Chemical vapour deposition of a solid state electrolyte for microbattery applications

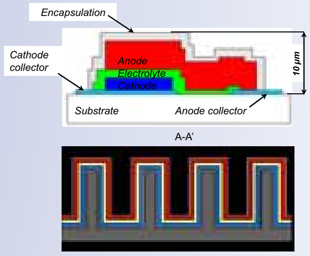
P. Achatz[1,2], J.-L. Deschanvres[1], C. Jiménez[1], L. Le Van-Jodin[2], S. Poulet[2], J.M. Decams[3], Y. de Puydt[4], M. Tran[4], F. Sommer[4], L. Dupuy[4], J. Viard[4], D. Guy-Bouyssou[5]

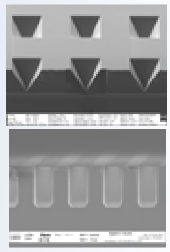
[1]LMGP, INP Grenoble Minatec, 3 parvis Louis Néel, 38016 Grenoble, France; [2]Liten/DTNM/LCMS, CEA Grenoble, 17 rue des Martyrs, 38054 Grenoble, Cedex 09, France; [3]Annealsys, Rue de la Vieille Poste, 34055 Montpellier, France; [4]Biophy Research, Actipôle St Charles, 131 Av de l'Etoile, 13710 Fuveau, France; [5]STMicroelectronics Tours SAS, 16 rue Pierre et Marie Curie, 37071 Tours, France

Introduction

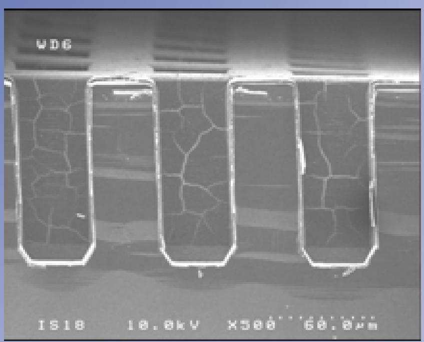
Conventional batteries contain liquid electrolytes, which are more conveniently replaced by a safer and more stable solid-state electrolyte. This is one of the requirements in order to improve the safety and to prevent the risk of electrolyte leakage. The miniaturization of future device technology, including numerous wireless autonomous devices as for instance hearing aids, medical implants, integrated lighting solutions, or smart cards, makes the development of battery systems with higher storage capacity necessary.

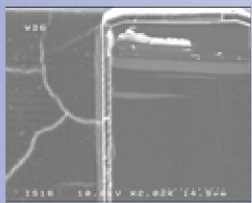
New architectures and technologies could be applied to all-solid-state batteries, leading to 3D miniaturized energy storage systems. Increaing the active surface area is directly related to the enhancement of the battery capacity. We present results on the elaboration and characterization of a solid state electrolyte suitable for future microbattery applications. A chemical vapour deposition process has been applied, making the deposition possible on 3D structured surfaces with high aspect ratio.

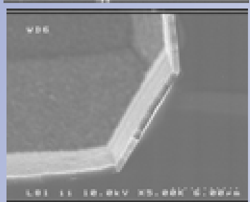




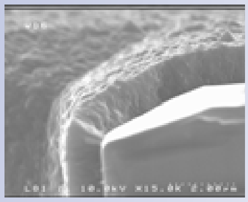
CVD on 3D structured substrates

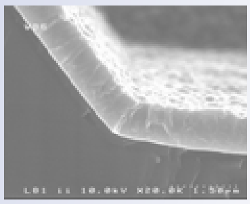






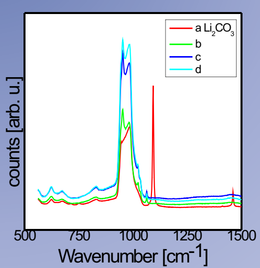
Scanning electron microscopy has been performed on the cross-section of a sample deposited on a high aspect ratio substrate (100 µm x 40 µm). As can be seen from the different images, a highly conformal (around 70 %) and very homogeneous around 1 µm thick film has grown, following the countours of the structured substrate.

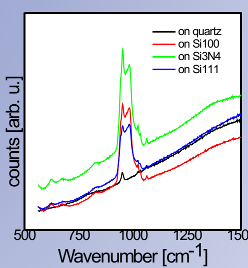




Structural and chemical characterization

Raman spectroscopy

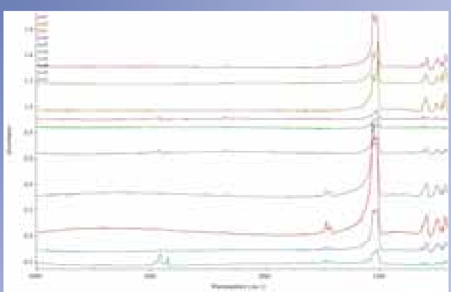


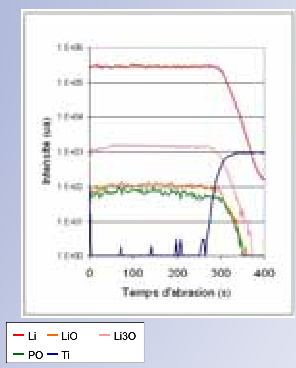


Raman spectroscopy has been used as a non-destructive tool in order to obtain information about the cristalline nature of our thin films. On the left, Raman spectra of our samples are shown in comparison to Lithium carbonate (in order to show that no contamination occurs at the surface). The Raman spectra of our samples resemble that of those found for Lithium phosphate found in literature. On the right, Raman spectra of several thin films are shown grown on different types of substrate. The grown layers are suitable for any type of underlying material.

1. L. Popovic et al., J. Raman Spectrosc. 34, 77-83, 2003;
2. L. Popovic et al., J. Raman Spectrosc. 36, 2-11, 2005;

FTIR and Tof-SIMS

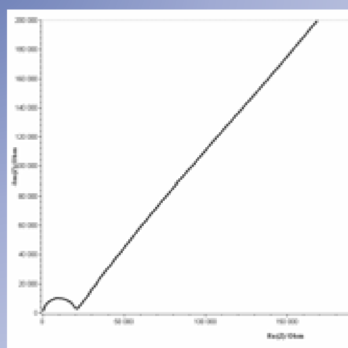




FTIR spectroscopy has been applied to our samples in order to investigate the bonding structure. The most prominent feature is the double peak around 1028 cm^{-1} and 1060 cm^{-1} due to P-O-P bonding. The variation of intensity depends on the thickness. Correlations with the composition of the samples remains difficult.

Depth profiles of the composition of our samples have been obtained with Tof-SIMS measurements, showing very low compositional variations through the layer thickness. A composition close to Lithium phosphate has been found, as also observed by XPS measurements.

Impedance spectroscopy



Electrochemical impedance spectroscopy has been applied in order to evaluate the electrical behaviour of our samples. From the Nyquist diagrams, an estimation of the ionic conductivity of about 10^{-8} S/cm can be made. This is still lower than 10^{-7} S/cm as for conventional Lithium phosphate films, but highly motivating for further studies.
The thickness of the films can be adapted for future microbattery applications, taking into account the gain in energy storage capacity due to the high aspect ration