batteries

Supplementary Information

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Laser diffraction analysis

The laser diffraction analysis was done with a laser diffraction analyzer of the type LS 13320 of the company Beckmann Coulter.

Table S1 Characteristic particle size distribution values

Sample	d_{10} (µm)	d_{50} (µm)	d_{90} (µm)
Mn_2O_3, original	3.98	8.51	16.4
Mn_2O_3, ball milled	1.38	3.21	5.79

Energy-dispersive X-ray spectroscopy

By Energy-dispersive X-ray spectroscopy (EDX) three different points in a SEM image were analyzed (s. Figure S1) in order to find out if the bigger particles in the electrode are manganese sesquioxide particles. In the EDX diagram it can be seen that point 1 and point 2 are manganese sesquioxide particles (manganese (Mn) and oxide (O)) whereas point 3 is carbon black (carbon (C)) (s. Figure S2).

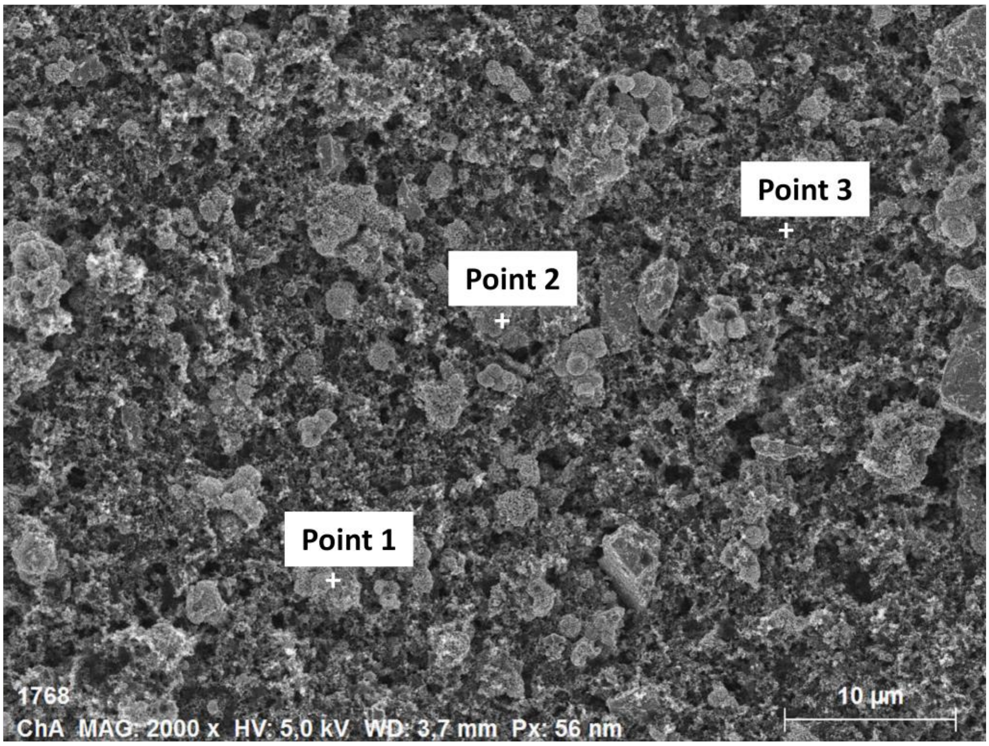

Figure S1 Points in the SEM image of the cathode which were analyzed by Energy-dispersive X-ray spectroscopy

