The discovery of high-temperature (high-T_c) superconductivity in 1986 at a temperature of about 35 K in the copper oxides (cuprates) contradicted the previous theoretical paradigms limiting the formation of superconductivity to very low temperatures (of about a few Kelvin). The theory proposed by J. Bardeen, L.N. Cooper and J.R. Schrieffer in 1957, which explained the phenomenon of resistance-free charge transport in conventional superconductors through bosonic excitations, had to be verified. This led to many novel theoretical concepts, as well as the improvement and development of new experimental tools. However, despite years of efforts, the mechanism of high-T_c superconductivity has not yet been entirely explained. The formulation of a coherent theory is particularly difficult due to the complex chemical composition of the cuprates, the richness of their phase diagrams, and the occurrence of magnetic and charge correlations which interplay with superconductivity.

Research conducted to date has focused on identifying these factors which would expand the temperature range at which superconductivity is observed, with the hope that it would lead to the application of the superconductors in technologies available at room temperatures. Despite the significant progress that has allowed to increase the transition temperature T_c up to 166 K, the underlying mechanism remains unexplained. The aim of our project is to conduct the experimental research that will contribute significantly to the understanding of the high-T_c phenomenon but through the precise determination of the mechanism responsible for the decrease of the critical temperature. In our novel approach, we will use the external parameters such as uniaxial pressure, magnetic field, and zinc substitution, which result in lowering the transition temperature, but without inducing significant changes in the normal-state properties of the material, from which superconductivity emerges. Changes in the transition temperature and the electronic transport properties will be observed through Hall effect, electrical resistance, and magnetoresistance measurements. At the same time, using modern synchrotron techniques, we will study the symmetry of the crystal lattice, its dynamics, as well as the influence of electronic excitations on the suppression of superconductivity. Determination of the factors having a destructive influence on high-T_c superconductivity will allow us to identify those which are important and should be taken into account in building a coherent model explaining the phenomenon of unconventional superconductivity.

To avoid complications resulting from structural differences between different compounds, all studies will be conducted mainly in one material, model, structurally simple superconductor $HgBa_2CuO_{4+d}$. This choice is motivated by a large amount of experimental data we have already collected, but most of all by the discovery of phenomena such as charge ordering or dynamic charge correlations in this material. Further research on these phenomena, and in particular their relation with superconductivity, will be the subject of our work.

The project includes the development of the research infrastructure at the AGH University of Science and Technology in Krakow. Furthermore, it is planned to expand cooperation with the Vienna University of Technology, which is one of the key leaders in the development of the uniaxial pressure techniques. Also, close collaboration will be established with the University of Zagreb, and in particular with the crystal growth laboratory, where the samples of high-T_c superconductors will be synthesized.