Shining light on ferroelectric thin films: towards multistate memories and photostrictive devices

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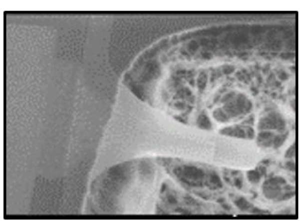
Ferroelectric materials are known to exhibit a reversible spontaneous electric polarization whose magnitude and sign can be precisely tuned, in particular by electric field. What makes ferroelectrics very interesting, by offering rich physics and a high potential for applications, is the coupling between their electric polarization and other properties. The coupling between electric polarization and mechanical deformation leads, for instance, to remarkable piezoelectric response with numerous applications in microelectromechanical systems (MEMS) - actuators and sensors. Their interaction with light has shown above bandgap photovoltages, induced by a particular polarization-related charge-separation mechanism in ferroelectrics, the so-called bulk photovoltaic effect. In addition, the complex interplay between light, ferroelectric polarization, and deformation induces photostriction – a mechanism of non-thermal deformation under illumination – which is usually described in a ferroelectric as a combination of photovoltaic and piezoelectric effects. Photoinduced effects in ferroelectrics offer thus a wide field of possible investigations into interesting physics and exciting new applications, with the potential for remote (optical) control.

In this talk, I will present studies on the control of photovoltaic effect and photostrictive response by tuning the ferroelectric polarization in the prototypical $Pb(Zr,Ti)O_3$ (PZT) ferroelectric material, epitaxially grown in thin films and integrated into microdevices. In the first part, I will show how the photocurrent and the photovoltage can be used as a non-destructive read-out signal of the polarization states [1, 2], which offers great promise for next-generation ferroelectric memory devices with increased memory storage density and lower power consumption. In the second part, I will demonstrate that we can control both magnitude and sign of the photo-induced strain in ferroelectric devices by tuning the ferroelectric polarization, at ultrafast timescales in capacitors [3] and in PZT integrated in MEMS [4]. These results have important implications for the development of optically driven microdevices, and more generally for the light-mediated engineering of materials and devices functionalities.



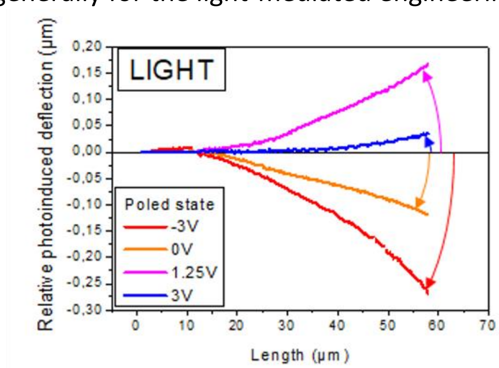


Figure: SEM picture of a PZT cantilever and relative photoinduced deflection for four different electrical states showing the control of optically driven bending by the applied voltage.

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[2] A. Zing, S. Matzen, K. Rani, T. Maroutian, G. Agnus, P. Lecoeur, Optical reading of multistate non-volatile oxide memories based on the switchable ferroelectric photovoltaic effect, Appl. Phys. Lett. 121, 232904 (2022)

[3] S. Matzen, L. Guillemot, T. Maroutian, S. K. K. Patel, H. Wen, A. D. DiChiara, G. Agnus, O. G. Shpyrko, E. E. Fullerton, D. Ravelosona, P. Lecoeur, and R. Kukreja, Tuning Ultrafast Photoinduced Strain in Ferroelectric-Based Devices, Adv. Elec. Mater. 5, 1800709 (2019)

[4] S. Gable, K. Rani, T. Maroutian, G. Agnus, P. Lecoeur, S. Matzen, Photostriction tunability in ferroelectric thin film-based MEMS, (submitted)