Self-organised coatings on 3D substrates for Hydrogen Evolution Reaction – synthesis, nanostructure and properties.

Due to the need to reduce CO_2 emissions, the modern economy is turning to new energy sources, one of the most important of which is hydrogen. It can be used to store energy from renewable sources instead of batteries or pumped power plants. However, producing hydrogen with minimal greenhouse gas emissions is essential to prevent accelerating climate change. Such hydrogen is called green, which accounts for less than 1% of total hydrogen production.

The leading research on the production of green hydrogen is currently focused on the electrolysis of water using electrolysers operating in an acidic or alkaline environment. Each technology has its limitations and challenges: critical materials, performance and durability.

One of the challenges is developing electrode materials with high catalytic activity and maximum durability. The project focuses on developing new electrode coatings that take over the catalytic functions. They are deposited on massive electrodes that only act as electric current collectors. Magnetron sputtering is planned for the synthesis of the coatings. This method consists in generating in a vacuum chamber an intense electric discharge supported by a magnetic field, in which atoms of the material are sputtered. Then these atoms are deposited on substrates placed in the chamber. If reactive gases are used to generate the plasma, the deposited atoms form chemical compounds and their composites.

Among the many materials proposed for catalytic layers, nanostructured coatings are particularly interesting. Under certain conditions, nanostructured coatings with the desired morphology can be obtained. Our recent research resulted in the development of quasi-amorphous metal-carbon coatings exhibiting a specific self-assembled nano-columnar structure with column axes parallel to the growth direction, as shown in the figure below. The nanocolumns have diameters of 3 to 7 nm and consist of metal cores surrounded by amorphous carbon.

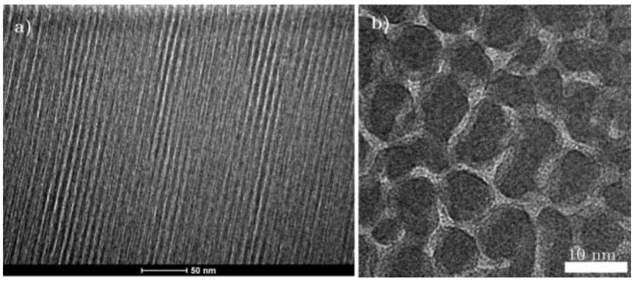

Fig. Images from the transmission electron microscope of the NiCr-C coating: (a) cross-section and (b) top view relative to the substrate surface.

We believe that thanks to the use of coatings containing metals such as nickel, titanium and niobium for the synthesis, it will be possible to obtain the described nanostructure, which is also beneficial from the point of view of water electrolysis. The fronts of the columns will be catalytic centres, and the metallic columns penetrating the entire coating will conduct electricity well. The carbon sheath will improve the corrosion resistance of the coating.

One of the essential tasks of the project is to find the right chemical composition of the coatings to obtain their desired structure. Another task is to test the catalytic ability of the coatings in the water electrolysis reaction and the process of releasing hydrogen bubbles from the electrode surface.

The gas should be released as soon as possible because its presence on the electrodes reduces the actual contact surface of the electrolyte with the electrode and slows down the process. Therefore, the goal is also to achieve the best possible surface wettability by the electrolyte. The wettability of a surface is related to its chemical composition and structure, but it is also associated with the geometry (shape) of the surface. Therefore, electrodes with flat and textured surfaces will be used as part of the project. They will be produced by 3D printing through selective laser melting. The project will involve three research teams: the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences, the Koszalin University of Technology and the University of Gdańsk. They will jointly research the synthesis and structure of coatings and their catalytic properties in the electrolysis reaction, as well as the processes of releasing gaseous hydrogen from the surface of the electrodes.