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## Study of limiting factors of power performance within Li-ion batteries

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# Study of Limiting Factors of Power Performance within Li-ion Batteries

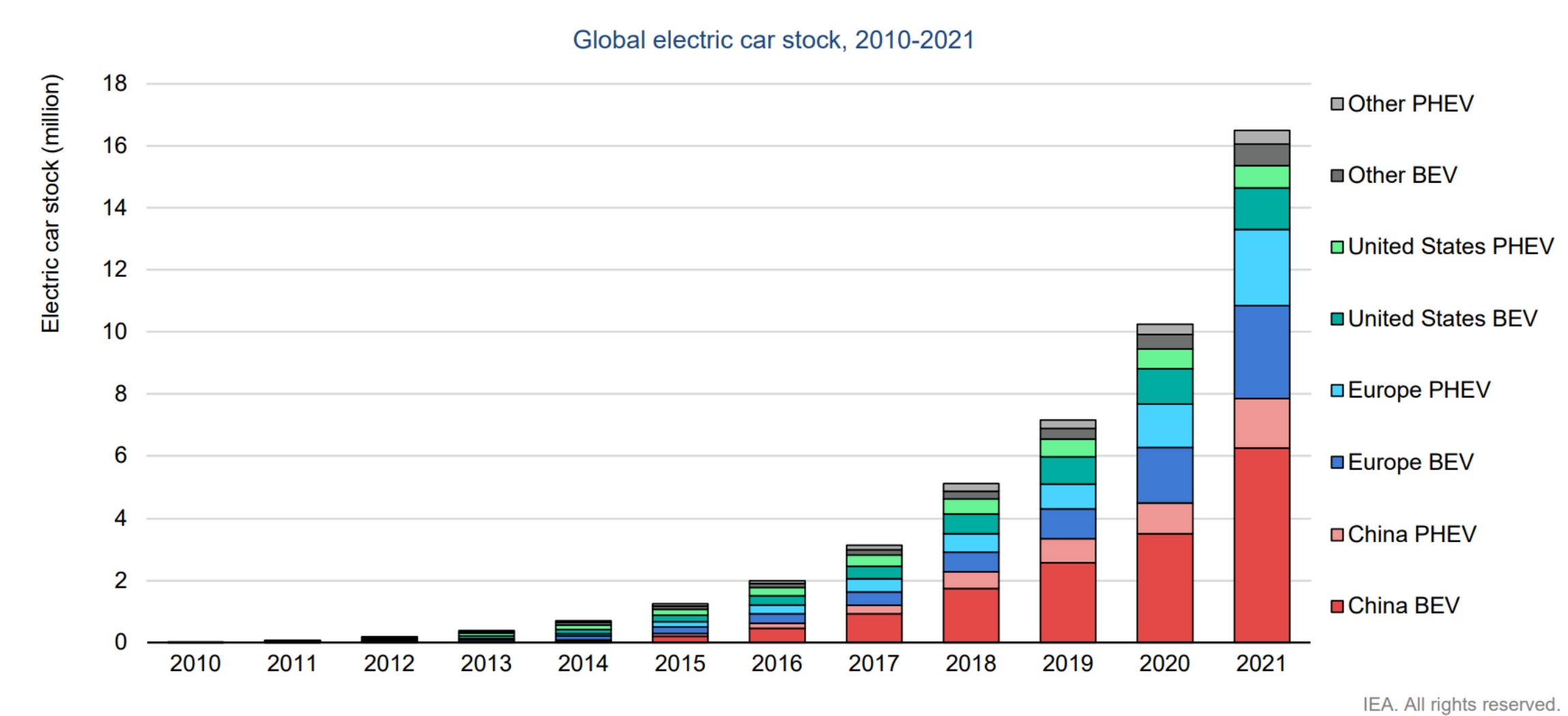
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## Context & Objectives

To meet the ever-growing requirements of the transport sector, improvement of current Li-ion systems is needed in terms of energy density, safety, cycle life, and costs. Among the different strategies to increase battery autonomy, one focuses on electrode loading to increase the ratio of active materials to inactive components. However, by doing so, the output power density becomes strongly limited by the charge transport within the composite electrodes. (1)(2)

- Objectives**
- Study of battery power performance with respect to **electrode design (loading, porosity...)** as well as **temperature and ageing**
  - Determination of the **limiting current density ( $J_{lim}$ )** and **effective limiting process** of power using an electrochemical approach
  - Optimization of the battery design to **maximize the energy/power**

