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JOŽEF STEFAN INTERNATIONAL POSTGRADUATE SCHOOL

THE GIANT ELECTROCALORIC EFFECT: phenomenon for application in cooling and heating devices of new generation

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Abstract

Electrocaloric effect (ECE) is a change in the temperature of material due to electric field under adiabatic conditions, and it generates great interest due to its application, for example in electrical refrigeration. A giant electrocaloric effect was observed in inorganic ferroelectrics [1]. These observations were based on the indirect measurements of the electrical polarization. We show direct measurements of ECE in PMN, PMN-30 PT, PMN-35 PT and in PLZT 8/65/35 ceramics. Both bulk samples and thin films were measured. The temperature dependence reveals that the maximum of ECE is obtained at the ferroelectric phase transition. The magnitude of ECE shows that the giant ECE can be easly found in different classes of relaxor ferroelectrics.

GIANT ELECTROCALORIC EFFECT

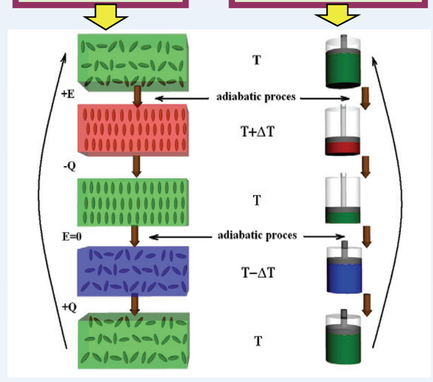
application

cooling/heating devices

- simple design
- no moving parts
- more energy efficient
- friendlier for environment

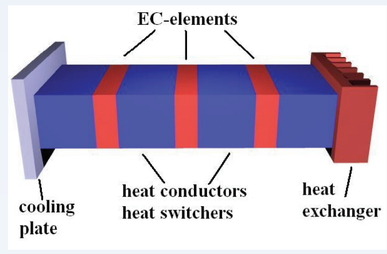
Electrocaloric cooling cycle

"Compressor" cooling cycle



Electrocaloric cooling cycle is comparable with a corresponding cooling cycle of a classic compressor where pressure p of the gas is changing.

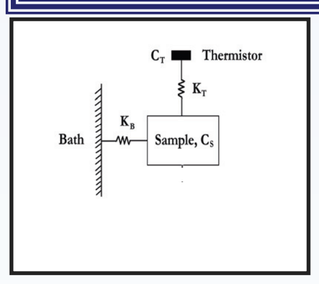
The electrocaloric device:



Exprimental method

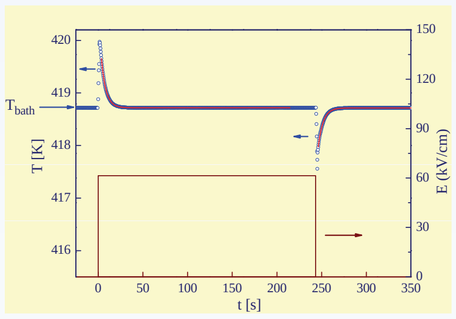
SAMPLES

Direct electrocaloric measurements via high resolution calorimeter

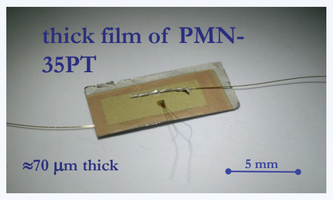


A simple diagram of the system of sample and calorimeter. A sample is coupled to a bath and thermistor by the thermal conductances.

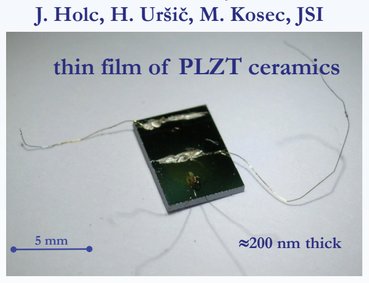
Measurement:



- step electrical signal used
- ΔT calculated from fits to the exponentially decaying wings
- resistive heating also taken into account



Produced by J. Holc, H. Uršič, M. Kosec, JSI



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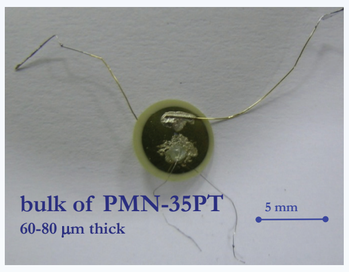

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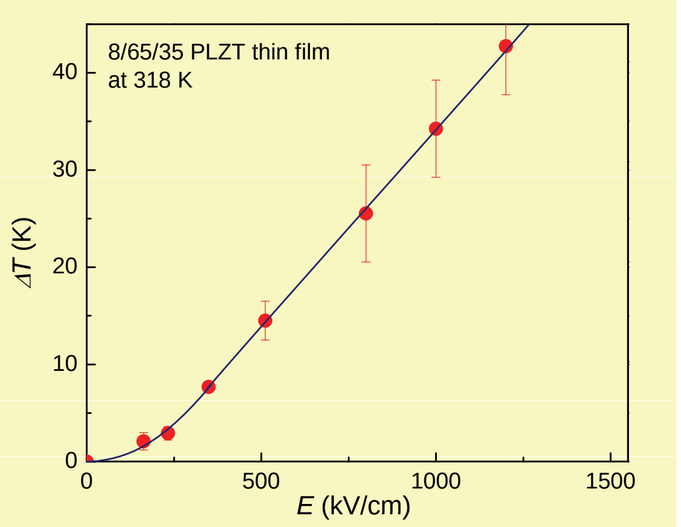
Direct measurements of the giant electrocaloric effect

