# Linking Material and Electrode Properties to the Cell Performance of Commercially Available Sodium-Ion Cells

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Abstract: As the first commercial sodium-ion-batteries (SIBs) are available for purchase, it is possible to investigate material composition. Gaining an insight into the material composition of these SIBs is of interest not only for the classification of possible safety risks and hazards, but also in regard to recycling. Herein we report the preliminary investigations of the chemical and structural composition of first commercial SIB-cells.[1,2] Two different SIB-cell types were compared in terms of electrode size, thickness, loading etc. Furthermore, the composition of the active materials and electrolyte was investigated and compared. Finally, the gained results were linked to the different data sheet performance of the two cell types.

## Disassembly of Sodium-Ion Battery Cells

## Cell Type A 18650

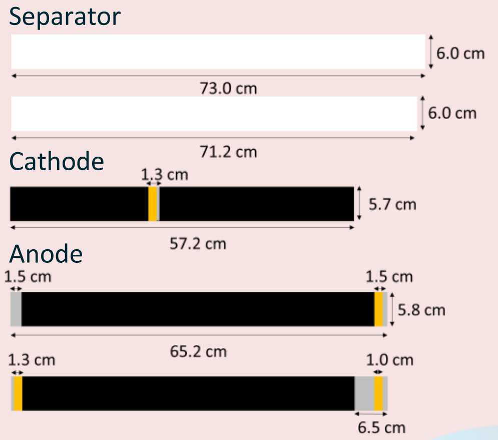
### Data Sheet Specifications

| | |
|---|---|
| Nominal Capacity | 1500 mAh |
| Nominal Voltage | 3.10 V |
| Max. charging rate | 1.0 C |
| Max. discharge rate | 3.0 C |

### Electrode Characteristics

| | |
|---|---|
| Anode Area | 686 cm² |
| Cathode Area | 637 cm² |
| Anode Thickness | 105 µm |
| **Cathode Thickness** | **65 µm** |
| Anode Loading | 10.8 mg/cm² |
| **Cathode Loading** | **18.8 mg/cm²** |
| Tot. Anode Capacity[1] | 2422 mAh |
| Tot. Cathode Capacity[2] | 1525 mAh |

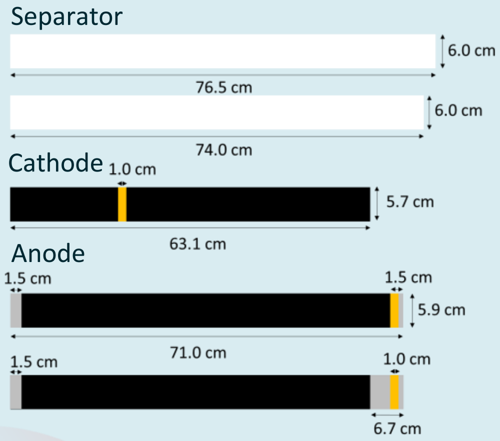
### Electrode Size




- Calculated total capacity in good agreement with specifications from supplier
- Relatively high **n/p ratio of 1.59**

## Cell Type B 18650

### Electrode Size




- Electrode thickness of both cells differ only slightly
- Electrode areas of cell B is larger than of cell A
- **n/p ratio of 1.56**

### Data Sheet Specifications

| | |
|---|---|
| Nominal Capacity | 1300 mAh |
| Nominal Voltage | 3.05 V |
| Max. charging rate | 1.0 C |
| Max. discharge rate | 6.0 C |

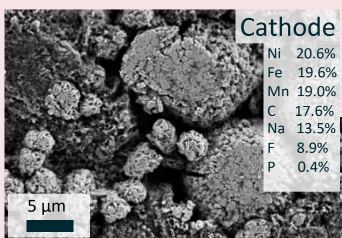
### Electrode Characteristics

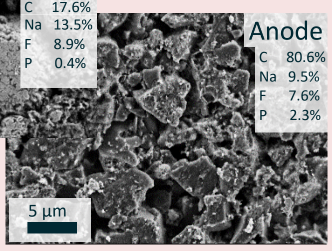
| | |
|---|---|
| Anode Area | 772 cm² |
| Cathode Area | 708 cm² |
| Anode Thickness | 103 µm |
| **Cathode Thickness** | **69 µm** |
| Anode Loading | 10.4 mg/cm² |
| **Cathode Loading** | **15.8 mg/cm²** |
| Tot. Anode Capacity[1] | 2205 mAh |
| Tot. Cathode Capacity[2] | 1418 mAh |

## Material Characterisation (Cell Type A)

**S**canning **E**lectron **M**icroscopy (SEM)

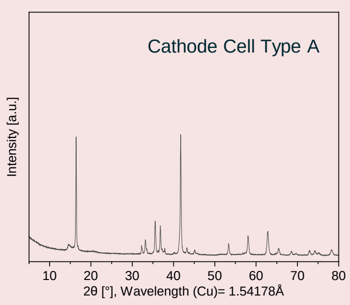
**E**lectron **D**ispersive **X**-ray spectroscopy (EDX)