## Experimental

### Positive electrode formulation

Active Materials (AM) : LFP & NMC-811

Electrode	Composition	Loading (mg.cm <sup>-2</sup> )	Theoretical Capacity (mAh.cm <sup>-2</sup> )	Porosity (%)	Temperature (°C)
LFP / C65 / PVDF	80 / 10 / 10	2 - 17	0.4 - 2.7	50 - 23	5°C - 40°C
	85 / 7.5 / 7.5				
NMC / C65 / PVDF	90 / 5 / 5	2 - 17	0.5 - 3.4	50 - 20	5°C - 40°C
	90 / 5 / 5				

### Cell Assembly

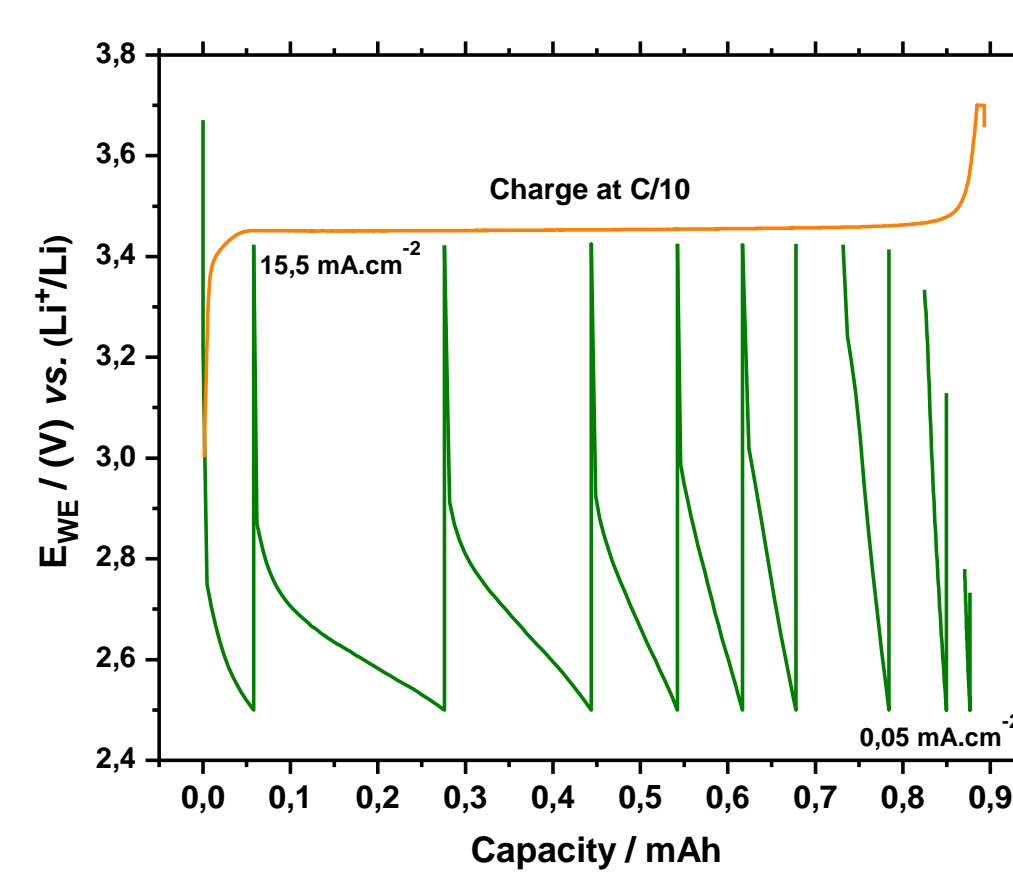
Coin cell CR2032

Electrode // LP30 // Li

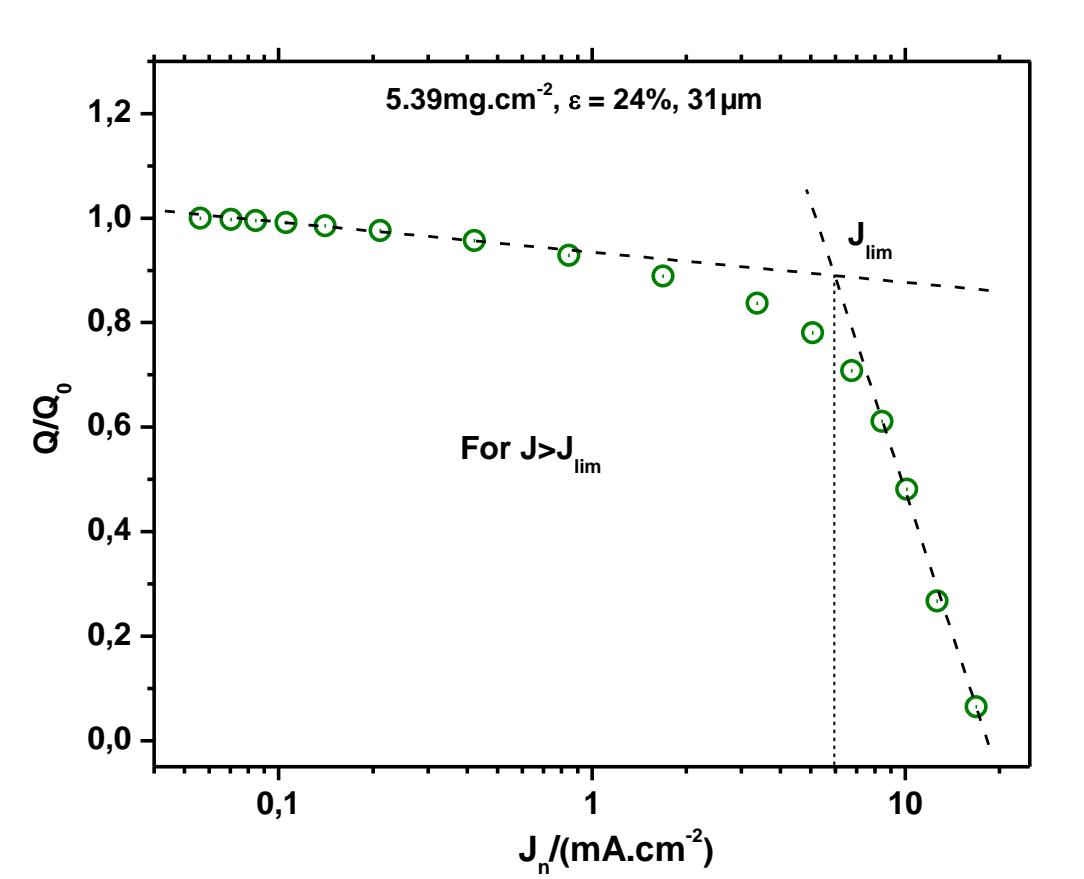


## Methodology

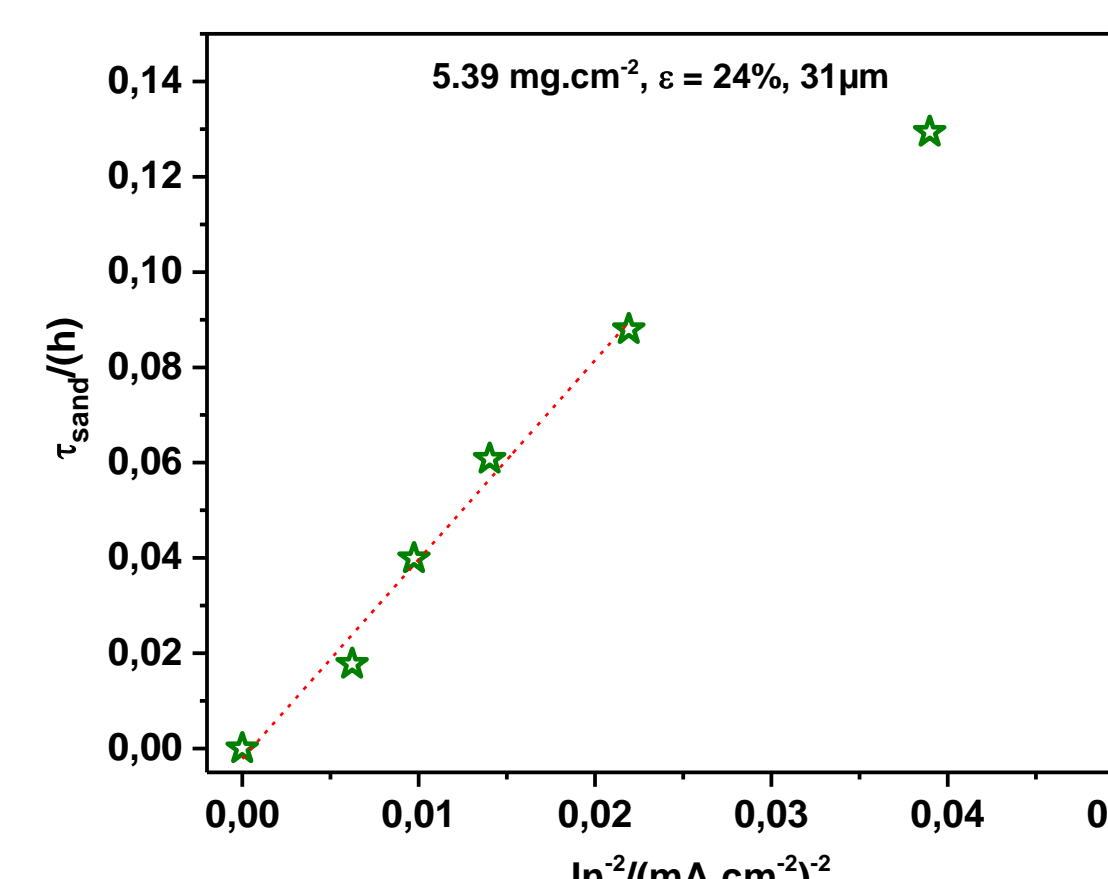
### Cycling protocol (3)(4)



