Workshop »Coatings for Energy Technologies«

Vacuum Coating Technologies for Silicon-based Next Generation Anodes for Lithium-Ion Batteries

Dr. Stefan Saager, Ludwig Decker, Dr. Jens-Peter Heinß, Steffen Straach, Claus Luber, Dr. Bert Scheffel, Dr. Torsten Kopte, Dr. Nicolas Schiller

Fraunhofer FEP, Dresden

stefan.saager@fep.fraunhofer.de

The demand for high-energy-density lithium-ion batteries (LIBs) is increasing due to the growing need for portable electronic devices and electric vehicles. Silicon has been identified as a promising anode material due to its high theoretical capacity, but it suffers from significant volume changes during cycling, leading to rapid capacity fading and reduced cycle life. To address these issues, vacuum technology has been employed to improve the synthesis and performance of silicon anodes. In this presentation, we will present FEP's approaches in the development of high-energy-density LIBs using vacuum technology. According to the specific requirements for the anodes, the R&D basis already starts with an innovative approach for the current collector in terms of texture, surface structure and weight. This includes the preparation of a light-weight current collector by metallization of polymer films. For silicon anodes, various complementary innovative approaches based on vacuum technology are pursued. On the one hand, powder-based silicon anode material is functionalized by coating Si particle surface with carbon using a plasma enhanced chemical vapor deposition (PECVD) process. This process provides raw material for silicon-carbon composite anodes which can be processed via conventional slurry-based procedures. On the other hand, alternative approaches are based on the synthesis of structured silicon thin film anodes by physical vapor deposition (PVD). This can be realized by several strategies. One promising method consist of coating a current collector foil featured with a roughened layer of copper dendrites by PVD in a roll-to-roll process. The substrate surface topography causes the silicon to grow in columnar structures and thereby incorporating free spaces in the layer in order to compensate for the volume expansion. Another strategy is the synthesis of highly porous Si layer structures in a dealloying process. In this process, a multiphase layer consisting of silicon and zinc with separated grains is deposited in the first step. Afterwards, annealing in vacuum results in expelling of the Zn and the generation of vacancies at the locations of former zinc grains. Both strategies show promising electrochemical properties. A more sophisticated strategy represents the deposition of lithium-silicon compound layers to prepare a pre-lithiated Si anode. Due to lithium extraction while discharging, pores within the Si matrix will be generated and in return the initial state should be achieved after re-charging. Furthermore, by depositing pure lithium layers by PVD we found an opportunity to prepare porous lithium metal anodes, which represents a promising option of for perspective next generation LIBs and beyond. This presentation aims to demonstrate the potential of vacuum technology to overcome the challenges of integrating silicon anodes into next-generation LIBs.