1. Research project objectives/Research hypothesis

The primary objective of this research project is to investigate the process of **"3D printing of turbine blades based on boron carbide and intermetallic additives for use in aerospace and energy production industries."** The proposed innovative approach involves two distinct 3D printing techniques for creating gas turbine blade components using a novel composition. By combining boron carbide with intermetallic additives, the synthesis temperature is reduced, which is the most significant advantage of the proposed blade materials in terms of production cost and environmental protection. The LAS X Industry core software with modules for 2D and 3D image assembly will enable surface change analysis, cavity depth calculation, and surface change mapping after thermal analysis. This research develops a methodology for synthesising UHTCs composites and ceramic pastes with intermetallic additives and testing the obtained materials. for 3D printing technology such as Direct Ink Writing (DIW) assisted by UV. This approach enables photocrosslinking during printing, thus improving the quality of the printed element surface. Another 3D printing method planned for this project is Fused Deposition Modelling (FDM), also known as Fused Filament Fabrication (FFF), which has not been used to obtain UHTCs composites. Designing filaments for FDM will expand the 3D printing potential, enabling gas turbine blade components to be printed on commonly available FDM printers, thereby increasing the possibility of commercialising the results.

2. Project scientific hypotheses

- The use of boron carbide in conjunction with intermetallic additives results in a higher density of the final materials, attributable to reaction sintering during synthesis, when compared to existing materials with a density of up to 50%.
- The incorporation of intermetallic compounds from Ti-Al, Ti-Si, and Zr-Si systems into boron carbide decreases the synthesis temperature from 2000 to 1600 °C or lower.
-Integration of 3D printing techniques, including Direct Ink Writing with UV assistance, improves the print quality with a higher ceramic phase content.
-Production of ceramic-infused filaments enables traditional FDM printing to fabricate gas-turbine blades or other elements.
-Utilisation of 3D printed materials allows gas turbine blades to operate at temperatures reaching 2000 °C or higher, that is, higher than those of current materials (1400 °C).
-The selection of infill patterns, such as honeycomb, gyroid, and parallel lines, significantly influences the printing and surface quality of the resulting composites. Additionally, these infill patterns are expected to affect the mechanical and thermal parameters of gas turbine blades.

3. Impact of expected results on the development of science

The proposed study is innovative from the perspectives of basic research and future applied science. UHTCs materials will be obtained in specific shapes using two different 3D printing methods. In the current methods, mechanical processing of the resulting shapes is necessary, which significantly increases costs and environmental pollution. This work describes the use of novel methods to synthesise B_4C nanoparticles. The use of boron carbide (B_4C) enables the synthesis of UHTCs composites comprising carbides and borides. B_4C can be considered a source of carbon and boron for the synthesis of composites. Owing to its specific properties, it is possible to obtain reaction sintering during the synthesis process, which simultaneously allows the material to be densified and lowers the synthesis temperature.

In addition, the non-stoichiometry of boron carbide makes it possible to donate carbon and boron from its structure for composite synthesis. The hybrid DIW method with UV enables efficient 3D printing of ceramic mass, which under the influence of additives enables photocrosslinking and results in better prints. This improvement consisted of a more accurate surface and greater conformity to the designed model. The DIW process precisely controls the rheological properties of the extruded paste.

The use of a second 3D printing method, called FDM, makes it possible to obtain filaments based on various polymers with ceramic additives and the possibility of using popular traditional printers. The proposed ceramic composites have never been used in 3D printing and have high resistance to corrosion and thermal shock, allowing their use as cutting tool components, wear-resistant machine parts, electrodes for electrical discharge machining, and armor materials. Using the method developed at AGH and experience of the team leader, composites consisting of B_4C and an intermetallic compound from the Ti-Si system were obtained by sintering at a lower temperature of: 1650-1750°C. The obtained composites, owing to their specific phase composition, were characterised by high thermal resistance and composites based on them allowed operation at temperatures above 2000°C. The use of these two 3D printing methods will allow the development of commonly available compositions and printable materials, which will influence the development of materials engineering and 3D printing.