Piezoelectric materials characterization

Resonance Ultrasound Spectroscopy applied to the characterization of piezoelectric material

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Classical **characterization methods of piezoelectric materials** are based on electrical measurements, and several samples have to be used to identify the entire **electromechanical tensors** leading to possible inconsistencies in the identified values. **Ultrasonic Resonance Spectroscopy** allows the characterization of piezoelectric materials thanks to the study of their mechanical and electrical resonances. Characterization are carried out by comparison of the experimental resonance spectra of parallelepipeds to that of a theoretical model [1,2]. The main advantage of this characterization methods is that it allows the identification of the entire set of electromechanical constants of piezoelectric materials from only one sample. We have developed a new experimental set-up for resonant ultrasound spectroscopy measurements. It is based on an electrical excitation of the piezoelectric sample and on the detection of its mechanical vibrations through a laser interferometer. The method has been applied to the identification of the full tensor of a piezoelectric ceramic cubes. This method has been know extended to extract the properties from electrical admittance measurement of piezoelectric cubes [3,4].

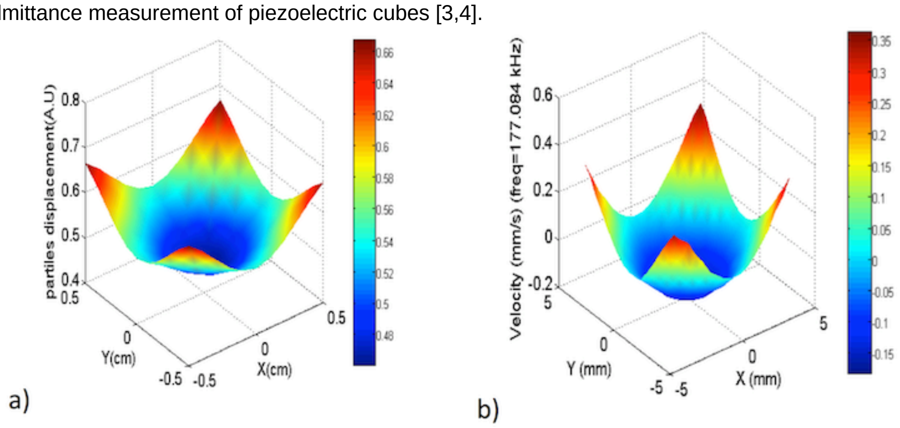

Figure : a) measured and b) calculated particle velocities for PMN34,4PT ceramic cube (10x10x10 mm3).

Electromechanical characterization of pre-stressed piezoelectric materials

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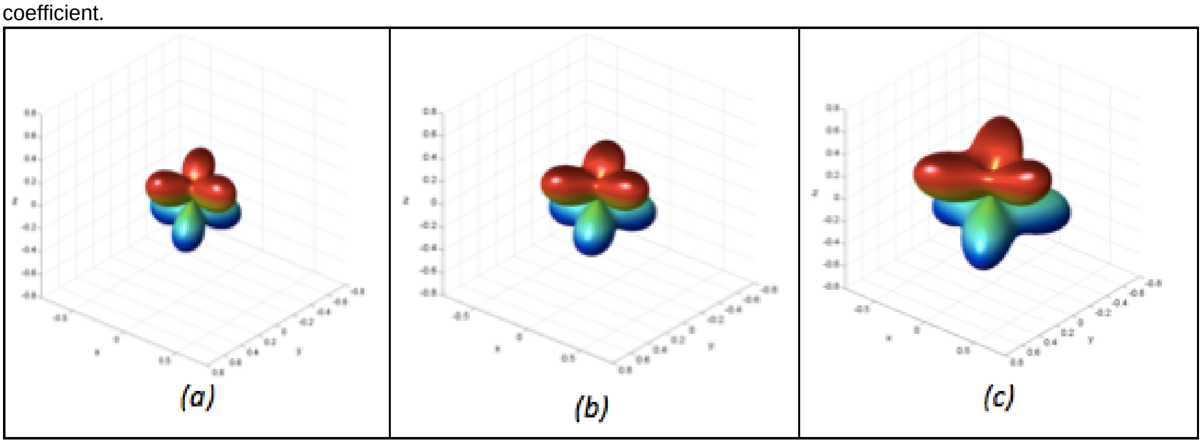
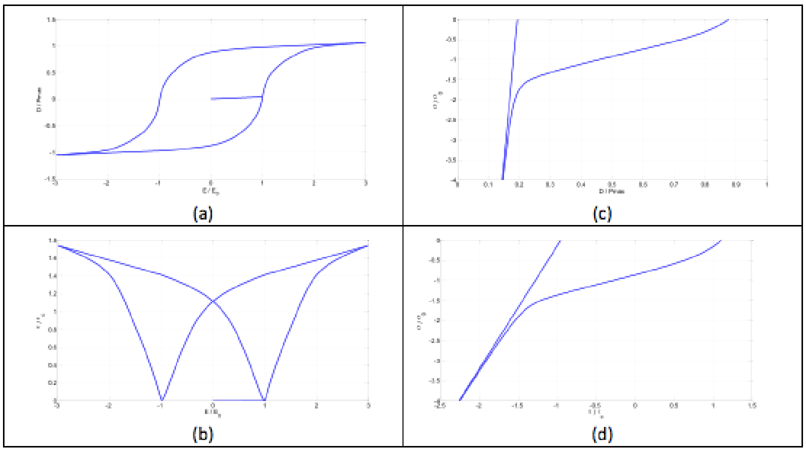
Nowadays, piezoelectric materials are frequently used for various applications. They can operate under various environmental conditions, like high temperature, high pressure, external electrical DC fields or residual or applied mechanical pre-stress. The presence of high **mechanical or electrical pre-stress** in piezoelectric materials induces modifications of their electroacoustic parameters.

For non hysteretic piezoelectric materials such as **lithium niobate**, the presence of a mechanical pre-stress induces a shift of their electroacoustic parameters through nonlinear modifications of their standard elastic, piezoelectric and dielectric parameters. As far as hysteretic piezoelectric materials are concerned, such as **piezoceramics**, a pre-stress induces nonlinear hysteretic behaviours that significantly modify the piezoelectric characteristics through a shift of material properties from their pre-stress-free values. **Nonlinear ferroelectricity** may be characterized by four typical hysteretic loops: the **dielectric** (electric displacement versus electric field), the **butterfly** (strain versus electric field) and two **ferroelastic curves** (stress versus strain and stress versus electric displacement).

Thus, our work consists firstly in modelling the nonlinear effects of a mechanical pre-stress on both **non-hysteretic and hysteretic piezoelectric materials**. Secondly, our goal is to predict, quantify and compare with experimental values, the modifications of their electroacoustic parameters, such as coupling coefficient.



Simulations of electromechanical thickness coupling coefficients of lithium niobate, as a function of elevation angle q and azimutal angle j, for a pre-stress s^0 = - 3 GPa (a), s^0 = 0 (b), s^0 = 3 GPa (c).



Simulations of hysteretic behaviors for a piezoceramic PLZT material: (a) electrical displacement in function of the electrical polarization field; (b) corresponding butterfly loop for the deformation; (c) depolarization curve of the electrical displacement under a compressional mechanical stress; (d) corresponding curve for the deformation.