### Power performance



### Sand Plot



Graphical determination of  $J_{lim}$

Sand Equation (4)(5)

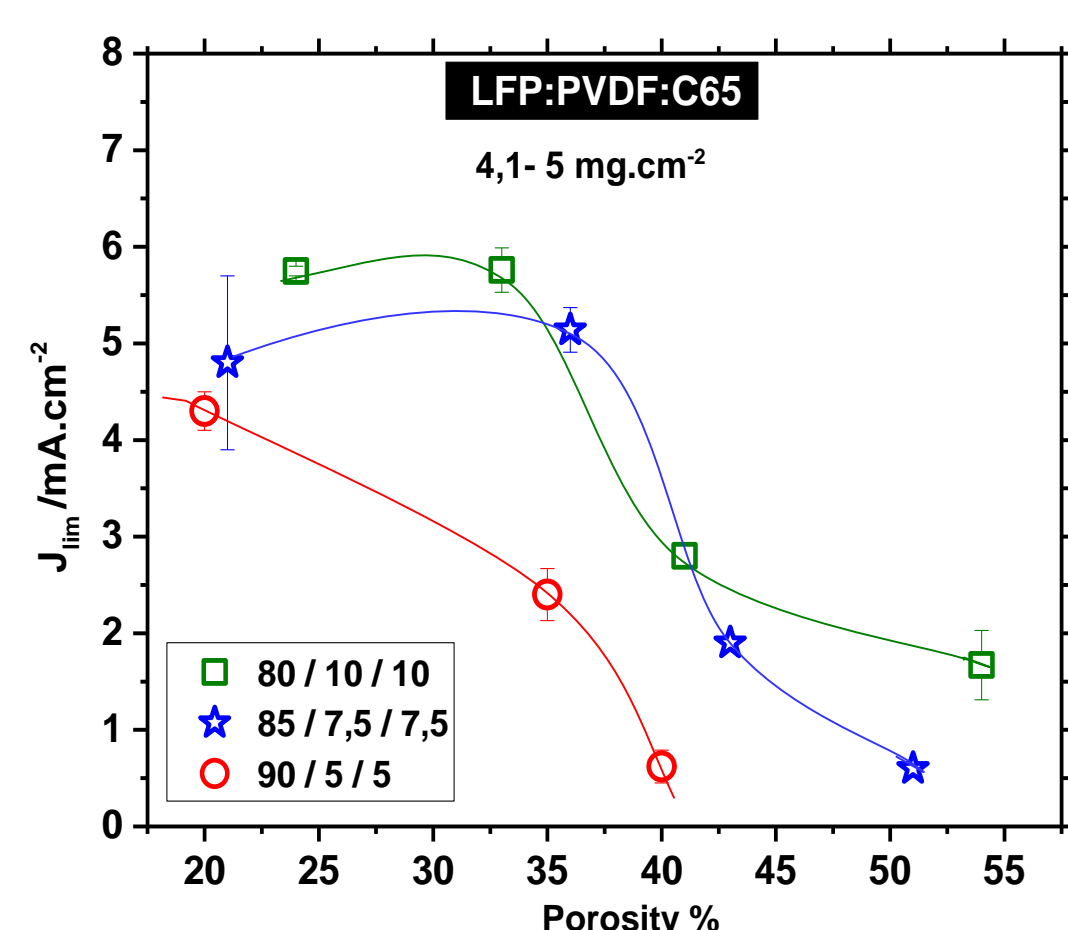
$$t_{sand} = \pi \cdot D_{eff} \left( \frac{n \cdot S \cdot F \cdot C_{max}}{2 \cdot J} \right)^2$$

