Safer Sodium Battery: Thermal and electrochemical studies of Na-ion based cells

POLiS Post Lithium Storage Cluster of Excellence

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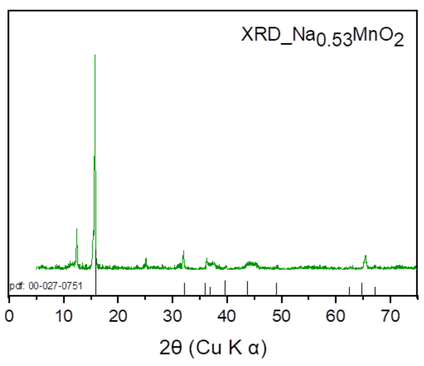
Motivation:

- The abundantly available precursors, the environmental friendliness and the inherent safety are always a driver for new energy storage applications.
- Much interest in Na-ion batteries is generated, because of the lower material cost compared to Li-ion batteries.

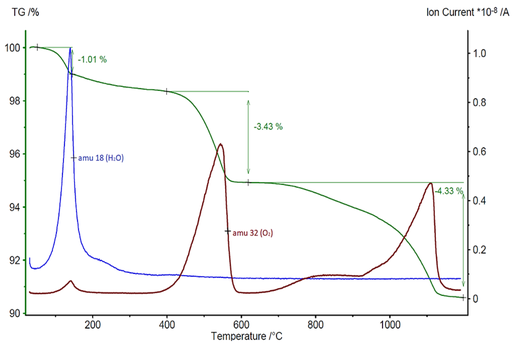
Objectives:

- Thermal characterization of selected material (specific heat, thermal diffusivity, thermal stability and thermal conductivity)
- Understanding of the electrochemical characteristics of P2-layered structural $Na_{0.53}MnO_2$ Cathode
- Na coin cell safety analysis; Heat generation during charge and discharge

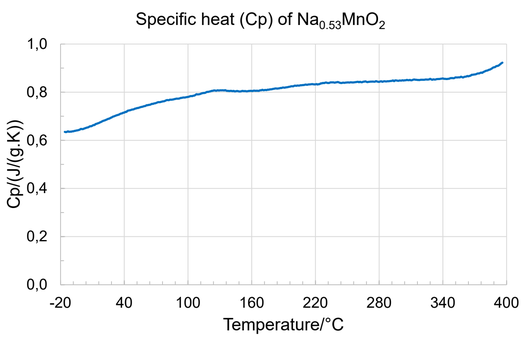
Thermophysical Characteristics:

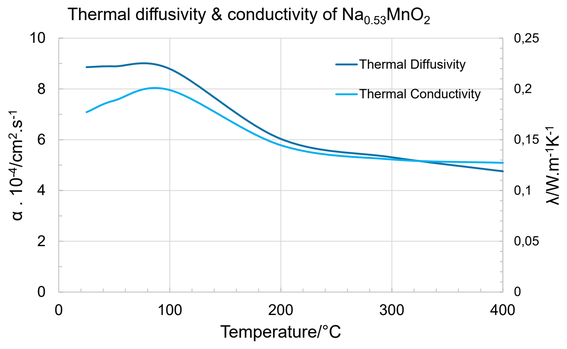


- XRD analysis shows some impurities peaks and crystal structure was compared with P2-layer sodium manganese oxide Powder diffraction file(pdf).



- TGA-MS shows different mass loss peaks with increasing temperature. These mass losses were identified with respect to the evolved species. The first mass loss represents the presence of water/moisture in the powder material and a sharp H_2O peak was observed at 100 °C. The second mass loss at an onset temperature of 400°C shows the thermal decomposition of the compound evolving O_2 , followed by further evolving of O_2 at high temperature. This means that manganese oxide decomposes into Mn_2O_3 and Mn_3O_4 species as reported in literature [1].

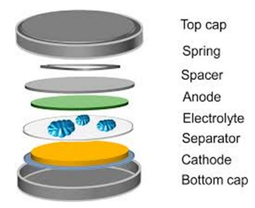




- As we have observed that the cathode material starts to decompose at 400 °C therefore, specific heat C_p and thermal diffusivity were measured up to 400 °C. The thermal conductivity was calculated from material density, C_p, and thermal diffusivity.
- Thermal diffusivity decreases significantly from 100°C to 200 °C and then remains almost constant. The same trends was found in the thermal conductivity as depicted above.

Coin cell CR-2032 Assembly:

Cathode	Anode
90wt% $Na_{0.53}MnO_2$	Pure Na Metal
5 wt% PVDF	Electrolyte: 1M NaClO4
5 wt% Carbon Black	[EC:DMC:EMC (vol, 1:1:1) 2% FEC]
Active mass: 5.2 mg/cm²	Separator GFA (Whatman)



The electrochemical performance of coin cell was thoroughly studied in various tests before executing the heat generation test.

Heat Generation Test:

Tian-Calvet MS80 Test Run Profile:

Charge parameter

Constant Current, Constant Voltage (CCCV) Profile at 25°C,

CV-Step at 4.0 V (I < C/20 or t > 30min)

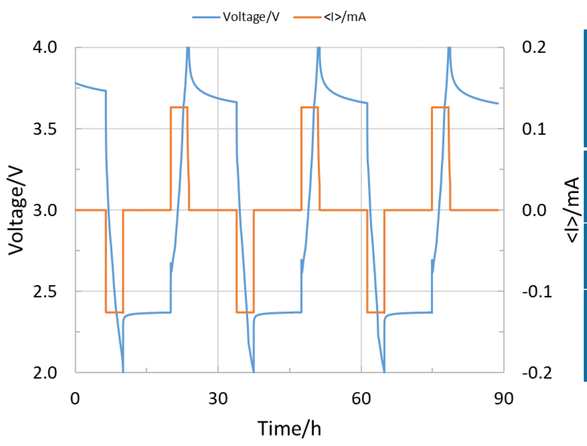
V_{max} = 4.0

Discharge parameter

Constant Current (CC) Profile at 25°C

V_{min} = 2.0

Tian-Calvet MS80 calorimeter (vessel Ø: 32 mm)



Voltage and Current profile (0.5C) of heat generation test.

Current flow 1 C = 0.63 mA	Capacity mAh.g^{-1}	Heat determined via MS80 calorimeter (J/g)	
		Charge	Discharge
0.2 C	60	64	96
0.5 C	32	64.6	90.5

Heat Generation in $Na_{0.53}MnO_2$ half-cell during charge and discharge cycles with different C-rates

Conclusions:

Initial thermophysical properties of $Na_{0.53}MnO_2$ cathode material for Na-based coin cells were measured and electrochemical performances have been investigated. Such data are highly relevant and important for thermal simulation studies of thermal management and thermal runaway in all type of batteries. The heat generation during charging and discharging of Na half-cell was measured by Tian-Calvet MS80 calorimeter.

Reference:

[1]. K. Terayama and M. Ikeda, Study on Thermal Decomposition of MnO_2 and Mn_2O_3 by Thermal Analysis, Trans. Of Japan Inst. Of Metals, Vol. 24 (11), (1983), pp 754-758.

Outlook:

In addition, a safety-relevant analysis of these coin cells will be carried out by means of Accelerating Rate Calorimetry (ARC). The evolved gas analysis during thermal runaway is planned too in order to design safer Post Lithium batteries.

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