Development and investigation of ultra-small on-chip resistive switching memory devices

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Resistive switching memory devices – also known as memristors – are generally metal-insulator-metal nanostructures whose resistance can be varied via electrical signals, enabling information storage in the value of the resistance. Based on this property, memristive devices provide a promising platform for hardware-level encoding of large matrices. With a network of memristors, computationally intensive vector-matrix operations can be performed in a single step, considerably speeding up the operation of an artificial neural network (ANN). Memristors can also serve as real physical building blocks for biologically inspired algorithms through their neuromorphic properties.

The aim of the studies presented in my dissertation is twofold: one goal is the development of new memristive devices from a wide array of materials, and an equally important aim is to provide insights into their switching mechanisms to build accurate physical models verified by experiments. Relying on these studies, I also show some circuit-level applications I worked on related to these self-made memristive elements.

In this thesis, I present my work on the development of on-chip resistive switching memory devices, which ranged from producing samples with standard nanofabrication techniques to their characterisation by various methods. As the foundation of my studies, I have developed and produced on-chip memristors from a variety of materials, using electron beam lithography and thin layer deposition methods. I investigated the stochastic nature of resistive switching in SiO_x *memristors, revealing that crystal nucleation governs the dynamics of the set process. I also present the results of superconducting spectroscopy performed on* Nb_2O_5 *and* Ta_2O_5 *STM point-contact devices. This approach provides a non-destructive diagnostic tool for the in-situ, experimental study of nanofilaments present in the active region of the devices. Beyond the directly extracted information on filament width, it is possible to obtain the individual transmission eigenvalues or the transmission density function of the nanofilament. The former has great importance from the viewpoint of device scalability, whereas the latter quantities reveal fine details on the atomic structure of filaments, providing possibilities to validate atomic-scale memristor models (e.g. models based on density functional theory). Finally, I investigate the application possibility of a* VO_2 *memristor-based relaxation oscillator circuit in an auditory sensing unit. In this project, I coupled the oscillator to a MEMS cantilever, and demonstrated several bio-realistic traits of the circuit, which fulfil some important prerequisites to a possible application in cochlear implants.*