Quick access to the effective diffusion coefficient

- Time-saving methodology
- One charge, followed by successive discharges at ever-decreasing C-rates

## LFP based electrode

### 1) Porosity effect on $J_{lim}$

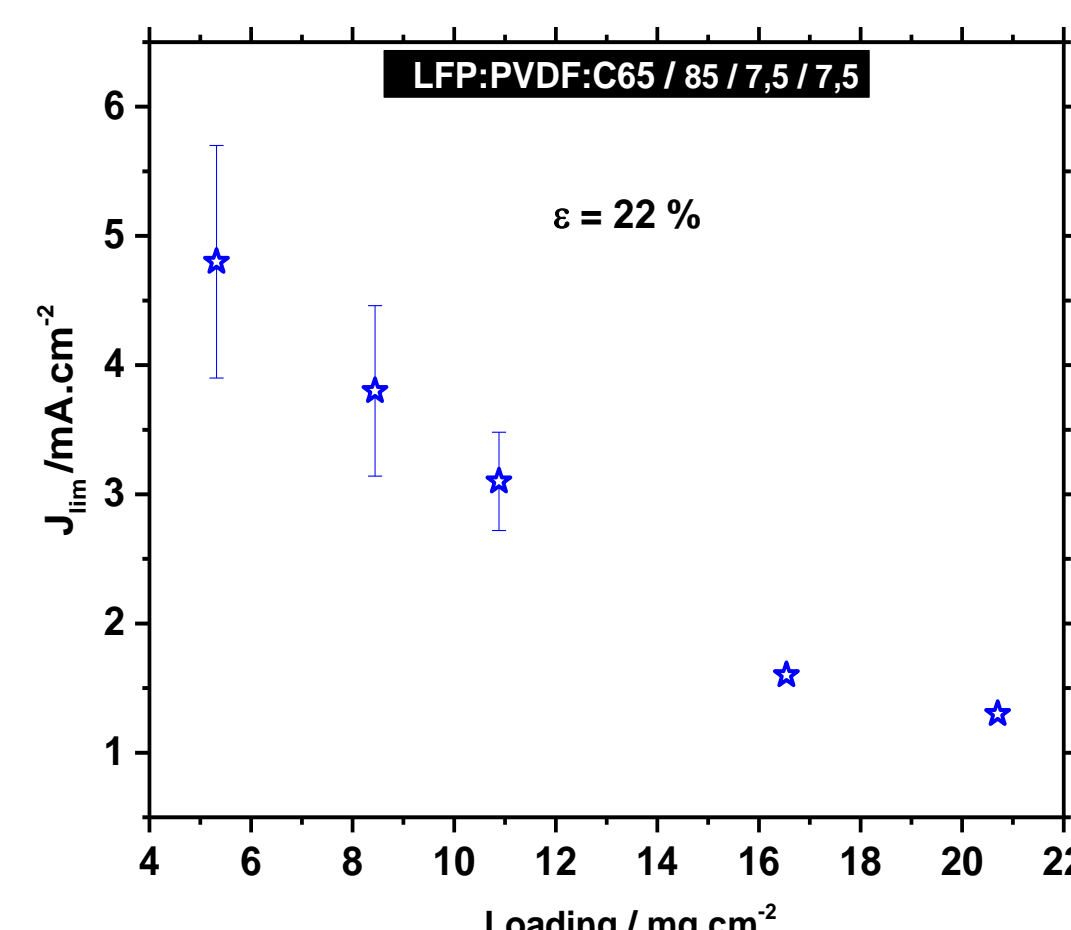


- Lower porosity results in higher  $J_{lim}$ , and higher operating C-rates.
- Carbon content has a non-neglecting effect on  $J_{lim}$
- Calendering enhances contact particle-particle and particle-current collector

→ For non-calendered electrode, **electronic percolation** would be the limiting factor

Porosity (%)	50	24
$J_{lim}$ (mA.cm <sup>-2</sup> ) (80/10/10)	1.6	5.7
$J_{lim}$ (mA.cm <sup>-2</sup> ) (90/5/5)	0.5	4.3

