Project summary

Porous materials are a class of materials, which have a controlled distribution of voids, called pores, in their volume. Based on the pore size, the materials are classified into three categories: microporous (pore sizes < 2 nm), mesoporous (pore sizes 2 – 50 nm), and macroporous (pore sizes > 50 nm). Most of the research effort is related to the microporous materials, which have been studied and applied in sensing, decontamination and filtering, catalysis of chemical reactions or energy storage. A special class of porous materials are porous metals, prized for their combination of light weight and mechanical toughness as well as high electrical and thermal conductivity. Due to their typical fabrication ways, usually through molten metal foaming with gas or similar processes their pore sizes remain large, usually of the order of several μm at minimum. This kind of pore size works well with their current macroscale applications in construction elements but can prove too large for coating applications where a surface modification of material is beneficial. Metallic coatings with nanoscale features could enhance many of the microporous applications described above, e.g. by providing better charge transport to the microporous material through a more developed surface of a current collector or better heat dissipation.

One of the most important barriers hindering the development of porous metallic coatings is the lack of a well adopted, appropriate coating technique that would enable a high degree of control of the nanostructure morphology, repeatability and large scale deposition. A good candidate could be magnetron sputtering, which is used efficiently for coating large scale areas from architectural glass to metallic coatings. It is however a technique that strives to deposit the films as dense as possible. Only a few works investigated the possibilities of depositing porous materials using sputtering. Most notably, the glancing angle deposition (GLAD) approach enabled to develop porous films through sputtering by using very oblique (<10°) angles of the incident material flow with regard to the substrate surface. However, the problem with its application lies in the complex geometry necessary and low growth rates, making efficient large area coating cumbersome.

Our group at Łukasiewicz – Institute of Microelectronics and Photonics (Ł-IMiF) showed that it was possible to deposit porous zinc in a normal, non-GLAD, sputtering geometry with very high rates using reactive deposition with a small addition of oxygen to the inert working gas, argon by applying low pressures and an oxygen concentration below a given threshold. We also showed that contrary to the usual assumptions during magnetron sputtering, not only the Ar to O_2 gas flow ratio plays a role in controlling the microstructure of the films, but also the flow rate values themselves are crucial to take into account. We demonstrated a wide array of nanostructures grown using this approach, from very branched out ones to densely-porous, with pore sizes controlled in the mesoporous range and thicknesses up to several micrometers, which were subsequently well applied in supercapacitors and gas sensors.

In the frames of this project, based on our results, we want to tackle the challenge of enabling porous metallic coatings by means of reactive magnetron sputtering by thoroughly studying the conditions leading to porous Zn growth in the approach developed by our group. We hope that by studying and modelling the porous Zn system we will be able to understand the growth and apply the same mechanism to grow other porous metal coatings.

We will start by studying the conditions leading to porous Zn growth by means of modelling of the sputtering process and the film growth process individually. We will also explore additional process parameters that we have not studied yet. We will deposit Al, Cu and Mg films in the same conditions as for porous Zn and based on the film characterization will develop a description explaining which elemental properties relate to which process conditions and how. Additionally, we will deposit porous Zn with the metals at the same time to fabricate alloys and to see how the metals influence the growth of the films, giving insight for the general description of such porous film growth. To introduce micropores to the porous metals we plan to do simultaneous deposition of metal and NaCl with subsequent dissolution of NaCl in water. The properties of the processes and films will be measured by an extensive array of complementary techniques. Finally, to relate the basic science of the porous films to the device world we will apply them in electrodes of supercapacitors – energy storage devices.