Modern sciences such as materials engineering, physics, chemistry, and related disciplines face a tremendous challenge: to develop materials that not only withstand extreme conditions but also fulfill specialized functions — such as optical transparency across a broad spectrum, from ultraviolet to far-infrared, while maintaining high mechanical strength. One prominent example of this need is the use of transparent viewports in ballistic missiles and advanced space exploration devices, where materials must endure not only immense mechanical loads but also extreme temperature fluctuations, radiation, and the impact of high-velocity micro-particles. The development of such materials is based on the latest advances in powder forming and sintering technologies — currently among the key methods used for producing modern tools and technical components. Today's engineering demands require materials that combine seemingly contradictory properties: high hardness and wear resistance with flexibility and resistance to dynamic impact. Research on advanced, ultra-light transparent ceramics — especially those based on light metal oxides doped with rare-earth metal oxides — is paving the way for the design of so-called "gradient and multilayered materials". These are materials in which mechanical properties vary with depth — from a hard, wear-resistant outer layer to a more flexible, ductile core. This concept can also be applied to transparent ceramic materials, where it is possible to engineer the structure such that the surface is damage-resistant while the inner layers remain less brittle and more resilient. Preliminary laboratory experiments, supported by an extensive literature review, have enabled the identification of ceramic oxides suitable for the development of a new class of materials, termed "**Ultrahigh-Temperature Transparent Lightweight Ceramics**" (UHTTLCs).

Although initially developed for industrial tooling applications, these technologies hold significant potential for adaptation in the field of transparent materials — especially in cases where the combination of mechanical durability and optical clarity is critical, such as in optical shields for rockets or satellite observation sensors.

The research will include a full physicochemical characterization of the powders and final ceramic products. A holistic research approach will allow for capturing the subtlest quantum and thermal effects that arise in these materials when exposed to near-real operating conditions. Various analytical methods will be employed, including phase and chemical analysis, structural studies, spectroscopic and spectrofluorometric analysis, thermal and dielectric testing. Both standard investigative techniques — such as X-ray diffraction and electron microscopy — and cutting-edge tools involving synchrotron radiation and single-atom observation will be implemented.

The development of these materials represents not only a technological challenge but also a significant step forward in fundamental science, where researchers seek to uncover the smallest physical effects. Observing and understanding new phenomena in the developed ceramics will yield a range of scientific and technological benefits. Thanks to precise control over structure and chemical composition, it becomes possible to design "tailor-made materials" — optimized not only for mechanical performance but also for specific functionalities such as transparency, radiation resistance, or even self-healing of micro-damages. The final result of this project will be the possibility of implementing these materials in new Polish satellites.