### 2) Loading effect

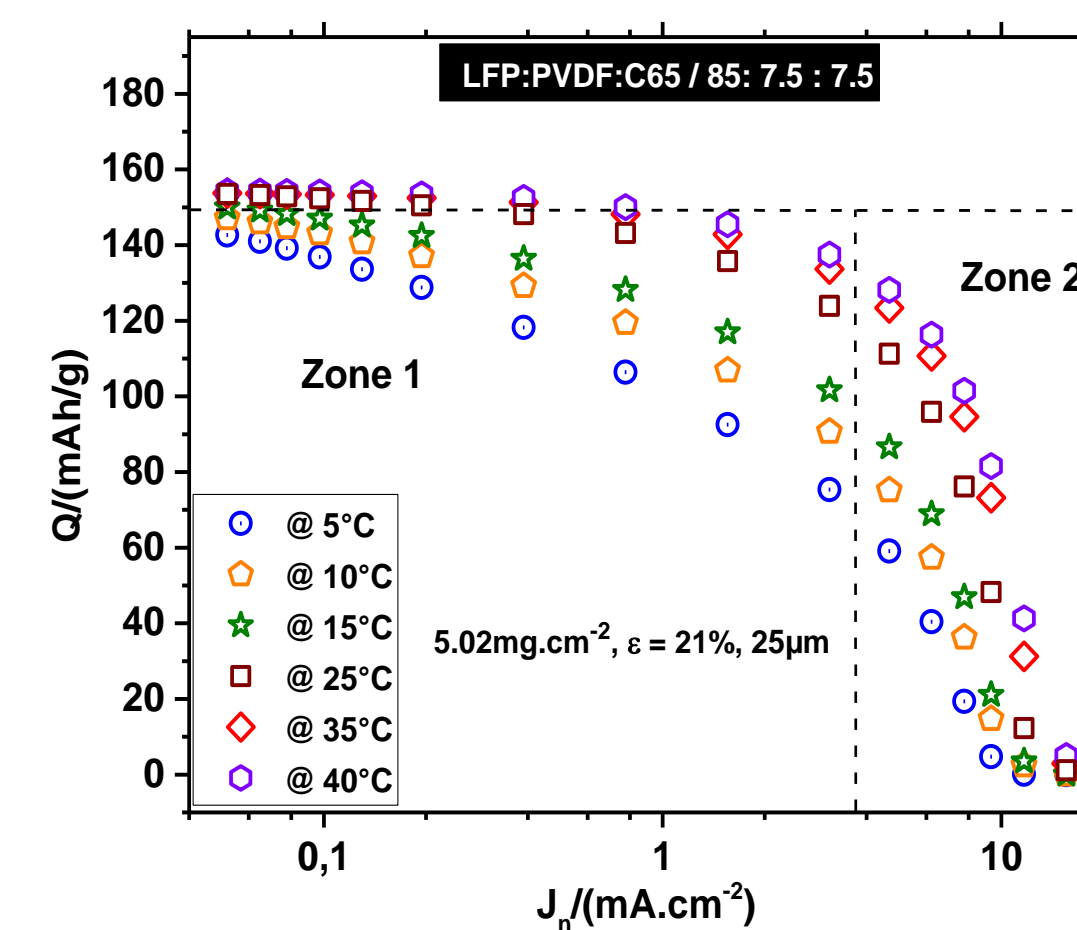


- Thicker is the electrode; lower is  $J_{lim}$

→ At high loading, the major limiting process is probably the diffusion within the electrode porosity

Loading (mg.cm <sup>-2</sup> )	5.3	19
$J_{lim}$ (mA.cm <sup>-2</sup> )	4.8	1.8
$D_{eff}$ AM limitation (cm <sup>2</sup> .s <sup>-1</sup> )	$1.7 \cdot 10^{-14}$	$2.5 \cdot 10^{-15}$
$D_{eff}$ electrolyte limitation (cm <sup>2</sup> .s <sup>-1</sup> )	$5.2 \cdot 10^{-7}$	$1.1 \cdot 10^{-6}$

