MAX materials are a new group of materials that bridge the gap between ceramics and metals due to their beneficial properties such as resistance to thermal shocks, oxidation and corrosion, combined with favorable fatigue and creep resistance. For this reason, they show great potential for applications in high temperature environments. The MAX phase density typically ranges from 4 to 6 g/cm^3, which is comparable to most ceramics and twice as low as the high-temperature alloys used in the aerospace industry.

The name of the MAX materials comes from their chemical composition, where "M" is a transition metal, "A" is a group A element (e.g. Al), and "X" is carbon, nitrogen or boron. Their excellent properties at high temperature create new possibilities of using them as protective coatings for components of industrial and aviation turbines. The development of aircraft engines is associated with increasing the operating temperature of their components, which leads to an increase in efficiency and a reduction in CO_2 and NO_x emissions to the atmosphere. This is a motivation for the development of new materials and protective coatings that enable them to work in increasingly demanding conditions. The service life and operating temperature of parts such as turbine blades made of intermetallic γ-TiAl alloys or components made of ceramic matrix composites (CMC), e.g. SiC-SiC, can be increased by depositing appropriately adapted MAX nanolaminate coatings while maintaining the mechanical properties of the materials substrate.

Within the project, research will be carried out on the deposition of nanolaminate coatings from MAX materials (M = Cr or Ti and A = Al) by various methods of Physical Vapor Deposition (PVD) and new knowledge will be gained on the mechanisms of their degradation at high temperature and in an atmosphere containing water vapor. For the first time, three different PVD technologies available at partner institutions in Poland and Germany will be compared, including high power magnetron sputtering (HPPMS), direct current magnetron sputtering (MS-DC) and closed hollow cathode deposition (CHC-PVD). The coatings will be applied to substrate materials such as TiAl intermetallic alloys and SiC-SiC ceramic matrix composites. The international cooperation between Polish and German institutions on various coating deposition parameters offers a unique opportunity to understand the influence of numerous parameters on the properties of MAX nanolaminate coatings.

The project will focus on understanding the phenomena occurring during the operation of coated alloys in high temperature and aggressive environments containing water vapor. The oxidation resistance of TiAl alloys is expected to increase at 850 °C. In the case of the base material of the ceramic matrix SiC-SiC composite, the need to protect against corrosion caused by water vapor is currently achieved by modern, yet complex systems of environmental barrier coatings (EBC) based on rare earth silicates. Their potential replacement with MAX coatings could allow for a more sustainable use of raw materials and an increase in their resistance to oxidation due to the formation of a protective oxide layer composed of aluminum oxide (Al_2O_3). Therefore, special attention will be paid to the phenomena occurring at the interfaces between the coatings and the oxidizing atmosphere, as well as between the coatings and the substrate materials made of TiAl alloys and SiC-SiC composites. The research on diffusion processes between nanolaminate coatings and substrate materials will be analyzed using the cutting-edge scanning and transmission electron microscopy (STEM) techniques and will be supported by thermodynamic simulations using CALPHAD methods. New knowledge will be gained about the phenomena occurring during the growth of protective coatings as well as their degradation at high temperature. The resistance of the new types of coatings to the effects of an aggressive environment and temperature will be revealed during long-term tests of cyclic and isothermal oxidation in a water vapor containing atmosphere. The influence of MAX type coatings on the mechanical properties of alloys under fatigue and creep conditions will be investigated.