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# Electrochemically induced breakdown of integrated microsupercapacitors based on LiPON

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Lithium Phosphorous Oxynitride (LiPON) solid electrolyte has gathered a lot of attention due to its favorable ionic conductivity ( $10^{-6} \text{ Scm}^{-1}$ ), good electronic insulation ( $10^{-14} \text{ Scm}^{-1}$ ) and electrochemical stability[1]. Solid state microsupercapacitors based on LiPON have been demonstrated to meet demanding performances required for novel on-chip technologies[2,3]. The electric double layer (EDL) formation at the electrode interface results in the high capacitance and energy density of these devices. The EDL and to an extent the bulk of the electrolyte layer will be affected by the electric potential/field present during the operation. In this work, the electrochemical breakdown of microsupercapacitors were studied under different bias conditions. The influence of device geometry and test conditions on failure of LiPON based devices will provide the scope for potential applications as well.

PVD depositions of thin LiPON films in MIM structure (20nm,50nm,100nm) were fabricated for the study with Pt bottom electrode and Ti/TiN top electrodes. The devices were electrically characterised by Impedance spectroscopy and subjected to a voltage sweep from 0 to  $\pm 19\text{V}$  at various scan rates. LiPON was found to undergo electrochemical degradation followed by electrical breakdown as previously reported elsewhere[1]. Increasing the scan rate and thickness of LiPON, increased the breakdown voltage of LiPON. The electrode material influenced the degradation and the interface was found to evolve with successive voltage levels. The interface was found to drive the degradation using equivalent circuit analysis of Impedance spectroscopy results. Charge densities extracted for breakdown indicate possible electronic conduction and Li depletion, which were further verified with physico-chemical characterisation. A model of capacitive and resistive elements will be discussed to capture the individual contributions for electrochemically driven failure and thereby identify the parameters to tune or delay such mechanisms.

This work identifies various factors which could modify electrochemical breakdown behaviour of LiPON. The modification of electrochemical breakdown voltage/strength and variation in charge density with scan rate has been newly identified. Further, resolving various contributions to different circuit elements will provide a way to understand and decorrelate their role in electrochemical breakdown.

References:

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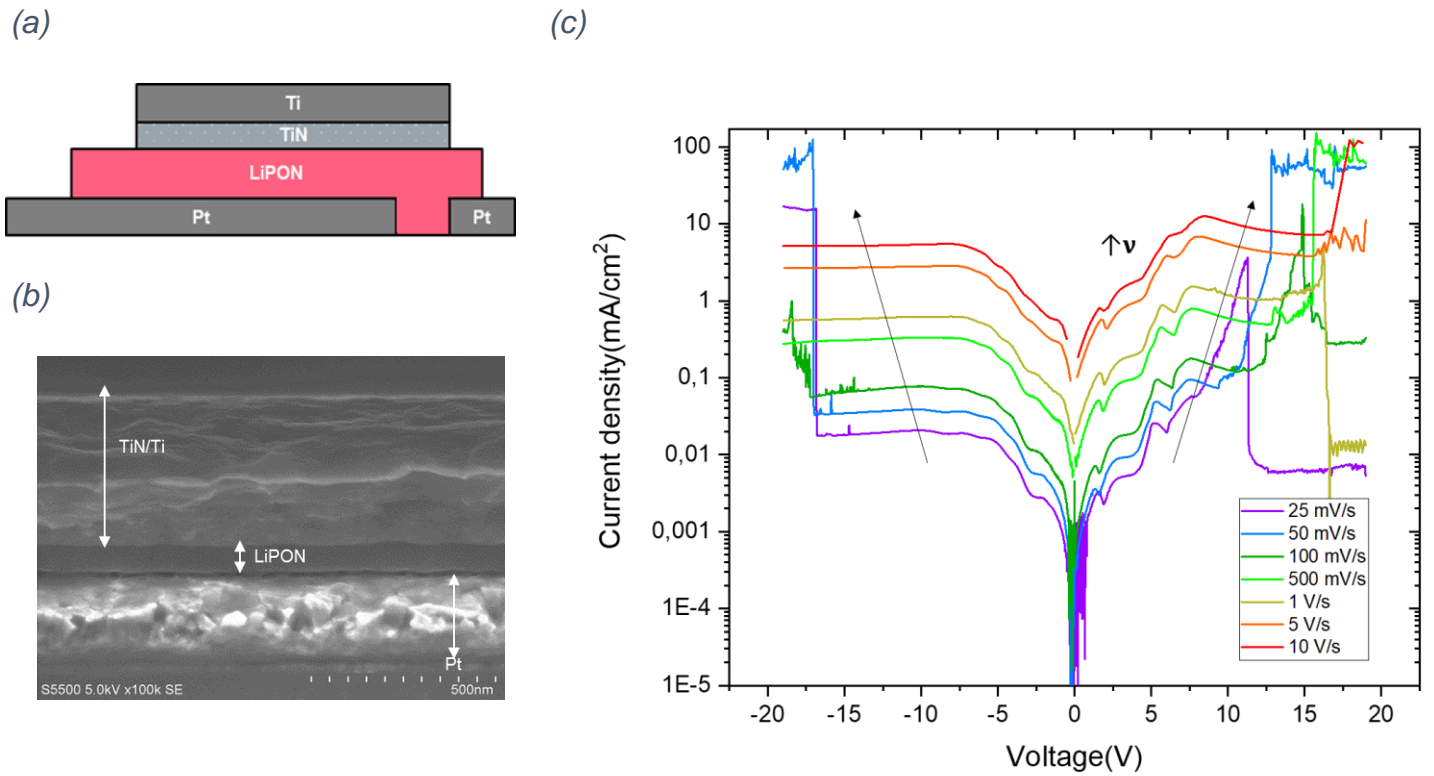


Figure 1 (a) Cross-sectional layout for Pt/LiPON/TiN/Ti microsupercapacitor used for the study, (b) SEM image of LiPON MIM structure, (c) Current density versus voltage for Pt/LiPON/TiN stack of 100nm thick LiPON for scan rates from 25mV/s to 10V/s taken at ambient temperature ; the arrows indicate the trend of increase in current density and breakdown voltage with scan rate