Synthesis and characterization of functionalized porous silicon electrodes for supercapacitor applications.

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Context and objectives of the study: In the GREMAN, a team is working on the synthesis and characterization of porous silicon-based materials. Porous silicon can be synthesized by electrochemical etching (anodization) of monocrystalline silicon. After electrochemical treatment, this material is made of non-interconnected pores with size varying from the nanometer to the tens of micrometers. Porous silicon can be applied in a lot of different domains such as optics, microelectronics, biomedicine or energy storage. “Energy” is a research domain studied by the porous silicon team in Tours for more than 10 years since the synthesis and characterization of porous silicon gas diffusion layers for microfuel-cell in collaboration with STMicroelectronics and CEA-Liten (between 2006 and 2010). Energy storage applications are still intimately linked to porous silicon activities in the GREMAN. Since 2012, porous silicon has been used as Li-ion battery anode through 3 different projects (2 Région-Centre projects in collaboration with PCM2E and 1 European FP7) and reported a few breakthroughs in the literature such as the synthesis free-standing and binder-free macroporous silicon anodes thanks to a collaboration between GREMAN and PCM2E laboratories [1].

The objectives of the current proposal are to extend the energy storage application of porous silicon toward supercapacitors electrode engineering and characterization. The feasibility of porous silicon-based electrodes for supercapacitors has been successfully demonstrated in the GREMAN a few years ago [2]. The results obtained are still used as reference by the scientific community whose interest for silicon-based supercapacitors is growing every year [3-5]. Promising capacitive performances are anticipated thanks to the high specific surface area of the porous silicon electrodes. The expertise of the GREMAN developed on the synthesis of high surface area porous silicon materials [6,7] will enable a better control of the parameters defining porosity (pore size distribution, pore volume) compared to the current literature. Simultaneously, the main drawbacks of silicon-based electrodes: their narrow electrochemical stability window (approximately 0.8 V) and their performance drop after repeated charge/discharge cycles will be solved by the control of the electrode surface chemistry. Two ways of porous silicon surface treatments are anticipated: impregnation of a carbon layer at the surface of the porous silicon electrodes or atomic layer deposition (ALD) of an active material on the CERTeM plateform in Tours. For instance, ruthenium oxide layer (RuO_x) can deposited by ALD in order to cover the porous electrodes and could offer promising performances in terms of electrochemical reversible capacity. In parallel, the PCM2E lab will bring its expertise and help on the determination of the appropriate electrolyte for silicon-based electrodes in order to optimize their performances. Combining the high specific surface area of porous silicon, its surface functionalization and an appropriate electrolyte, a capacity around the tens of mF/cm^2 can be expected. Physico-chemical (SEM/EDX, XRD, FTIR, granulometry…) characterization of the porous silicon electrodes will be mainly performed in the CERTeM platform of Tours. Whereas the electrochemical characterization of the supercapacitors (cycling and impedance spectroscopy) is expected to be performed at the INSA-Centre Val de Loire site of Blois.

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Laboratories' websites:

Laboratoire GREMAN : greman.univ-tours.fr

Laboratoire PCM2E : pcm2e.univ-tours.fr

Plateforme CERTeM : certem.univ-tours.fr

Applicant profile:

The applicant must hold an engineering diploma or a master's degree. Good knowledge on electrochemistry, chemistry and material sciences are required. Finally, basic knowledge on semiconductors and / or microelectronics (process) is also appreciated.

Application: Send an email to the following contacts attaching your detailed CV, your cover letter and your references/contacts.

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