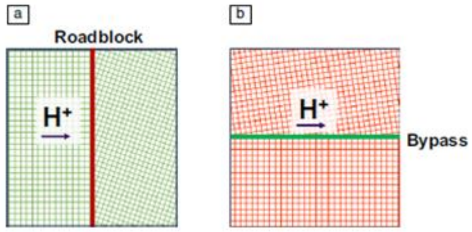
Reg. No: 2024/55/B/ST11/01911; Principal Investigator: prof. dr hab. inż. Maria Jadwiga Gazda

Interface Engineering – Aligned Ceramics for Protonics

The aim of the project is to develop the technology for preparing and to make vertically aligned ceramics and ceramic composites for proton-conducting oxide systems. By the systems of proton-conducting oxides, we understand those containing at least one oxide in which protonic defects are present. The interfaces are the borders between the grains, the borders between different materials and the borders between the material and the atmosphere.



Reasons for undertaking this topic

Interfacial processes and charge transport are of primary importance for ionic- and mixed ionic-electronic conducting materials because these materials rely on the efficient movement of charge carriers across interfaces. Within this project, we propose to enhance charge transport through interface alignment so that the internal surfaces are oriented in parallel to the electrical current direction. The idea, illustrated in the figure, is to take advantage of the transport along internal surfaces (Fig. b)

Description of the research

We will study how to make ceramic material with a microstructure in which grains and the interfaces between them are at least partially ordered in such a way that they are parallel to the direction of the current. We will do that using the following methods: (1) so-called templated grain growth in which a few percent of anisotropic large grains are added to the ceramic powder to force it to grow in the desired direction; (2) prolonged heating of the ceramics in conditions promoting directional growth, e.g. in a temperature gradient; (3) using a floating zone furnace in which a high-temperature region may be shifted along the ceramic rod forcing in this way directional growth. We will also use other methods, such as those that are traditionally applied to thin film deposition.

The materials which we would like to prepare, modify and study are based on state-of-the-art protonic ceramic materials. Among others, they are acceptor-doped barium zirconate-cerates ($Ba(Yb,Ce,Zr)O_3$) and the derivatives, and mixed proton-electron conductors (e.g. ferrites and cobaltites with perovskite structure). We will also perform experiments with composites of the above oxides and other oxides which are not proton conductors to study proton transport along their heterointerfaces.

The phase composition, crystal structure, and extent of grain alignment of the materials prepared for the project will be characterized using X-ray powder diffraction, scanning and transmission electron microscopy, and other methods. The materials will also be studied using thermal analysis methods, including thermogravimetry, dilatometry, and sorption studies. The electrical properties of materials with aligned interfaces will be studied using methods such as electrochemical impedance spectroscopy, conductivity relaxation, current-voltage characteristics, and DC polarization methods. We will measure the electrical conductivity in different directions, so it will be possible to check the anisotropy of properties.

The project results

The project will result in the technique for vertically aligned ceramic preparation and the knowledge of the relations between properties of various interfaces in ceramics and ceramic composites for proton-conducting systems. The project findings will influence not only the field of functional materials but also emerging hydrogen technologies, which are necessary for developing a green and sustainable energy grid for future generations. Understanding interfaces opens a new way to improve existing devices and enable future development of hydrogen technologies.