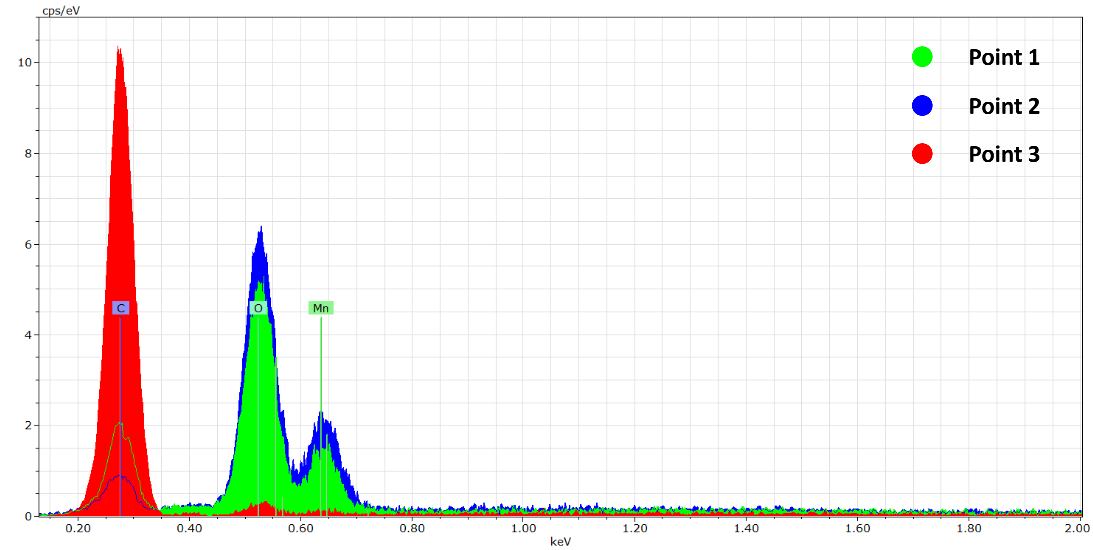

Figure S2 Energy-dispersive X-ray spectroscopy analysis

Equivalent Circuit Modelling

Values of every component in the equivalent circuit modelling. The data was fitted by simplex algorithm using the EC –Lab software of BioLogic Science Instruments.

Table S2. Values of every electric component of the equivalent circuit modelling

Battery Cell with big particles in the cathode (original)				
Component	Cycle 1	Cycle 31	Cycle 97	Unit
R_e	3.00	3.00	3.50	Ohm
CPE_1	2.00×10^{-5}	2.00×10^{-5}	2.00×10^{-5}	F
R_{ct1}	1.03	1.03	1.03	Ohm
CPE_2	0.61×10^{-3}	0.48×10^{-3}	0.72×10^{-3}	F
R_{ct2}	32.17	16.44	8.55	Ohm
s4 (Warburg coefficient)	8.69	5.81	3.56	$Ohm \bullet s^{-1/2}$

Battery Cell with small particles in the cathode (ball milled)				
Component	Cycle 1	Cycle 31	Cycle 97	Unit
R_e	0.62	0.60	0.53	Ohm
CPE_1	1.47×10^{-5}	1.47×10^{-5}	1.47×10^{-5}	F
R_{ct1}	1.96	1.96	1.96	Ohm
CPE_2	0.13×10^{-3}	2.14×10^{-5}	0.17×10^{-3}	F
R_{ct2}	16.52	59.91	83.5	Ohm
s4 (Warburg coefficient)	4.46	10.70	16.19	$Ohm \bullet s^{-1/2}$

Cell voltage curves of the cells with original an ball milled active material of the first cycle at a current density of 100 mA g^{-1}

