Global warming is one of the most serious problems the Planet Earth faces. One of the most important tasks for modern day science is to find ways to decrease the emission of greenhouse gases, which contribute to global warming. The European Union (EU) is currently the fourth largest greenhouse gas emitter in the world, and Poland is among the top five countries in the EU with the largest greenhouse gas emissions. The EU plans to become climate neutral by 2050. In order to achieve that, the emissions associated with two of the most prominent sources of greenhouse gases: the energy sector, and the domestic transport need to be reduced.

Even though producing energy from renewable sources is becoming more popular, the biggest problem related to them is the fact that energy is not available all the time as its production depends on, for example, the weather conditions. Therefore, an energy carrier, which can store the energy to be used when it is needed has to be utilized. This can be achieved by storing the produced energy in the chemical bonds of hydrogen gas. Its chemical energy can then be then transformed to electrical energy by fuel cells, such as Solid Oxide Fuel Cells (SOFCs). SOFCs operate at high temperatures (up to 800°C), in aggressive atmospheres (air and hydrogen-water vapor), and because of that their parts are prone to high temperature (HT) corrosion. Due to the fact that a single SOFC cannot produce enough power, the cells are multiplied to form a SOFCs stack, which can produce more energy. To separate the cells from one another, and to collect the charge produced by the cells a metallic plate, called the interconnect is used. The interconnect is especially affected by HT corrosion. This is a serious issue as the corrosion of the interconnect is detrimental to the efficiency of the SOFCs stack. This is why protective coatings with the ability to conduct electricity have to be applied to protect the interconnect against HT corrosion in the atmospheres of air, and hydrogen-water vapor.

Internal combustion engine vehicles are the most common ways of domestic transport, however they are the primary sources of greenhouse gases, such as CO_2. One of the ways to tackle this problem is to introduce hydrogen-fuelled vehicles which are more ecologically friendly as they emit primarily water vapor. It is even possible to transform a conventional internal combustion engine to work on hydrogen. Hydrogen engines work at high temperatures (ca. 900°C) in heating-cooling cycles, in the atmosphere of water vapor, and in the presence of residual hydrogen. The combination of these conditions make parts of hydrogen internal combustion engines, such as the exhaust valve, prone to (1) HT corrosion in water vapor during operation, and (2) potential degradation related to the permeation of residual hydrogen during cooling of the engine. Therefore, there is a need to obtain coatings with two features: resistance to HT corrosion in water vapor, and inhibition of hydrogen permeation.

Ceramic materials are known for their resistance to HT corrosion, therefore they are great candidates for the purpose of protective coatings for both of the mentioned applications. One group of ceramic materials, the so-called polymer-derived ceramics (PDCs) is especially appealing in the context of coating deposition as it allows a huge flexibility in terms of their features such as chemical composition and physical properties. PDCs are frequently obtained from so-called preceramic organosilicon precursors during pyrolysis (controlled thermal decomposition) in inert gas atmosphere. One interesting example of PDCs which will be studied in this project is silicon carbonitride (SiCN). It can be obtained from organosilicon polymers which contain silicon, carbon, nitrogen and hydrogen, such as polysilazanes. SiCN contains strong, covalent Si–C and Si–N bonds, which give this material its excellent resistance to high-temperature corrosion. Moreover, when the amount of carbon in the preceramic polysilazane is sufficient, nanodomains of the so-called free carbon phase appear, which enables SiCN to conduct electricity. Due to the fact that the structure of SiCN is made up of dense, strong bonds, it is a good candidate for a material with a low hydrogen permeability.

The aim of this project is to develop protective coatings based on polymer-derived ceramics (PDCs) from the SiCN system for metallic substrates working at high (600÷1000°C) temperatures in atmospheres containing hydrogen and/or water vapor, such as SOFCs interconnects, and exhaust valves for hydrogen internal combustion engines. At the same time the project will solve the problems associated with PDC-based coatings such as (a) their relatively low thickness; and (b) their insufficient electrical conductivity.

The project will consider coatings based on SiCN, and SiCN doped with aluminium, i.e. SiAlCN. The precursors of SiCN-based ceramic coatings will be synthesized from a silazane monomer, and modified by an aluminium-containing compound. The coatings will be deposited on four steels, two for each of the applications. To overcome the problem of the low thickness, and insufficient electrical conductivity, ceramic filler particles will be added to the coatings. The unfilled and filled coatings will undergo HT corrosion tests in the atmospheres containing hydrogen and/or water vapor, as well as hydrogen absorption and permeation experiments, electrical conductivity measurements, mechanical tests, and structural, microstructural, and chemical analyses before and after corrosion/hydrogen permeation, which will help to determine the mechanisms of HT corrosion, and hydrogen absorption and permeation.

The performed experiments will shed light on the behaviour of PDC-based coatings in hydrogen and water vapor rich environments. To make the transition from fossil fuels to hydrogen more fluent, there is a need to test materials in atmospheres containing H_2 and H_2O, and to design new, improved ones. Therefore, such results will be beneficial in the context of the EU's climate goals.