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Conformal deposition for 3D thin-film batteries

Philippe. M. Vereecken[1,2]

[1]Imec, Kapeldreef 75, 3001 Leuven, Belgium
[2]Centre for Surface chemistry and Catalysis, KU Leuven, Kasteelpark 23, 3001 Leuven
*Corresponding author: vereeck@imec.be

For the application of durable micro-storage for autonomous systems and implants, 3D thin-film batteries are leading candidates. Lithium ion batteries have the highest energy density of all known systems and are thus the best choice for these rechargeable micro-batteries. Since liquid electrolyte based batteries present safety issues and limitations in size and design, pure solid state devices are considered particularly for miniaturization. Planar thin-film lithium and lithium ion batteries are at present commercially available but have limited capacity (<1mAh/cm^2). The capacity can be increased by coating the thin-film stacks on micro-or nanostructured surfaces (3D thin-film batteries, see Figure below). The increase in surface area through 3D structuring also increases the maximum current and thus the battery power. The main challenges in the introduction of solid-state Li-ion batteries are low ionic conductance and limited cycle life time due to mechanical stress and shearing interfaces.

Managing ionic conductivity.
Solid materials with intrinsically high ion conductivity (~10^{-3} S.cm) do exist, but are not electrochemically stable. Vice versa, electronically insulating electrolytes with a large electrochemical window and good chemical stability to metallic Li are known, but typically have intrinsically low ionic conductivities (<10^{-6} S cm). By scaling down the electrolyte thickness, an overall acceptable ionic conductivity can be obtained even for material with poor ionic conductivity. The latter assumes conformal and pinhole-free coverage over large effective surface areas with large aspect ratio features. ALD is a surface sensitive technique that can provide superior conformal coatings of high-aspect ratio features, crevices and corners and is suitable for (but not limited to) ultra-thin films. In this paper, the requirements for functional and viable thin-film stacks will be discussed. The need for conformal deposition techniques such as ALD and MLD for electrode, electrolyte and buffer layers will be addressed.

Managing cycle life.
The mechanical integrity of the all-solid state stack in corners and confined spaces is a tangible issue. Considerable mechanical stress may build up during charge and discharge due to the rigid nature of the inorganic crystals and glasses that make up the battery stack. Furthermore, in-diffusion of at interfaces may consume part of the electrode which next to capacity and power loss can affect device reliability. In this paper, the importance of thin buffer layers will discoursed.