Pyroelectric and electrocaloric effects in PMN-based relaxors

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Electrocaloric effect (ECE) is considered as physical background for promising cooling technology based on effects and phenomena in solid materials at present time. ECE occupies a special place among other caloric effects since its use allows to minimize the size of the cooling elements controlled by an electric field and to adapt them to micro- and nanoelectronic devices.

Relaxor ferroelectrics are considered as promising ECE materials. As compared to conventional ferroelectrics, their characteristic features are diffuseness of the phase transition (thus, wide working temperature range is expected) as well as a high sensitivity to external influences including electric field. The extraordinary physical properties underlying numerous applications of relaxors are determined by the existence of a natural nanostructure in such media (polar nanoregions in the paraelectric matrix).

ECE is inextricably linked with the pyroelectric effect that mainly determines ECE response. In turn, two contributions to the pyroelectric effect have to be distinguished, namely, the dielectric contribution (primary pyroelectric effect) which is determined by the change of the polarization with temperature for clamped samples and electromechanical contribution (the secondary pyroelectric effect) whose influence is important for free samples. The contribution of the secondary pyroelectric effect to the total pyroelectric one is governed by piezoelectric and elastic properties of the material, as well as by its thermal expansion [1].

Relaxors do not exhibit real piezoelectric properties due to the macroscopically isotropic state. However, they have so-called giant electrostriction characterized by high effective piezoelectric coefficient up to $1000 \cdot 10^{-12}$ m/V as a result of induced polarization under external DC electric field. Therefore, solid solutions based on classical relaxor – lead magnesium niobate with high induced polarization and, respectively, induced piezoelectric properties were selected as the model objects for the study.

The numerous published values of pyroelectric and electrocaloric coefficients for relaxors are contradictory and largely depend on measurement and calculation methods. In the present study, to clarify the situation and to improve results, pyroelectric and electrocaloric measurements were performed by two different methods. Pyroelectric properties were investigated by LIMM (Laser Intensity Modulation Method) and MIR (Mid-Infrared Radiometry) methods for direct temperature measurements. Electrocaloric properties were studied by using quasi- adiabatic calorimeter and MIR method at actual heat exchange conditions between the sample under study and environment.

Specific features of pyroelectric and electrocaloric effects in relaxors as well as their correlation with other properties such as dielectric nonlinearity and electromechanical properties, including giant electroctriction and elasticity, have been studied and discussed.

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1. J.F. Nye, *Physical Properties of Crystals* (Clarendon Press) 376 (1964).