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Context

In 2008, researchers at Hewlett-Packard (HP) have unveiled a new electronic component, called the **memristor**. This electronic device is a **non-volatile, non-linear resistor**. By applying a voltage, it is possible to vary continuously the resistance of the device, and the device "memorizes" that resistance after the voltage is no longer applied.

In 2009, the UMPPhy-CNRS and Thales partners have patented a new component: the "ferroelectric memristors". The resistance changes are due to purely electronic effects and therefore preserve the materials structure.

Memristors behave exactly as artificial synapses, as they directly implement the synaptic **plasticity**. The synaptic weight (i.e. the resistance) can be continuously tuned and stored (non-volatility property). Thanks to these advanced functionalities, combined with their small size, **memristors could be the key to the future development of Hardware Artificial Neural Networks**.

Due to stringent power consumption constraints, the clock frequency of processors no longer increases or barely, so that a **hardware neural network would retain all its performance and power advantage** compared to the software version run on a processor.

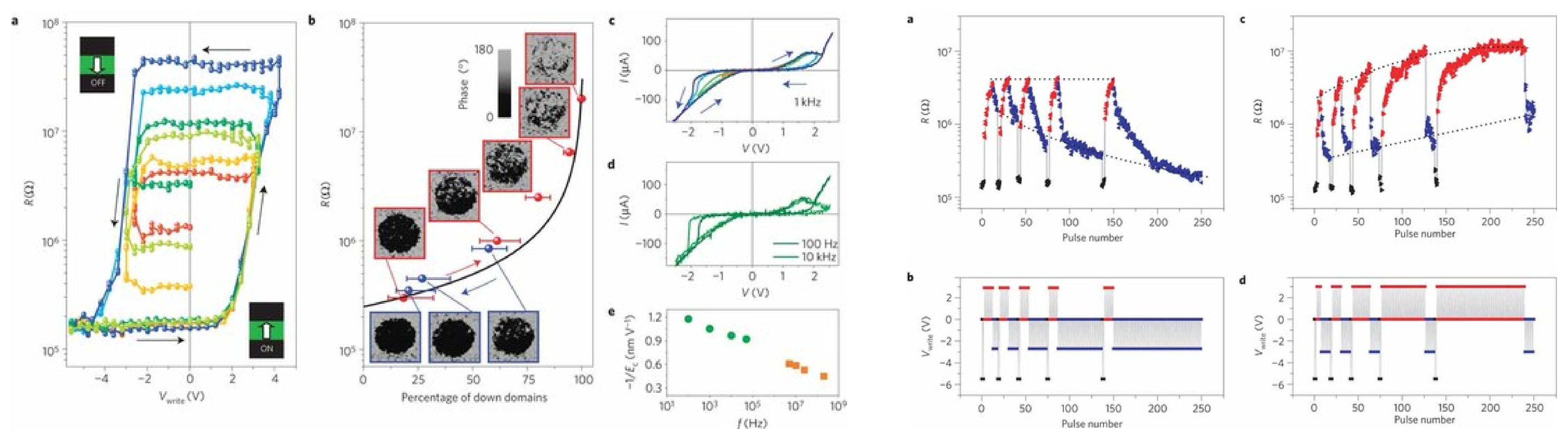
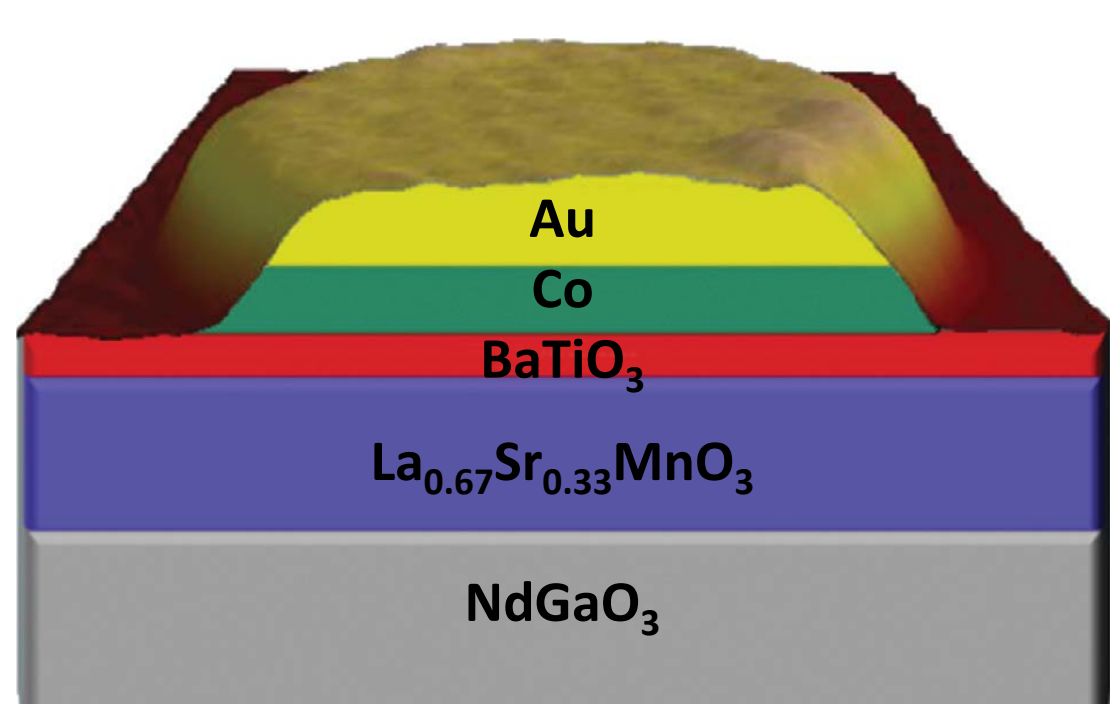
Hardware ANNs with an architecture composed of analog circuitry coupled with the aforementioned memristors open the possibility to build high-performance accelerators able to tackle the large computational tasks of Recognition, Mining and Synthesis applications.

