High areal capacitance micro-supercapacitor based on electrodeposited MnO_2 thin films on silicon 3D microstructures

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Recently, the miniaturization of electronic devices combined with the "More than Moore "concept, leading to high functionality microsystems, require the monolithic integration of power sources at the micro scale. To fulfill these challenging requirements, electrochemical micro-supercapacitors seem to be good candidates for high power needs. Carbon-based materials [1, 2], conducting polymer [3] and metal oxides [4, 5] are the most widely used electrode materials. The current trend is to develop micro-supercapacitor with exacerbated performance owing to 3D disruptive topologies. Several devices have already been reported using carbon-based technology [6] and conducting polymers [7]. The C-MEMS (Carbon-Micro Electro Mechanical Systems) 3D topology developed by M. Madou [8] has been used by M. Beidaghi & al.[9] to achieve to the best of our knowledge the most promising oxide based 3D-micro-supercapacitor. To be compatible with CMOS technological facilities, our approach consists in (1) micromachining a silicon wafer to design a 3D topology with high surface ratio, (2) patterning the platinum current collector made by atomic layer deposition to achieve intergitated electrodes and finally (3) electrodepositing pseudocapacitive metal oxide layers.

A top-down technology is used to create a high aspect ratio array of dense silicon microwalls or micropillars by combining photolithography and deep reactive ion etching (DRIE) processes. The typical diameter of the pillars and the spacing are respectively 2.5 µm and 1.5 µm. The etched depth can reach several tens of micrometers. A conformal layer of platinum made by ALD acts as current collector. Then, a pulsed electrodeposition technique is used to achieve a conformal manganese dioxide thin film (Fig. 1) on the platinum layer. First electrochemical measurements show a promising capacitance of 135 $mF.cm^{-2}$ for a 40 µm depth pillars electrode with a 200nm thick MnO_2 layer (Fig. 2): the benefit of the area enlargement factor of the 3D silicon based microstructure is clearly highlighted. This electrode is futher used to design a 3D electrochemical microsupercapacitor with interdigitated electrodes using a photolithography process (Fig. 3). In this communication, the fabrication method as well as the performance of the device will be presented.

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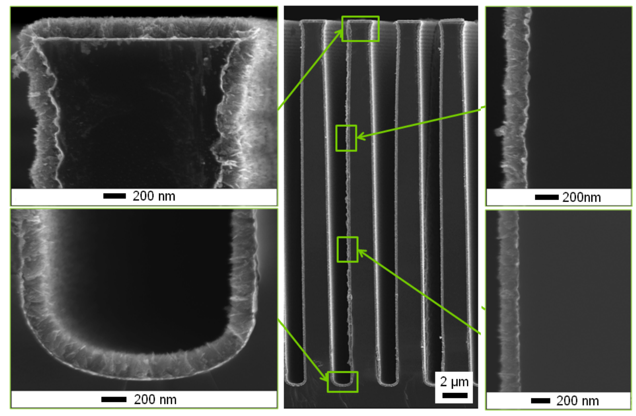

Fig. 1: SEM cross section view of microwalls coated by a conformal 200 nm pulsed electrodeposited MnO_2 layer on an ALD-deposited 30 nm platinum current collector.

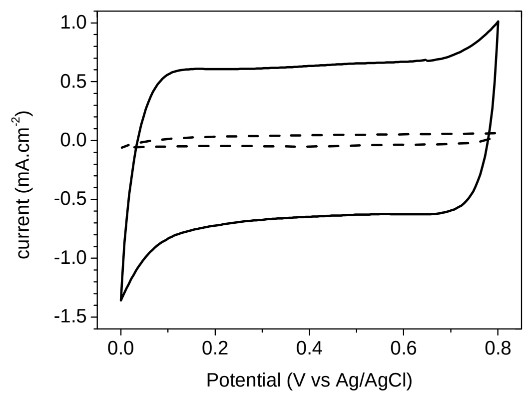

Fig. 2: voltamogram at 5 mV/s of a 200 nm MnO_2 coated 40 µm depth pillars electrode (line) in an aqueous electrolyte of 0.5M Na_2SO_4 and comparison with a 100 nm MnO_2 coated flat electrode (dash)

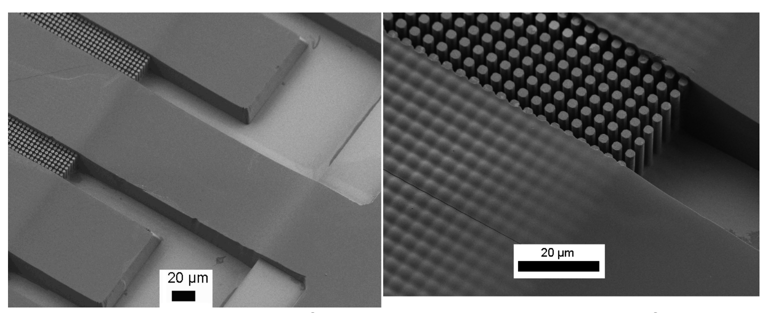

Fig. 3: SEM views of the photolithography step before etching of the platinum current collector

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