LiCoMnO$_4$ as cathode material for 5 V solid state thin film Li batteries prepared by magnetron sputtering

Christian Dellen$^{a,b}$, Anna Windmüller$^{a,b}$, Sören Möller$^{a,b}$, Sandra Lobe$^{a,b}$, Chih-Long Tsai$^{a,b}$, Uwe Breuer$^c$, Sven Uhlenbruck$^{a,b}$, Dina Fattakhova-Rohlfing$^{a,b}$, Olivier Guillon$^{a,b}$

$^a$Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, Materials Synthesis and Processing (IEK-1), 52425 Jülich, Germany
$^b$Jülich Aachen Research Alliance: JARA Energy, Germany
$^c$Forschungszentrum Jülich GmbH, Central Institute for Engineering, Electronics and Analytics (ZEA-3), 52425 Jülich, Germany

E-mail: c.dellen@fz-juelich.de

The spinel structured LiCoMnO$_4$ is a promising cathode material for future high energy density solid state batteries. By using LiCoMnO$_4$ as cathode material a cell voltage above 5 V vs. Li/Li$^+$ can be reached and in comparison to nowadays typically used LiCoO$_2$ cathodes the energy density can be increased by 25% [1]. Whereas the high operating voltage is essential with respect to energy density, it is also a criterion for exclusion when it comes to the selection of a suitable electrolyte. While conventional liquid electrolytes suffer from decomposition reactions at the high operational voltage above 5 V vs. Li/Li$^+$ [2], solid state electrolytes with their wide electrochemical stability window are more suitable for the realization of high voltage batteries. Solid electrolytes also offer additional benefits like for example the utilization of lithium metal as anode material and an inherent safety due to the lack of combustible electrolyte solvents.

In this presentation the preparation of LiCoMnO$_4$ thin film cathodes by radio frequency magnetron sputtering and the incorporation of the cathode material in solid state thin film batteries are addressed.

Firstly, the general parameters for the LiCoMnO$_4$ thin film deposition process were studied. The as-deposited amorphous thin films were prepared using a LiCoMnO$_4$ powder sputter target and different substrate materials. The following analysis of the thin films after heat treatment in ambient atmosphere by Raman spectroscopy and X-ray diffraction revealed, that a temperature of 550°C is sufficient to crystallize the material in the desired spinel structure. Additionally, measurements by nuclear reaction analysis and secondary ion mass spectrometry were carried out to analyze the elemental distribution within the LiCoMnO$_4$ thin films.

In a successive reactive magnetron sputtering process a LiPON thin film electrolyte was applied by using a Li$_3$PO$_4$ sputter target and nitrogen plasma. Afterwards, solid state thin film batteries were set up by using lithium metal as anode material. The concluding electrochemical testing by cyclic voltammetry and charge/discharge measurements showed a clear electrochemical activity of the LiCoMnO$_4$ thin film cathodes above 5 V vs. Li/Li$^+$. 

References: