The LIMM problem for ferroelectric thin films comprising space charge layers

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Abstract

The laser intensity modulation method (LIMM) was developed in the 80’s of the last century by LANG and DAS-GUPTA as an extension of COLLIN’s temperature pulse method and CHYNOWETH’s technique for dynamic pyroelectric measurements. This measurement technique determines the spatial polarization profile from the pyroelectric current spectrum caused by the interaction of a thermal wave generated by an intensity modulated laser and the unknown polarization distribution. However, the pyroelectric response consists of also contributions from piezoelectricity, thermal expansion, temperature dependence of the dielectric permittivity, and the spatially dependent space charge density. Usually, the pyroelectric spectrum is analyzed assuming a local compensation of the polarization gradient by an appropriate charge density r(z)=dP/dz. On the other hand, (i) the existence of space charge layers near the ferroelectric surface is well known for about 50 years, (ii) a space charge layer is artificially introduced during the initial film growth to produce self-polarized elements of pyroelectric sensor arrays, and (iii) the electric polarization in the ferroelectric layer causes depletion or accumulation of carriers near the interface of heterostructures composed of ferroelectric and semiconducting, superconducting, or magnetoresistive perovskites. Such heterostructures are promising candidates to achieve electric-field tuned ferromagnetic metal-insulator, and superconductor-insulator phase transitions at room temperature. Moreover, due to the existence of a depolarization field, there is always a lack of compensation. In this work, the LIMM problem is reconsidered for the case of a multilayer structure consisting of layers with ferroelectric polarization, with both ferroelectric and space charge induced polarization, and with solely space charge induced polarization. Boundary conditions are derived from the electric displacement of a short-circuited structure. The pyroelectric response was calculated from a thermal model consisting of up to eight different layers. The calculations were compared with the experimentally determined pyroelectric spectrum of PZT fer