TUT 3: Resistive Switching: From basic physics of memristive devices to neuromorphic systems (joint session HL/TUT)

The miniaturization of electronic devices combined with the ongoing digitalization of our live calls for a change in the paradigms of information processing. This goes hand in hand with the discovery of new physical effects that can be harnessed for electronic systems. A most promising candidate for this are resistive switching materials, in which atoms are used instead of electrons for information storage. In the last years, significant progress has been made in understanding the underlying physics and with its transfer into novel electronic devices, often called memristors or memristive devices. This Tutorial starts with an introduction to the physics of resistive switching and aims to explain how to use memristive effects to create new devices and architectures for tomorrows electronics. Furthermore, some concepts for bio-inspired, neuromorphic electronics based on resistive switching are presented.

Organizers: Martin Ziegler and Erich Runge (TU Ilmenau)

Time: Sunday 16:00–18:15 Location: H4

Tutorial TUT 3.1 Sun 16:00 H4

Oxide based memristive devices: Current status of understanding and future prospects — •Regina Dittmann — PGI-7, Forschungszentrum Jülich GmbH

Transition metal oxides exhibit a reversible, non-volatile change in electrical resistance upon electrical stimulus, a phenomenon known as resistive switching. In the simplest case resistive switching memory cells, or so called memristive devices, can be switched between a low resistance state (LRS) and a high resistance states (HRS) which can be interpreted as the logical "1" and "0", respectively. Moreover, resistive switching cells often exhibit multiple resistive states rather than only two logical states, which can be highly interesting for neuromorphic applications. Based on the current knowledge, resistive switching in memristive elements based on transition metal oxides can be ascribed to electrically induced redox-processes at the oxide/electrode interface, which occur either in a spatially confined switching filament, multiple filaments or in a spatially homogeneous, area-dependent manner. In most cases, the redox-process in the metal-oxide goes along with a change in the valence state of the metal ion modifying the Schottky barrier at the oxide/electrode interface. Therefore, this type of switching mechanism is also called valence change mechanism (VCM). In this tutorial, we will present the current knowledge about microscopic mechanisms which drive electroforming and resistive switching in different variants of VCM-type memristive elements. Afterwards, a brief overview about the current and future fields of application will be presented.

Tutorial TUT 3.2 Sun 16:45 H4

Memristors and memristive devices: theory, physics, criticisms — •Thomas Mussenbrock — Brandenburg University of Technology, Chair of Electrodynamics and Physical Electronics, 03046 Cottbus, Germany

The research in the field of memristive devices dates back to the 1970s when Chua introduced his idea of a missing lumped circuit element, which he named *memristor*. The idea has emerged a considerable interest only after 2008 when researchers at HP Labs linked their resistive switching device to Chuas's theory. Today, memristive (or synonymously resistive switching) devices have been identified as promising candidates for future non-volatile memory applications due to their distinct key features, the most important of which are i) low power consumption, ii) passivity, and iii) scalability into the nanometer scale. Beyond their potential applications as non-volatile memories, memristive devices turned out to be applicable as artificial synapses in neuromorphic circuits. It is interesting to notice that a large number of different devices and concepts turn out to show memristive behavior, while the underlying physics is not completely understood in most of the cases. Furthermore, the scientific dispute is still ongoing, whether the devices which show memristive behavior are in fact memristors in terms of Chua's theory. This contribution is intended to provide an introduction to memristors and memristive devices. Theoretical aspects as well as fundamental physical phenomena are discussed, while the criticism regarding the memristor concept is not concealed.

Tutorial TUT 3.3 Sun 17:30 H4

Memristive devices for bio-inspired electronics — •Hermann Kohlstedt — Chair of Nanoelectronics, Faculty for Electrical Engineering and Information Technology, Kiel University, Germany

Information processing in biological nerve system is characterized by highly parallel, energy efficient and adaptive architectures in contrast to clock driven digital Turing machines. Even simple creatures outperform supercomputers when it comes to pattern recognition, failure tolerant systems and cognitive tasks. Fundamental building blocks leading to such remarkable properties are neurons as central processing units, which are (with variable strengths) interconnected by synapses to from a complex dynamical three dimensional network. The field of neuromorphic engineering aims to mimic such biological inspired information pathways by electronic circuitries. The advent of memristive devices opened novel pathways to mimic basal synaptic functionalities as e.g., spike-time-depended plasticity (STDP). In the tutorial I will explain how such local learning mechanisms are mimicked by memristive. In addition I will address the opportunities and challenges to integrate memristive devices as a part of cognitive electronic circuits, in particular for the interesting field of non-linear dynamics in the context with correlation and synchronization phenomena in nerve systems. Acknowledgement: This work is support by the DFG Research Unit 2093 "Memristive devices for neuronal systems.