Self-assembled Vertically Aligned Nanocomposites for Solid-State Batteries

The need to use solid-state batteries arises from the safety problems and limitations of conventional batteries' liquid electrolytes. However, simply using solid-state electrolytes reduces the battery's specific power; that is how fast it can charge/discharge. This limitation can be overcome by employing tridimensional geometries. Daniel Monteiro Cunha (University of Twente) focused on using self-assembled methods, via Pulsed Laser Deposition (PLD), to create lithium-containing Vertically Aligned Nanocomposites (VAN) to form such 3D geometries for application in solid-state batteries.

Lithium-ion batteries are the primary power source for many applications - from portable electronics to electric vehicles, but none of the current devices can fully satisfy all the requirements for the projected energy storage needs. Standard rechargeable batteries are based on liquid electrolytes, which limit their design and safety. Therefore, the need for all-solid-state micro-batteries arises, showing enhanced safety, volumetric energy/power density and chemical stability. These micro-batteries, developed by thin-film architecture, enables the powering of micro-scale devices, such as stand-alone sensor systems for internet of things, implantable medical devices, labs-on-chip, and credit cards. However, commercial solid-state batteries are constructed as a planar stack (two-dimensional) of thin-film layers, which exhibit undesirable energy vs power balance. This drawback can be overcome by the application of 3D geometries, increasing the internal surface area. Vertically aligned nanocomposite (VAN) thin films show such tridimensional structures. They have been developed as a new materials' platform for creating self-assembled device architectures and multi functionalities. They show a wide range of attributes arising from the strong interplay among the materials' properties. Highly crystalline VANs are self-assembled through PLD without control of the deposition sequence, as is required for other thin-film fabrication methods. Although various VANs have been studied in the last decade, no lithium-based VANs have yet been explored for energy storage. Considering that self-assembled VANs are obtained through PLD, the study's main goal was to apply this principle for lithium-containing, non-toxic oxide materials and study its impact on the electrochemical behaviour for battery applications. Throughout the work, the possibility of obtaining such structures was demonstrated for various conditions. Its shape and distribution were

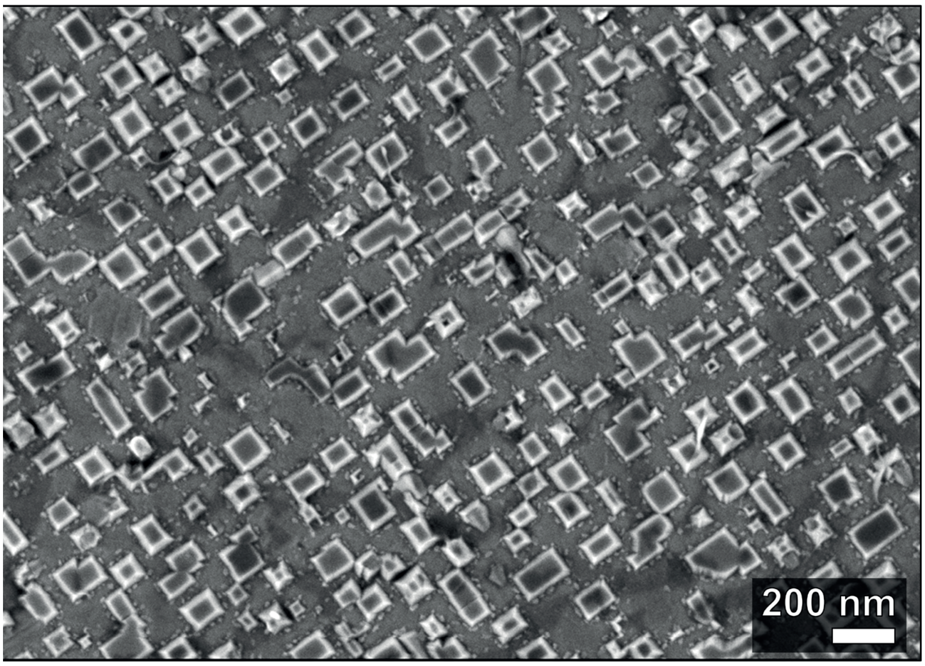

Figure 1: Top-view Scanning Electron Microscopy of a nanocomposite thin film composed of $LiMn_2O_4$ pillars embedded in an $LiLaTiO_3$ matrix, promising solid-state battery materials

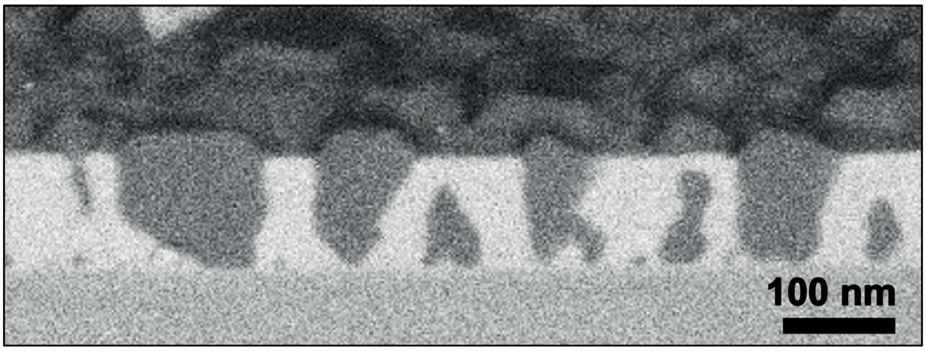

Figure 2: Cross-sectional energy selective backscattered scanning electron microscopy image showing the compositional contrast. This highlights the tridimensional geometry formation

tailored, and electrochemical analysis shows the first steps towards battery application.

If this can be realized, batteries with better performance and safety can power various devices.

The PhD research work of Daniel Monteiro Cunha was carried out in the Inorganic Materials Science Group. His supervisors were prof.dr.ir. Mark Huijben and prof.dr.ing. Guus Rijnders from the faculty Science and Technology at the University of Twente. He successfully defended his PhD thesis on the 10th of March 2021. The title of his dissertation is ‘Self-assembled Vertically Aligned Nanocomposites for Solid-State Batteries’.

The thesis can be found online>