Functional oxides induced strain for silicon photonics applications

Guillaume Marcaud, Sylvia Matzen, Carlos Alonso-Ramos, Xavier Le Roux, Mathias Berciano, Valérie Pillard, Pedro Damas, Thomas Maroutian, Guillaume Agnus, Ludovic Largeau, Eric Cassan, Delphine Marris-Morini, Philippe Lecoeur, Laurent Vivien

Silicon photonics is expected to allow the implementation of a wide range of applications including sensing, datacom and security with the potential to leverage the already existing CMOS fabrication facilities for cost-effective and large production. Among the building blocks to develop, optical modulator is considered as a key device for integrated circuits. The main physical effect to perform optical modulation in silicon is based on plasma dispersion effect. However the maximum modulation speed achievable with this approach is limited by the mobility and recombination time of the carriers. Furthermore, these types of modulators face some limitations in terms of power consumption, chirp and loss that may compromise their future integration in integrated circuits.

The purpose of this work is to explore an alternative approach, based on the use of the Pockels effect. Such an effect, commonly used in Lithium-Niobate, allows high speed and low power consumption optical modulation. Unfortunately silicon is a centro-symmetric crystal leading to a vanishing of the second order nonlinear coefficient, i.e. no Pockels effect. To overcome this limitation, it is possible to break the crystal symmetry by straining the silicon lattice. The new approach developed here is to generate strain by the epitaxial growth of crystalline functional oxides, which exhibit more appropriate strain-induced characteristics in silicon than the use of silicon nitride with lower defect concentration at the Si/oxide interface. Indeed, these functional oxides are deposited by epitaxial growth at high temperature on silicon with pulsed-laser deposition. The induced strain due to lattice parameter mismatch and the difference in the thermal expansion coefficients between oxides and silicon are strong. Furthermore, these functional oxides exhibit very interesting multiferroicity and piezoelectricity properties that paves the way to a new route to implement silicon photonic circuits with unprecedented functionalities.

Last results on the integration of high quality oxides on silicon waveguides will be presented as well as a full characterization of the strain-induced property changes including X-ray diffraction, AFM-SEM microscopies, and Raman spectroscopy. The first experiments of light propagation in hybrid oxides on silicon photonic structures will be also reported.