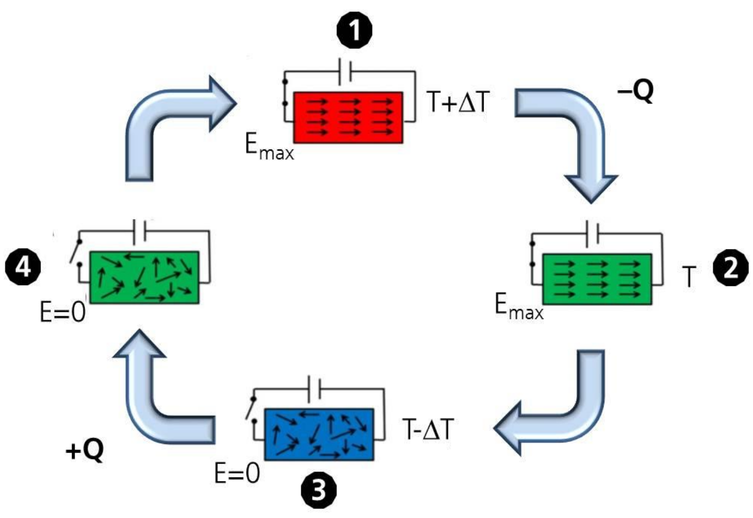
Information on "EC-Cool"

Today, almost any cooling and air conditioning system such as the omnipresent home refrigerator is based on conventional compressor based cooling technology. However, this very old technology has some significant **drawbacks** such as **low efficiency, emission of noise, bulkiness, low durability and a high global warming potential,** mostly due to leaks in the cooling circuit and a subsequent loss of harmful refrigerant fluid. Novel refrigerant-free solid state cooling systems based on **magnetocaloric and electrocaloric effects** have a number of **advantages** compared to conventional compressor-based technology:

- Higher efficiencies are expected to be possible
- No hazardous refrigerants with global warming potential are required
- There are no parts in the systems that are prone to wear and leakage, therefore, only a minimal level of maintenance is required
- The system operates without noise and the space requirement is low
- The electrical field necessary for operation can be generated relatively easily.

The working principle is as follows: Due to polarization effects, the **electrocaloric (EC-) materials** heat up when exposed to an electrical field and cool down when the field is removed. This effect can be used to **establish an effective cyclic cooling process** (figure 1). The heat that is generated when exposing the material to an electric field is discharged into a heat sink, such that the excess temperature is dissipated. When the electrical field is removed again, the temperature of the EC-material is now below the environment temperature. The "cold" EC-material is now brought into contact with the part that is required to be cooled, drawing the heat from it. With this cooling cycle, heat is transported from the part to be cooled to the heat sink.



Electrocaloric cooling cycle

1.) Polarization and temperature increase of the electrocaloric (EC-) material in an electric field.

2.) Dissipation of the generated heat into a heat sink and temperature decrease of EC material.

3.) Depolarization and temperature decrease of the EC-material below environment temperature after removal of the electric field .

4.) Heat is drawn by the „cool" EC-material from the part that is supposed to be cooled.

Figure 1: Electrocaloric cooling cycle

For the operation of the cooling cycle, the temperature rise and decrease ΔT caused by the electrocaloric effect is crucial and a higher ΔT will directly lead to a higher cooling power. ΔT is specific for each material. **Very high ΔT of up to 45 K** were reported for thin ceramic layers with a thickness in the range of micrometers and below. **The main goal of the associated project EC-Cool** is the fabrication of layers of the ferroelectric ceramic Lead-Tantalum-Niobate (KTN) and the establishment of measurement techniques to measure ΔT with high accuracy. The films are deposited with a Pulsed Laser Deposition setup (Figure 2). Additional electrode materials (i.e. metallic layers) have to be deposited in order to apply the necessary electric fields.

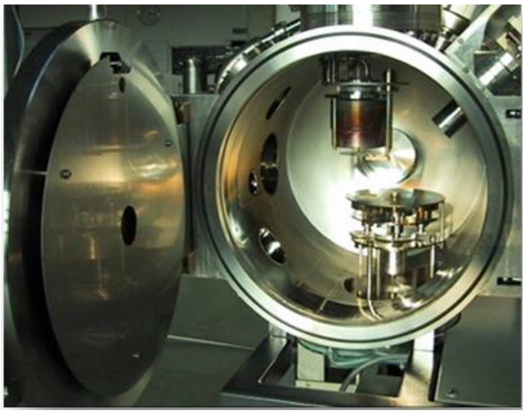


Figure 2: Pulsed Laser Deposition (PLD) setup for the deposition of KTN films and metal electrodes

With this project, the **great potential of thin films** for electrocaloric applications is developed. The mid-term goal ist to fabricate multilayered structures of EC-material and electrodes in order to create functional structures analogous to commercially available Multi-Layered Ceramic Capacitors (MLCC), Figure 3. For these structures, **very high cooling powers** are predicted since they combine a high value of ΔT with a sufficient thermal mass.

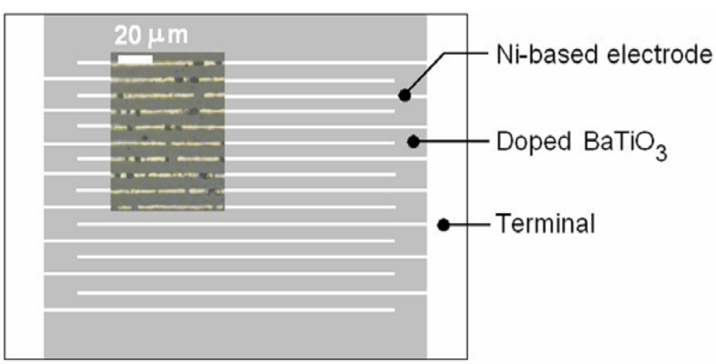


Figure 3: Multi-Layered Ceramic Capacitor (MLCC) structure. Thin films of dielectric material alternate with electrode layers.

This project is funded by the Ministerium für Finanzen und Wirtschaft Baden-Württemberg and is **associated** with project “Acti-Pipe” of the Leistungszentrum Nachhaltigkeit. One of the aims of the project is the integration of electrocaloric materials into heat pipes in order to realize an “active” heat pipe that can pump heat against a temperature gradient. Thus, the projects are **strongly interconnected** and share the common goal of establishing novel electro- and magnetocaloric cooling systems that combine high efficiency with environmental friendliness.

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