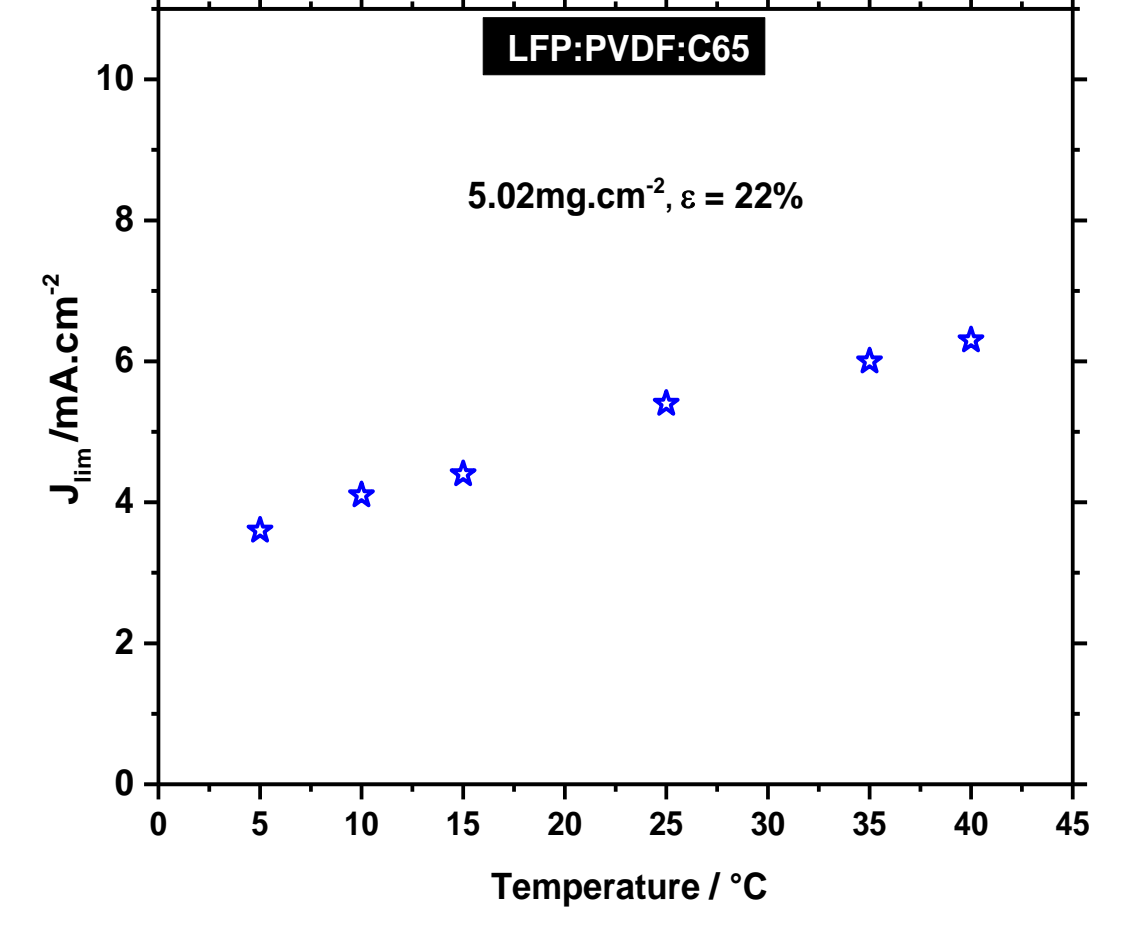
### 3) Temperature effect



- For  $J < J_{lim}$  (zone1), the slope  $Q$  vs  $J$  increases when T decreases
- The variation of  $J_{lim}$  with T shows linear behaviour