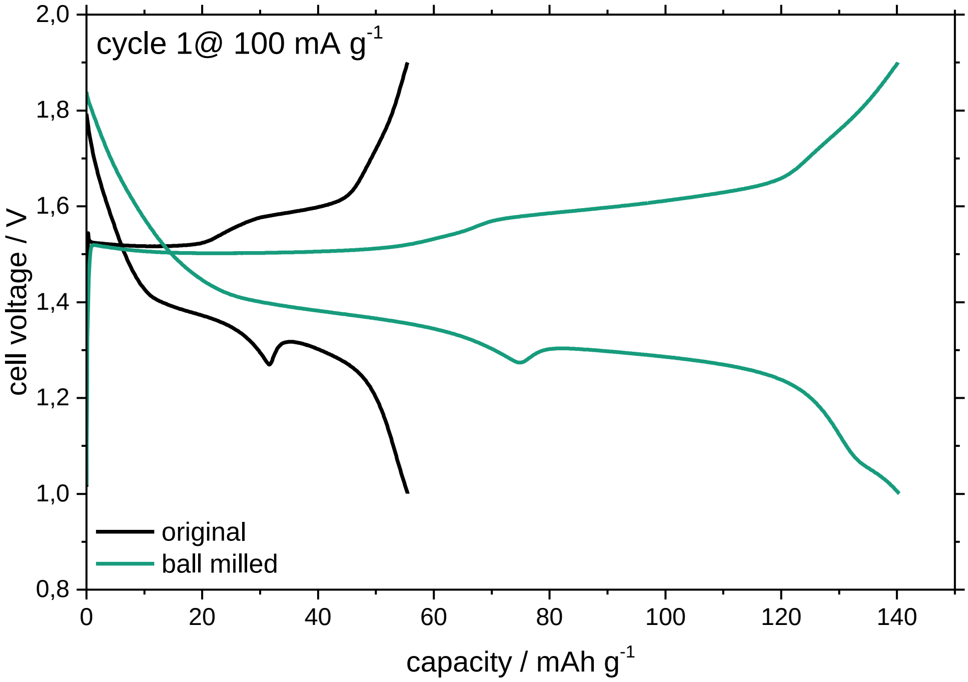

Figure S3 Cell voltage curves showing the first cycle with an applied current density of 100 mA g^{-1} of the cell with original (black line) and ball milled active material (green line). Two voltage plateaus each are visible in charge and discharge step (the voltage plateaus of the discharge steps are divided by a significant voltage drop), which can be dedicated to phase transformations effects.

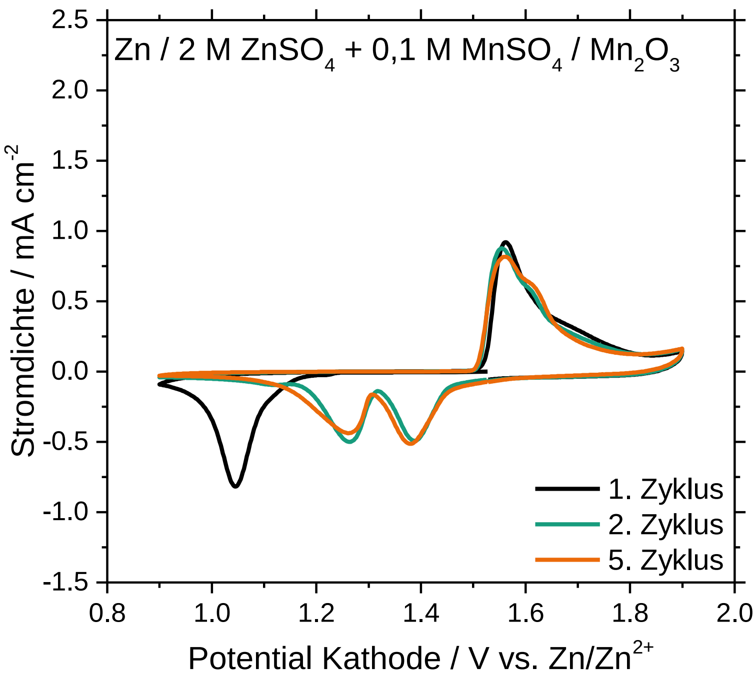

Figure S4 CV measurements (potential sweep rate 0.1 mV s^{-1}) of a battery with ball milled active material. The first cycle shows a sharp single reduction peak at 1.05 V and a broader oxidation peak at 1,56 V. The following cycles show two reduction (1,38 V and 1,26 V) an two oxidation peaks (1,56 V and 1,62 V) each. The broad, single oxidation peak of the first cycle seems to divide into two peaks, with one of the peaks getting formed out of the shoulder of the broad peak.