Objectives

- The first objective of the MHANN project is to **develop, engineer and optimize new memristor devices**, with a special focus on robustness, low-operating temperature and fast write operations.
- The second objective is to realize a functional but medium-scale **prototype of a hardware ANN using a combination of memristive synapses and analog neurons**.
- The third goal of the MHANN project is to **evaluate the benefit of memristor synapses on large-scale ANN for embedded systems**.

The MHANN project is multi-disciplinary in the sense that it proposes new physical concepts for devices (**physics**) and aims at integrating them into on-chip bio-inspired architectures (**micro-electronics, computer science and architectures**).

Results



a, Dependence of the junction resistance measured. The different curves correspond to different consecutive measurements, with varying maximum (positive or negative) V_{write} . **b**, Variation of a similar capacitor resistance with the relative fraction of down domains extracted from the PFM phase images. **c,d**, Current versus voltage curves for various amplitudes of the maximum voltage (**c**) and current versus voltage curves, measured at different frequencies: 100 Hz and 10 kHz (**d**). **e**, Evolution of the inverse of the negative switching field as a function of the measurement frequency (Green circles from **c,d**, and orange squares curves similar to **a**).

a-d, Evolution of the junction resistance (**a,c**) as a function of the different voltage pulse sequences (**b,d**) (plotted for $V_{write} = +2.9$ V and -2.7 V (**a,b**) and for $V_{write} = +3$ V and -3 V (**c,d**)).

Publications

A. Chanthbouala, V. Garcia, R. O. Cherifi, K. Bouzehouane, S. Fusil, X. Moya, S. Xavier, H. Yamada, C. Deranlot, N. D. Mathur, M. Bibes, A. Barthélémy and J. Grollier, "A ferroelectric memristor", *Nature Materials*, 11, 860-864, 2012

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