Materials design and defect engineering correlated with compact modelled device behavior towards neuromorphic memristors

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The physical realization of memristors in various material technologies is a complex challenge as multidimensional defects and their interactions play a key role in memristive device behavior. At the same time, the required memristor characteristics depend on the application area and specific circuit setup. It is not trivial to correlate materials and device/circuit properties by dedicated test routines and identify the materials properties that allow to manipulate the desired device behavior. A key effect in resistive switches based on OXRAM is that oxygen vacancies enhance electric conductivity in the conducting filament and thermal conductivity in the surrounding dielectric matrix. Furthermore, the controlled induction of grain boundaries has a dramatic effect on the forming voltages showing that complex defect interactions have to be considered for a full understanding of memristive devices [1,2,3]. In addition, we investigate the role of substoichiometric phases as a result of the oxygen dynamics and irradiation [4,5,6]. We show how defect engineering can be applied to implement analogue depression and potentiation of the resistance, and how the results serve as guideline for smart materials selection. We suggest modified HfO_2 and Y_2O_3 as most suited neuromorphic /multi resistive state materials due to their specific materials properties [7]. To tackle the challenge of identifying meaningful material-device correlations, we are using artificial intelligence based on compact modelling to evaluate the huge data sets from dedicated test circuits [8,9]. A recent emerging topic in memristor research is local activity and so-called edge-of-chaos-behavior. There are indications that this behavior occurs in several memristive systems and is essential for brain-inspired computing.

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