Dielectric materials that are capable, as a result of a phase transition, of changing their properties, i.e., ‘switching,’ e.g., electrical permeability or resistivity between two or more states with different crystallographic structures or degrees of molecular ordering in response to various external stimuli, have many potential applications.

For example, an optical switching material (when ‘switched’, second harmonic generation (SHG) occurs in it) can transition from the SHG-OFF state to SHG-ON and back again in response to external stimuli as a result of changes in the dynamics of the organic cations within the molecular cage during the shift in its symmetry at a phase transition of the first kind. Thanks to such properties, these materials have potential applications in optoelectronics, including, among others, switches and sensors that respond with a rapid, ‘step’ change of their parameters to a change in temperature or light intensity.

Recently, so-called switchable dielectrics, in which, due to a phase transition of the first kind, there is a step or quasi-steep change between states of high and low electrical permeability in response to an external stimulus (factor), have been increasingly sought and studied. This ability to ‘switch’ extends the applicability of these materials in the electronics industry. However, little is known about the intrinsic mechanism of dielectric ‘switching’ and its physical causes, even for the most easily investigated temperature-induced effect. The impact of mechanical stress (e.g., hydrostatic pressure) on the dielectric ‘switching’ phenomenon remains almost entirely unknown, meaning identifying potentially useful materials is not a solved task. This is particularly the case for thin-film systems, with several hundred...several dozen molecular layers, in which stresses arise as a natural consequence of changes in temperature alone.

The materials in question must meet several criteria to find a more comprehensive application, e.g., they must be capable of being manufactured in a controlled synthesis process and also in the form of thin films, which are of particular interest in microelectronics, they should have the desired electrical parameters at temperatures close to room temperature, and these parameters must also be stable under stress. And, of course, their manufacturing cost must be reasonable.

The project aims to produce and study materials that exhibit phase transitions of the first kind, which result in a ‘switch’ in electrical permeability caused by a change in temperature (e.g., hybrid perovskites), and to understand the molecular causes that trigger this for materials with different phase transition mechanisms. The relationship between macroscopic changes in the dimensions of the samples under study – measured by the dilatometry method - as a result of the phase transition and the change in their electrical parameters will also be investigated. To achieve this, the authors plan to synthesize (monocrystals and thin films) selected hybrid organic-inorganic perovskites and then carry out complementary studies by broadband dielectric spectroscopy combined with structural, infrared, Raman, and dilatometric measurements. Of particular interest, however, will be the study of these materials in terms of the effect that the mechanical stress generated by hydrostatic pressure has, or can have, on phase transitions - and consequently on ‘switching’. In particular, this type of isothermal measurement will make it possible to isolate the effect of stress on the phase transition, which is impossible with standard isobaric variable-temperature measurements performed at atmospheric pressure. Thus, for the compounds under study, it will be possible, among other things, to correlate thermodynamic conditions with the duration of the phase transition. The stability of the electrical parameters of the materials before and after the ‘switching’ and its repeatability will also be examined.

Undoubtedly, the systematic research proposed in the project can fundamentally expand the current knowledge of the molecular origin of the dielectric ‘switching’ mechanism in the studied organic-inorganic hybrid compounds with perovskite structure. Scientifically, this project can open a constructive debate and go beyond the current state of knowledge in interpreting the ‘switching’ effect as originating from a phase transition of the first kind, occurring under the influence of various thermodynamic factors, including mechanical stress.