

# Laser generated 3D microstructures in lithium manganese oxide cathodes

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## ABSTRACT

The development of future battery systems, e.g. for electric vehicles, is mainly focused on powerful rechargeable lithium-ion batteries (LIB). To satisfy this demand, current research studies are focused on cathodes based on nano-composite materials which lead to an increase in power density of the LIB primarily due to large electrochemically active surface areas. Electrode materials such as  $\text{LiMn}_2\text{O}_4$  are assumed to replace the commonly used cathode material  $\text{LiCoO}_2$  due to less toxicity, lower costs and improved safety properties. However, spinel  $\text{LiMn}_2\text{O}_4$  shows strong chemical degradation under operation with liquid electrolyte. For preventing the active material against liquid electrolyte, indium tin oxide (ITO) protection layers can improve cycling stability. In order to study the influence of the pure active material, thin films made of Li-Mn-O were investigated as model system. Direct excimer laser patterning was applied for increasing the active surface area of lithium manganese oxide thin films in the as-deposited state. Nevertheless, as-deposited Li-Mn-O films did not show preferred cubic spinel structure which is recommended for proper operation in an electrochemical cell. Therefore, a rapid laser annealing process was investigated for setting-up a cubic spinel-like phase. The effects of laser annealing on thin films were studied by using Raman spectroscopy, X-ray diffraction and scanning electron microscopy, respectively. Additionally, ITO passivation layers were sputtered on top of 3D microstructures for preventing the active material against the liquid electrolyte. The cycling behavior of unstructured and laser structured as well as passivated films was electrochemically analyzed by using the Swagelok<sup>®</sup> cell design with lithium metal as counter electrode and EC/DMC 1:1, 1M  $\text{LiPF}_6$  as electrolyte. Post-mortem studies were carried out by means of Time-of-flight secondary-ion mass spectrometry (ToF-SIMS) for analyzing the formation of solid electrolyte interphase (SEI). Focused Ion Beam (FIB) cuts revealed that ITO passivation layers remained stable upon cycling.

## Curriculum Vitae

Johannes Proell studied mechanical engineering at the Karlsruhe Institute of Technology (KIT). During his internship at ATL Lasertechnik GmbH he was involved in the development and construction of an excimer laser pre-ionization unit as well as in laser manufacturing and maintenance. During his work at Institute for Applied Materials (IAM-AWP) at KIT, he has been working on laser material processing and thin film modification. His Ph.D. thesis is about laser-assisted processing of thin and thick film electrodes on basis of lithium manganese oxides and their alloys. Since 2009, he has published up to 11 papers in ISI journals and peer-reviewed conference proceedings on the field of lithium-ion batteries. In 2011, he has submitted two patent applications about laser-assisted improvement of commercially available high power battery materials for stationary and portable electric devices.