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DLF
DYDAKTYCZNE LABORATORIUM FIZYCZNE

## Experiment 27

# Identification of phase transitions in ferroelectric crystals

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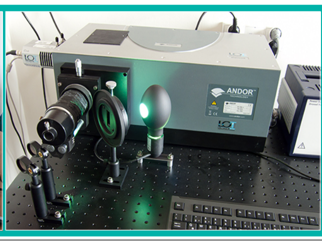
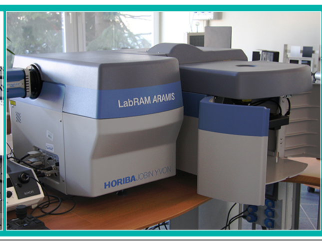
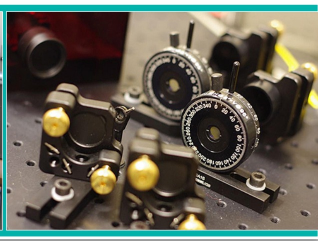





## I. Background theory.

1. Molecular dipole moments.
2. Local electric field acting on an atom in a crystal.
3. Electric field strength and induction.
4. The field in a dielectric medium between capacitor plates.
5. Dielectric constant and polarisability of a medium.
6. Polar and non-polar dielectric materials.
7. Polarisation of dielectric materials.
   a) electron polarisation;
   b) polarisation of elastic ions;
   c) orientation polarisation (dipole);
   d) orientation of dipoles in solids.
8. Domain structure of ferroelectric materials.
9. Ferroelectric hysteresis loops. Movements of domains.
10. Type I and type II phase transitions in ferroelectric materials.
    a) thermodynamic theory of ferroelectrics (Landau theory);
    b) spontaneous polarization of ferroelectrics and dependence on temperature;
    c) Curie temperature.
11. Capacitance of electric conductors. Parallel plate capacitors.
12. Design and operating principles of an RLC bridge.
13. Application of ferroelectrics.

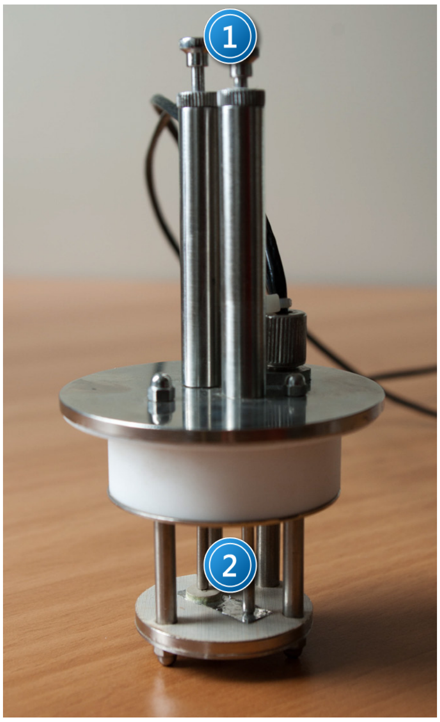
## II. Experimental tasks.

1. Refer to the experimental setup shown in *Picture 1*.


*Picture 1. Setup for measuring the dielectric constant of ferroelectric materials: 1 – heating oven with capacitor; 2 – RLC bridge; 3 – set of samples (ferroelectric crystals).*

2. The laboratory supervisor will tell you which crystal to mount into the capacitor (*Picture 2*).

   To do this, raise both electrodes slightly (1 in *Picture 2*), place a properly cut piece of aluminium foil (2 in *Picture 2*) on the base and then place the selected crystal between the foil and one of the electrodes (as in *Picture 2*).
   Place the capacitor in the heating jacket (1 in *Picture 1*).




*Picture 2: View of the capacitor: 1 – capacitor electrode handles; 2 – correctly cut aluminium foil with test crystal.*

3. Turn on the measurement module, setting the switch to the *ON* position.
4. Preheat the system to the maximum recommended temperature for a selected sample (see *Table 1*).

   To do this, set the *OVEN* switch on the RLC bridge to the *ON* position, then raise the temperature with the *SET TEM* knob. After reaching the desired temperature, set the *OVEN* switch to the *OFF* position.

**ATTENTION!**

**Due to the slow temperature response, turn off the heater when the temperature reaches above 20 $^{o}$C lower than the desired temperature.**

5. Measure the capacitance as a function of temperature.

   To do this, heat the system to the maximum temperature for the selected test crystal.

   Recommended values of temperature and pressure ranges are given in *Table 1*.

Table 1: Recommended temperatures for TGS and $BaTiO_3$ crystals.

| Crystal | Maximum temperature [°C] | Temperature range [°C] |
|---|---|---|
| TGS | 60 | 45 - 55 |
| $BaTiO_3$ | 170 | 50 - 170 |

Switch of the heating and while the system is cooling, note the temperature and capacitance in steps of 1 °C for the TGS crystal and in steps of 3 °C for the $BaTiO_3$ crystal.

**Hint**

**You should take more readings in regions where the capacitance changes rapidly.**

6. Calculate the dielectric permittivity of the test crystal for the suggested temperature range. The dimensions of the crystals are given in the specifications in tray 3 in *Picture 1.*
7. Prepare the following graphs:
   a) dielectric permittivity vs. temperature;
   b) inverse dielectric permittivity vs. temperature.
8. Determine the Curie temperature of the test crystal..
9. Compare your result for the Curie temperature with values given in the literature.
10. Specify the type of phase transition.

## III. Apparatus.

1. RLC bridge system with capacitor and heating oven.
2. Set of sample crystals – TGS (triglycine sulfate) and $BaTiO_3$ (barium titanate).

## IV. Literature.

1. C. Kittel – “*Introduction to Solid State Physics*”, Wiley, 2004.
2. R.P. Feynman, R. Leighton, M. Sands – “*The Feynman Lectures on Physics*”, Vol. 2. Parts 1-2., Addison - Wesley, 2005.