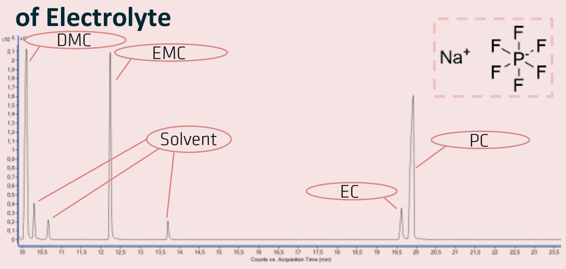




- EDX reveals **cathode as NFM**

**P**owder **X**-**r**ay **D**iffraction (PXRD)




**GC-MS & L**iquid **C**hromatorgaphy **LC-MS** Analysis of Electrolyte

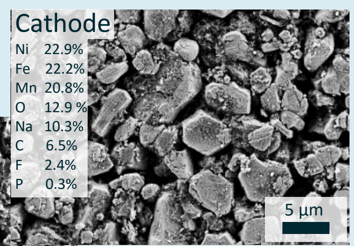


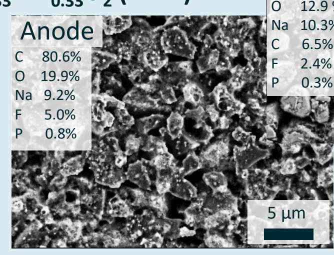

- Electrolyte of cell A:
  - Dimethyl Carbonate (DMC)
  - Ethylmethyl Carbonate (EMC)
  - Propylene Carbonate (PC)
  - Ethylene Carbonate (EC)

## Material Characterisation (Cell Type B)

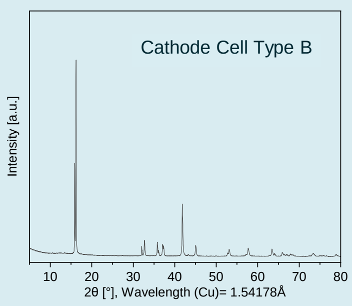
- **Cathode** materials of cell A and B show **different morphologies**
- EDX reveals for **cathode** **$NaNi_{0.33}Fe_{0.33}Mn_{0.33}O_2$ (NFM)**

SEM/EDX

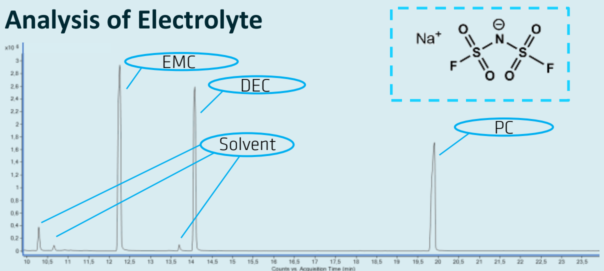



PXRD




**G**as-**C**hromatography/**M**ass **S**pectrometry **GC-MS** Analysis of Electrolyte




- Electrolyte of cell B:
  - Ethylmethyl Carbonate (EMC)
  - Diethyl Carbonate (DEC)
  - Propylene Carbonate (PC)

Conclusion: For the positive active material the same chemical composition was found ($NaNi_{0.33}Fe_{0.33}Mn_{0.33}O_2$) for both SIB cell types, but the particles exhibit different morphologies. The negative active materials show a very similar morphology. According to the specification sheet, cell B has double the maximum discharge rate of cell A. This is probably connected to a lower density of the positive layer as the negative layer has roughly the same density in both cells. Moreover, the composition of the electrolyte could also explain the higher maximum discharge rate in cell B.

[1] based on a theoretical capacity of 300 mAh $g^{-1}$ of the negative electrode and only considering the area facing the cathode
[2] based on a theoretical capacity of 127 mAh $g^{-1}$ of the positive electrode

L. Sander, R. Leonhardt, J. Scholl, J. Krug von Nidda and T.-P. Fellinger, Sodium-Ion Battery Reserach at BAM (II): Linking Material and Electrode Properties to the Performance of Commercially Available Sodium-Ion Cells, **2025**, in preparation.

**References:**
[1] K. Bischof, V. Marangon, M. Kasper, A. A. Regalado, M. Wohlfahrt-Mehrens, M. Hölzle, D. Bresser, T. Waldmann, *J. Power Sources Adv.* **2024**, *27*, 100148.
[2] V. Marangon, K. Bischof, A. A. Regalado, M. Keppeler, M. Pogosova, M. Wan, J. Choi, S. Fleischmann, T. Diemant, M. Wohlfahrt-Mehrens, M. Hölzle, T. Waldmann, D. Bresser, *J. Power Sources* **2025**, *634*, 236496.

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