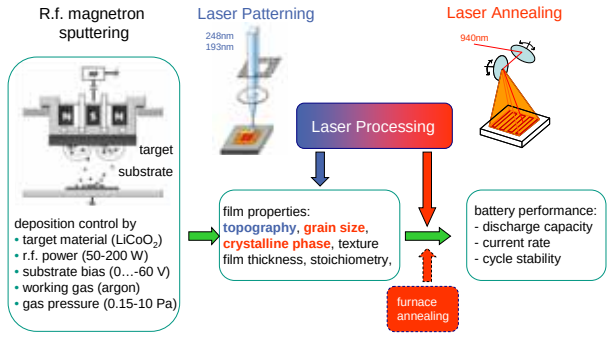
Influence of grain size and micro-structure on battery performance of thin film cathodes for lithium-ion batteries

Karlsruhe Institute of Technology

Institute for Materials Research I and III

R. Kohler, S. Ulrich, M. Bruns, W. Pfleging

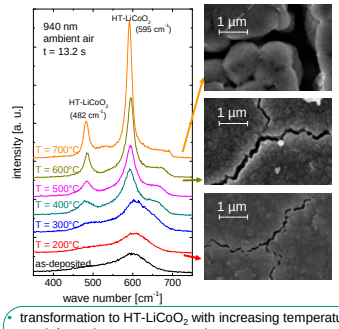
Introduction / Motivation



Motivation: Thin film electrodes are used to create high performance lithium ion batteries. Large surface area allows for high lithium diffusion and thereby high charging currents.
Objective: Defined adjustment of thin film properties
Approach: Combination of thin film deposition and selective laser processing

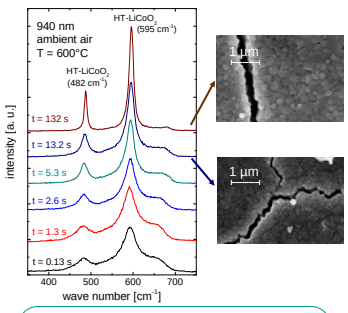
Laser annealing

Influence of annealing temperature (Raman)



- transformation to HT-$LiCoO_2$ with increasing temperature
- crack formation occurs even at low temperatures, though film adhesion persists
- the crystallite sizes range from
  10 - 20 nm (as-deposited film)
  about 100 nm (annealed at 600°C)
  >1 µm (increased grain growth at 700°C)

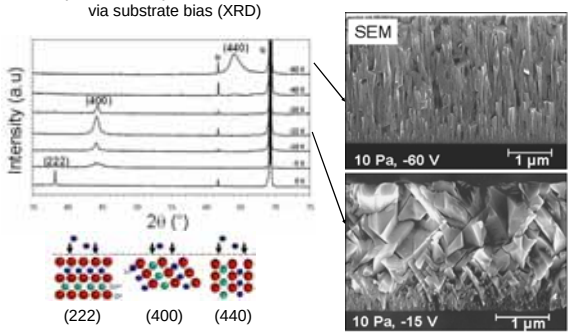
Influence of annealing time (Raman)



- transformation to HT-$LiCoO_2$ with increasing annealing time
- the crystallite sizes range from
  10 - 20 nm (as-deposited film)
  about 100 nm (annealed for 13.2 s)
  about 200 nm (annealed for 132 s)

Thin film deposition

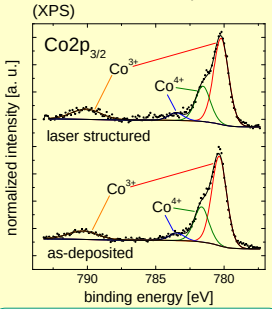
Adjustment of crystalline orientation via substrate bias (XRD)



The thin film deposition parameters have significant influence on film properties:
- stoichiometry can be influenced by working gas pressure (with 10 Pa nearly stoichiometric $LiCoO_2$ films are created)
- substrate bias can control the thin film density, morphology and the texture. The crystalline orientation of the thin films can be adjusted → optimization of electrochemical properties.

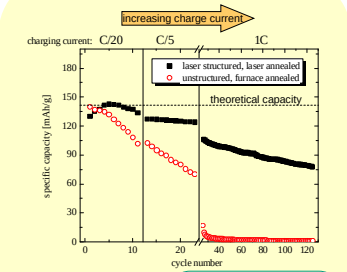
Analytics and battery cycling

Chemical surface composition (XPS)



- main peak from Co^{3+}, but Co^{4+} was also detected
- after laser structuring no significant surface changes were detectable

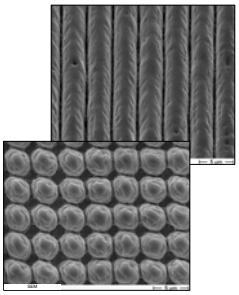
Battery cycling



- laser structuring leading to increased surface area and enhanced lithium diffusion
- improved battery performance especially at high charging currents

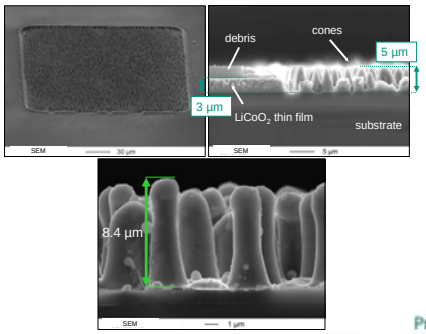
Laser patterning

Direct structuring via mask imaging



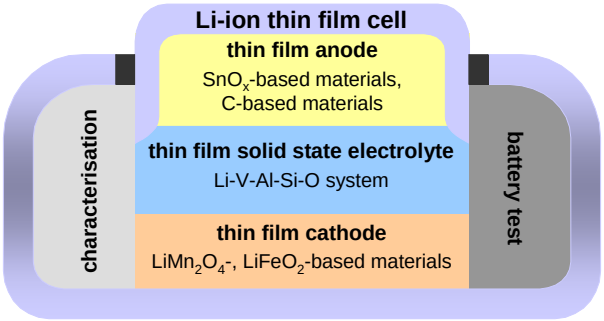
- grating and line patterns with minimum channel widths ~ 600 nm
- high laser fluences (>2 J/cm²) lead to smooth ablation

Large area structuring using re-deposition process creating conical surface structures



selective material ablation and re-deposition lead to growth of surface structures
- growth of cones (up to 8.4 µm)
- small material loss (0% - 20%)

Outlook



Projekthaus e-drive
DAIMLER
LIB 2015 (BMBF)
"LIB-NANO"
EVONIK
li-tec

Karlsruhe Institute of Technology (KIT)
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
Germany

corresponding author:
robert.kohler@kit.edu