Functional oxides for energy efficient information technology: from material to device

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Oxides exhibit a wide range of electrical, magnetic, optical, mechanical properties, which may even be coupled. Research on oxides has been revitalized in the past 15 years with the studies on high-κ dielectrics for gate replacement in front-end transistor technologies. The development of material growth techniques, of advanced characterization methods and of predictive modeling boosted other fields of research such as OxRAM memories, memristive devices for new computing paradigms or high capacitive structures for back-end and above IC applications. It also benefited to other fields of research such as oxides on flexible substrates or glass and it triggered a renewed interest in an extraordinary palette of new phenomena in complex oxides (strain-induced ferroelectricity, 2DEG at insulating interfaces…). Many complex oxides are correlated electron systems with a strong interplay between charge, spin, orbital and lattice, giving rise to many possible schemes for tunable properties. If complex oxides could be integrated as an add-on to semiconductor technologies in a seamless process, their extraordinary wealth of physical properties could offer a huge potential for developing new functionalities in devices in order to address societal needs related to health, energy, or information & communication technologies.

In this talk, I will present some aspects of my past work on functional oxides and the projects that will be developed at the Institute "Functional oxides for energy efficient information technology".
After introducing functional oxides, I will discuss, in a first part, the monolithic integration of complex oxides on semiconductors. I will review the related scientific and technological challenges raised and the issues to be addressed. Molecular beam epitaxy (MBE) provides advantages to precisely construct, almost atom by atom, the oxide/semiconductor interface. With the case of the ferroelectric $BaTiO_3$ perovskite on Si and SiGe, I will exemplify the various strategies developed to engineer the interface with the substrate and to control the oxide crystalline structure and properties. I will discuss how the world class large-scale research infrastructure provided by BESSY II, among which the *Energy Materials In situ Laboratory* (EMIL), will be instrumental for conducting unique research in the field of monolithic integration of oxides (ferroelectrics, mulitferroics) on semiconductors and, more generally, for developing new materials in synergy with HZB groups.
In a second part, I will discuss other applications of metal oxides and the possibilities offered by deposition techniques such as liquid injection chemical vapor deposition (CVD) or atomic layer deposition (ALD) for engineering (e.g. by flexible doping) metal oxide thin films and nanostructures (oxide nanowires, core/shell nanowires) in order to enhance their properties.
As applications are concerned, I will present, in a final part, current and potential realizations towards oxide nanoelectronics. This includes components for conventional and future computing technologies (negative-capacitance ferroelectric field-effect transistors, piezotronics, memristive devices or domain-wall-based ferroic devices) as well as components for advanced silicon integrated photonics and for various energy-related applications (catalysis…).