**Thin film electrodes deposited by high power impulse magnetron sputtering (HiPIMS) for 3D microsupercapacitors**

***Keywords :*** *Thin films, Plasma, Sputtering, HiPIMS, 3D Micro-supercapacitors*

***Context***

Micro-supercapacitors (MSC) are electrochemical miniaturized systems, which can be used in the energy storage unit of devices for the Internet of Things. In order to improve the energy density of such electrodes while maintaining reduced footprint, 3D electrodes with high surface-to-volume ratio design were proposed as an innovative solution [1].

Recently, transition metal nitrides (TMNs) such as RuN, VN or TiN have emerged as promising electrode materials for electrochemical supercapacitors. These materials can be deposited by magnetron sputtering, which is usually carried out on flat substrates but is not appropriate to obtain conformal thin films on 3D patterned surfaces (micro-pillars, micro-trenches…).

High power impulse magnetron sputtering (HiPIMS) is a particular type of sputtering technique where the discharge consists of a plasma dominated by metal ions (by opposition to neutral species in conventional sputtering), which has the potential to achieve conformal coatings on high aspect ratio 3D structures.In IMN, we have built a unique HiPIMS reactor equipped with five synchronized power supplies controlled with microsecond resolution. This offers an additional control of the plasma and allows enhancing the ionisation of metallic species within the gas phase (Ti+ ions at the expense of Ar+).



Figure 1 : Thin film deposition on 3D substrates by DC sputtering and HiPIMS

***Thesis subject***

**The objective of the thesis is to investigate the deposition of titanium and titanium nitride thin films by HiPIMS and characterize these films for microsupercapacitors applications**. The first part of the thesis will focus on the characterisation of the plasma discharge (electrical parameters measurements, mass spectroscopy, time-resolved optical emission), with the objective to get better understanding of the gas phase and how one can use the multiple power supplies to specifically enhance metallic Ti ions and achieve higher degree of ionisation of the plasma discharge. The second part will deal with the fabrication and characterization of thin films by HiPIMS on planar and microstructured substrates. The aim of this second part will be to achieve conformal Ti and TiN films on microstructures with high aspect ratios. Thanks to the large number of techniques available at IMN, the films will be characterized by X-ray diffraction, scanning and transmission electron microscopy, and X-ray photoelectron spectroscopy. Finally, the electrochemical performance of films deposited on microstructured substrates will be evaluated by cyclic voltammetry and impedance spectroscopy. An overall analysis of the relationship between deposition parameters, plasma, thin-film properties and device performance will then be carried out at the end of the thesis.

***Student profile***

You have (or are about to obtain) a Master (M2) or equivalent with a background in materials science, materials physics/chemistry, thin-film materials or related fields. The subject include a large proportion of experimental work associated with the production of thin-film materials and their physico-chemical and functional characterization. We are looking for a student strongly motivated by the experimental work and able to work with accuracy and autonomy within a multidisciplinary team. The candidate should have good oral and written communication skills in French and English with a variety of audiences. Initial lab experience in the field of plasmas/thin-film materials and/or structural characterization is expected.

***Work environment***

This thesis is funded under the PERFORM project of the French National Research Agency (ANR). The host laboratory is the Institut des Matériaux de Nantes Jean Rouxel (IMN, UMR 6502, http://www.cnrs-imn.fr). The IMN currently brings together over 130 researchers (chemists, physicists, materials engineers from the CNRS and the University of Nantes) and is one of France's largest materials science research laboratories, located north of downtown Nantes, a dynamic and attractive city in western France. The laboratory develops new materials for a wide range of applications, and explores chemical and physical mechanisms at the nanoscale. The candidate will be recruited within the Plasma and Thin Films team (PCM) and will work in the Thin Films theme (https://www.cnrs-imn.fr/index.php/themes/couches-minces).

***Funding***

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Please provide a detailed CV, including at least two references, a cover letter, a summary of the Master's thesis topic (1 page max), and grades and ranking in Master 1 and 2.