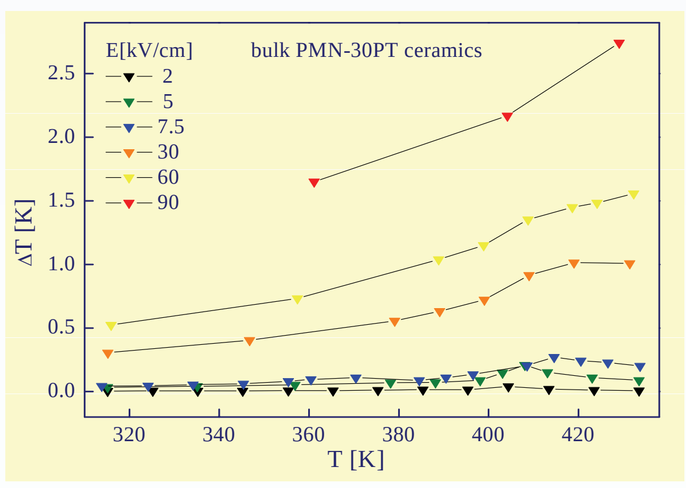
THICK FILMS

THIN FILMS

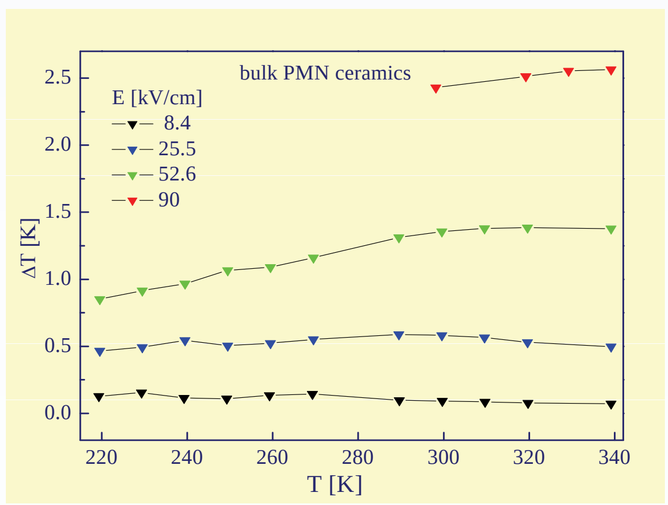
thin films of PLZT ceramics



bulk PMN-30PT ceramics

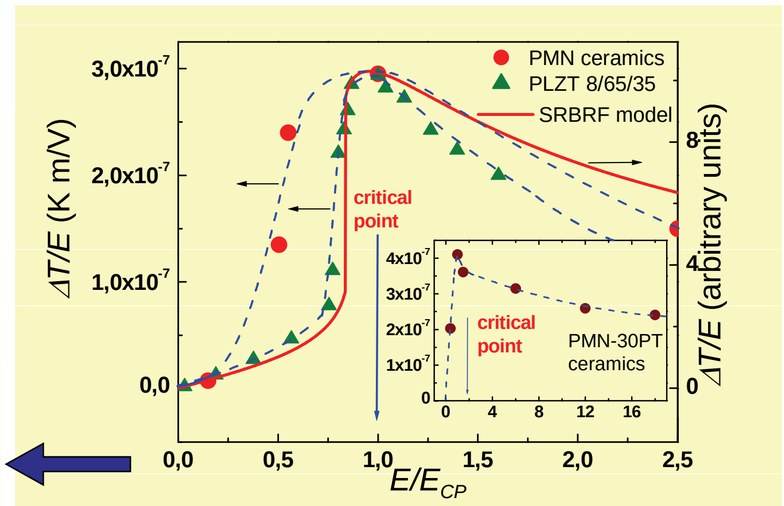


bulk PMN ceramics



Conclusion

We can conclude that direct measurements confirm existence of the giant electrocaloric effect in different classes of relaxor ferroelectrics. The largest electrocaloric effect is observable in thin PLZT films.



ΔT/E as a function of the maximum of the amplitude of the electric-field pulses (in units of E_{CP}) in bulk PMN, 8/65/35 PLZT and PMN-30PT ceramics (inset with same axis labels). Solid red line represents results of calculations of *ΔT/E* based on on a SRBRF model [2].

References

[1] A.S. Mischenko, Q. Zhang, J.F. Scott, R.W. Whatmore, N.D. Mathur, Science 311, 1270 (2006).

[2] B. Rožič, Sheng-Guo Lu, Z. Kutnjak, B. Malič, H. Uršič, J. Holc, M. Kosec, R. Pirc, R. Blinc, B. Neese, M. Lin, E. Furman, Q. M. Zhang (poslano v objavo, 2010)