# Direct Electrocaloric Effect Measurements in $BaTiO_3$-based Ferroelectric Ceramics

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Nowadays small size and high performance of electronic components are highly demanded. However, use of miniaturized high power electronic devices often faces large heat dissipation, which reduces the performance of these devices. Recently, solid-state refrigeration based on the electrocaloric effect (ECE) has been proposed as a promising solution of this problem. ECE is the adiabatic temperature change or isothermal entropy change of a dielectric material in a varying external electric field. ECE based refrigerators should combine high efficiency, low cost, be environmental friendly and easy scalable. Therefore, search for environmentally friendly materials with large ECE is important.
In this presentation, we report on development of two experimental setups to measure the ECE directly: a modified differential scanning calorimeter[1] and a custom built quasi-adiabatic calorimeter. The setups allow measurements in the temperature range 230-420 K at applied electric fields up to 40 kV/cm.

We performed the ECE measurements in several lead-free ferroelectric ceramics:

- $(1-x)Ba(Zr_{0.2}Ti_{0.8})O_3$-$x(Ba_{0.7}Ca_{0.3})TiO_3$,[2]
- $BaTiO_3$ with Ce-doping,
- $BaTiO_3$ with Zr-doping.[1]

Temperature, electric field, and composition dependences of the electrocaloric effect have been studied. Furthermore, we compare results of the direct measurements with frequently used indirect estimations based on Maxwell relations to judge the compatibility of these measurement methods.

1. **Modified Differential Scanning Calorimeter for Direct Electrocaloric Measurements,**
M. Sanlialp, C. Molin, V.V. Shvartsman, S. Gebhardt, D. C. Lupascu, IEEE TUFFC 63, 10 (2016)

2. **Strong electrocaloric effect in lead-free $0.65Ba(Zr_{0.2}Ti_{0.8})O_3$-$0.35(Ba_{0.7}Ca_{0.3})TiO_3$ ceramics obtained by direct measurements**,
M. Sanlialp, V.V. Shvartsman, M. Acosta, B. Dkhil, D. C. Lupascu, APL 106, 062901 (2015)