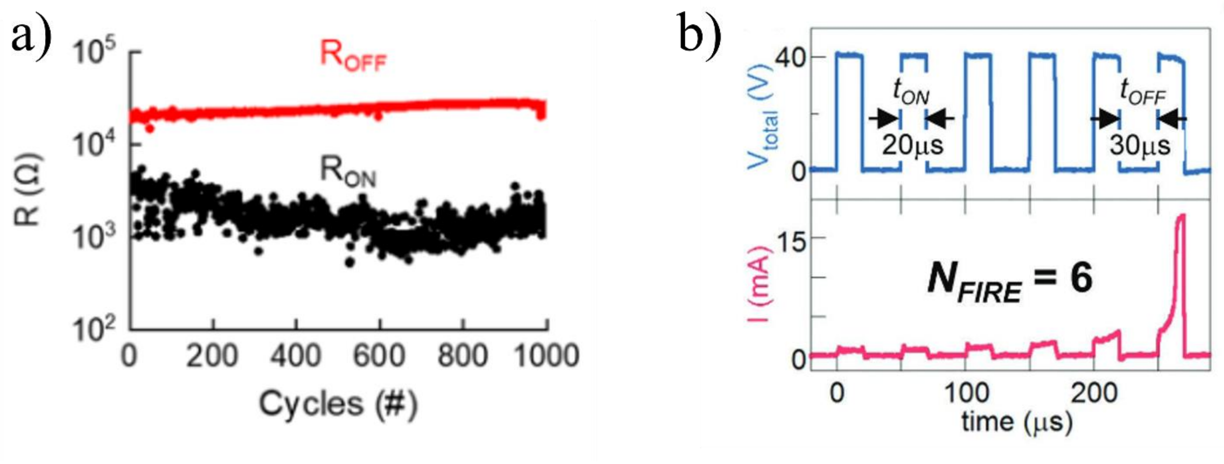

Figure 1: a) Non-volatile [2] and b) volatile LIF [3] behavior of Mott devices

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[3] P. Stoliar *et al.*, Adv. Funt. Mat., 27, 1605740, 2017
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