ZnO nanowires for memristive devices with enhanced functionalities

Abstract and summary

The emulation of human brain functionalities represents one of the main challenges in information technology, being a key element for the development of artificial intelligence and intelligent systems. For this purpose, scientists are exploring new bio-inspired computing paradigms beyond the conventional von-Neumann architecture. However, new computing paradigms require the development of new hardware components able to perform brain-inspired data processing. One of the most promising electronic devices able to fulfill this purpose is the *memristor*. The working principle of this two-terminal device is based on the change of the internal resistance state depending on the history of the applied voltage and current. In these terms, memristors are resistor with memory. Conventional memristors are realized by sandwiching an active material in between two metal electrodes in a metal-insulator-metal (MIM) structure, where the insulator is usually a metal-oxide thin film. Despite the growing interest in memristors not only for neuromorphic computing but also for storage and logic applications, a detailed understanding of the physical processes of resistive switching responsible for the memristive behaviour still represents a challenge for the scientific community.

In this work, memristive devices based on crystalline ZnO nanowires (NWs) are proposed as suitable model systems for the investigation of the physical mechanism of switching at the nanoscale. Indeed, besides exhibiting all-in-one memristive functionalities such as multistate non-volatile memory, selector capabilites and neuromorphic functionalities, NW-based devices are shown to be good platforms for a direct investigation of resistive switching due to the high localization of the switching events. After an introduction concerning the background of memristors and resistive switching devices, methods and technologies exploited during this work are summarized. Then, results of the growth process of ZnO NWs by means of Chemical Vapor Deposition (CVD) are reported, together with a detailed characterization of the chemical and structural properties of as grown nanostructures. The dissertation continues with an analysis of the corrosion and dissolution process that occurs in ZnO NWs and a method for tuning ZnO wettability by means of electron beam irradiation is proposed and analyzed. Resistive switching mechanism in ZnO NW arrays is then investigated, revealing that in this case the switching behaviour is strongly related to the peculiar device morphology. However, the main part of the work was devoted to the investigation of electronic and ionic transport mechanisms in single isolated nanostructures. By considering single NW devices, temperature-dependent electrical characteristics and field-effect measurements allowed the investigation of the electronic conduction mechanism while memristive devices were realized by coupling ionics and electronics. The single NW model system with multiple functionalities was then employed for investigating the effect of moisture on memristive behaviour. Finally, conclusions and perspectives of NW-based memristors are discussed.