Simultaneous Mechanical Displacement and Ferroelectric Pulse Switching Measurements of Piezoelectric MEMS Devices

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Many piezoelectric MEMS devices rely on the use of an integrated ferroelectric material as the active element for device actuating or sensing. For this reason it is desirable to link the ferroelectric properties of the material directly to the mechanical response of the device. To ensure that the ferroelectric properties are properly correlated with the mechanical displacements of the MEMS device the measurements must be made using the same device and made simultaneously to avoid errors due to differences in device processing, boundary conditions, and operating history. A method for simultaneously measuring the mechanical displacement of actuated MEMS devices and the switched polarization of integrated ferroelectric materials has been developed by combining the techniques of laser Doppler vibrometry (LDV) and ferroelectric PUND pulse switching. The combined LDV-PUND measurement provides a much needed technique for simultaneously measuring mechanical device response and the ferroelectric material characteristics in devices such as non-volatile ferroelectric mechanical memories (FEMM) that will be described in a separate presentation.

A waveform generator was used to drive a PZT actuated cantilever device and simultaneously trigger a digital oscilloscope and a Polytec MSV LDV. The mechanical displacement of the cantilever was obtained by focusing the LDV HeNe laser onto the cantilever tip, and the ferroelectric pulse switching signal was obtain by measuring the voltage on a load resistor placed in series with the PZT capacitor. Both the mechanical displacement output from the LDV and the equivalent current from the oscilloscope were measured as a function of time as shown in Fig. 1. A four-pulse positive-up-negative-down (PUND) series was applied to the cantilever as is typical for pulse switching measurements. The enhanced current flow and reversal of mechanical displacement direction are observed during the ferroelectric polarization switching events that occur during the P and N applied voltage pulses. Unipolar cantilever displacements are observed along with non-switching current peaks for U and D pulses. Additionally the asymmetry of the hysteretic material response is observed in the magnitude of both the displacement and current when comparing the P with the N and the U with the D pulse events. The signals exhibit the expected correlation and allow for the associated extraction of ferroelectric mechanical displacement and polarization.

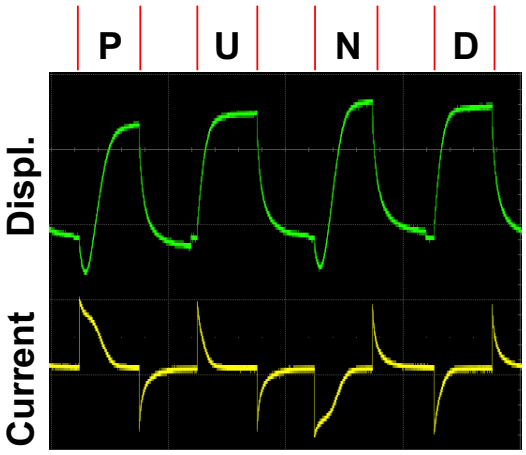

Fig. 1 – LDV determined cantilever mechanical displacement signal (top) and current (bottom) from a load resistor in series with the PZT capacitor/actuator for a ferroelectric pulse switching PUND measurement.