LOCAL ELECTROMECHANICAL PROPERTIES OF FERROELECTRIC MATERIALS FOR PIEZOELECTRIC APPLICATIONS

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Ferroelectric materials are being intensively investigated due to their high dielectric, ferroelectric and piezoelectric properties useful for various applications. In particular, piezoelectric sensors and actuators utilize strong piezoelectric effect, which is determined by the domain arrangement and its evolution under applied electric field. These domain arrangements have to be investigated with the maximum resolution because of the polycrystalline nature and small grain size of the most frequently used materials. Imaging of domains with nanoscale resolution is becoming also an important issue for microelectromechanical systems (MEMS), which size is approaching to submicron dimensions. Scanning Probe Microscopy has recently proved its usefulness for high-resolution piezoelectric studies.

In this presentation, the local piezoelectric properties of Pb-based ferroelectric films (mainly of the PZT family) will be analyzed and compared with their respective macroscopic behavior studied using conventional techniques. Several important issues will be addressed including grain size effect, local polarization switching, local non-linearity, self-polarization, and aging after poling. Local variation of piezoelectric properties of ferroelectric films will be linked to their specific texture, composition, and morphological characteristics of individual grains. Based on these observations, the difference between the local and averaged macroscopic properties will be delineated. The effect of local polarization switching by pure mechanical force exerted by the SPM tip will be demonstrated. This effect may be detrimental for the functionality of ferroelectric films in MEMS where mechanical stress is essential. On the other hand, it will be shown that in ferroelectric films this stress and significant misfit strain can induce polarization states with elevated piezoelectric properties. In the second part of the talk, the local piezoelectric properties of ferroelectric relaxor single crystals of the $PbMg_{1/3}Nb_{2/3}O_3$ and $PbZn_{1/3}Nb_{2/3}O_3$ families will be discussed. In these materials, the extraordinary piezoelectric behavior is observed for the compositions near the morphotropic phase boundary. It will be shown that on the nanoscale the properties of relaxor single crystals are different from the macroscopic observations and nanoscale domains related to polarization clusters may play essential role in their high piezoelectric performance.