Modelling of the Time-Dependent Poling Behaviour of Ferroelectric Multilayer Structures

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A time-dependent electric model of ferroelectric multilayer structures was developed by means of equivalent circuit analysis.
Each ceramic layer of the structure is described as a parallel circuit of a capacitor with dielectric and a resistor. These RC-elements are connected in serial. By using the constitutive equation of the dielectric, a relation between dielectric displacement (D) and electric field (E) can be found. The electric polarisation (P) of each layer is included in the model using D=eps0*E+P. According to Maxwell's equations the displacement current is given by the derivate of D in respect to time. Adding the conductive current (in first order proportional to E), the total current through a RC-element can be calculated. Using Kirchhoff's laws, a time-dependent system of ordinary differential equations for the whole equivalent circuit can be found. When a formula for P(E) is given, the system can be solved numerically by using Runge-Kutta-method.
The time dependence of the electric field applied to the multilayer, the electric conductivities and the hysteresis P(E) for each layer are the input of the model. As results, the electric field and the polarisation in each layer can be calculated in dependence of time.
With this model, the poling behaviour of a bimorph-structure has been calculated in good agreement with experimental results, when fitted virgin-loops were used as P(E)-equations. The conductivities of the layers have been estimated by varying them in the repeatedly solved model.
In order to consider switching effects, a complete model of hysteresis is preferable. The Preisach model provides an established approach for hysteresis in different systems. Its basic idea is the weighted superposition of elementary hysteresis loops in order to model arbitrary hysteresis curves.
The implementation of the Preisach model into the poling model allows the time-dependent modelling of switching effects and arbitrary varying input voltages.