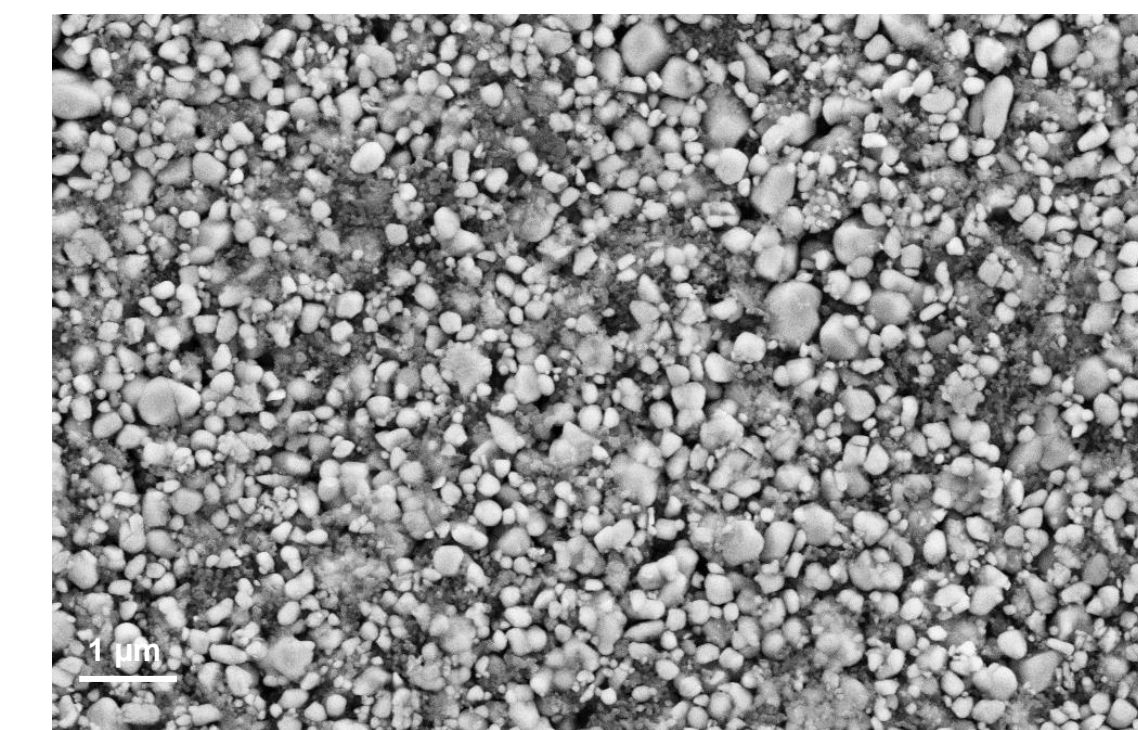
### Activation Energy

Ea (5-40°C) 0.2 eV

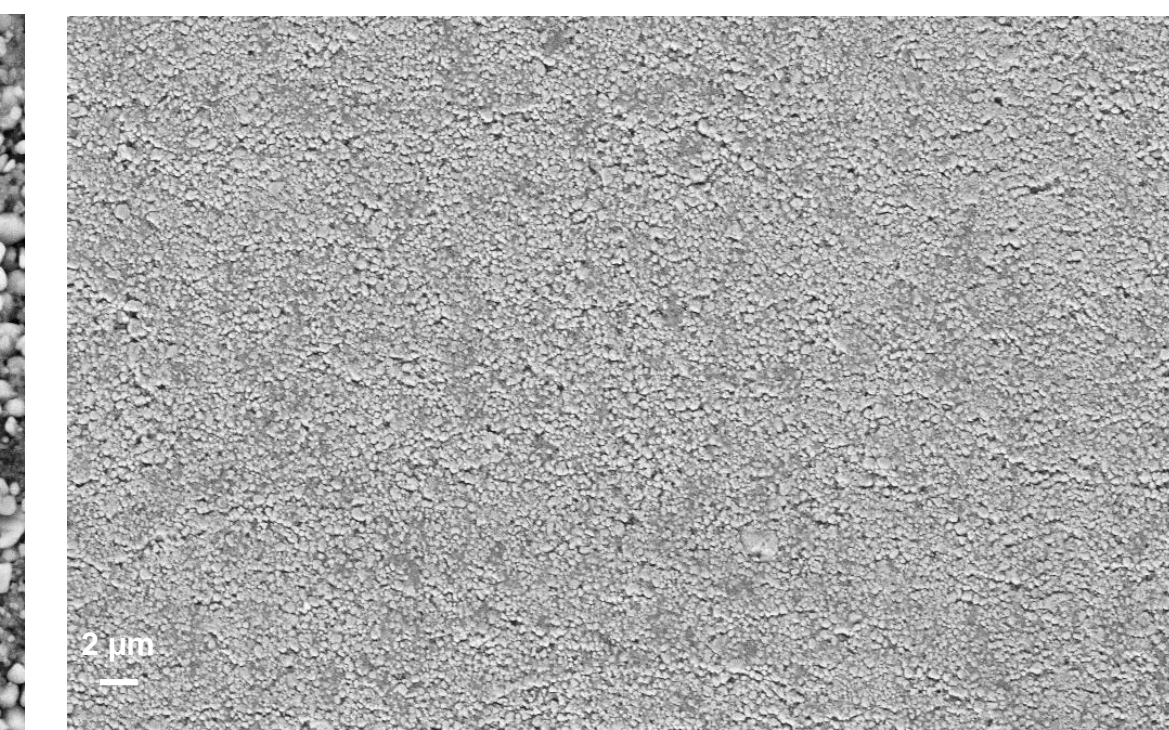


### 4) SEM images

#### Plane



#### Cross-section

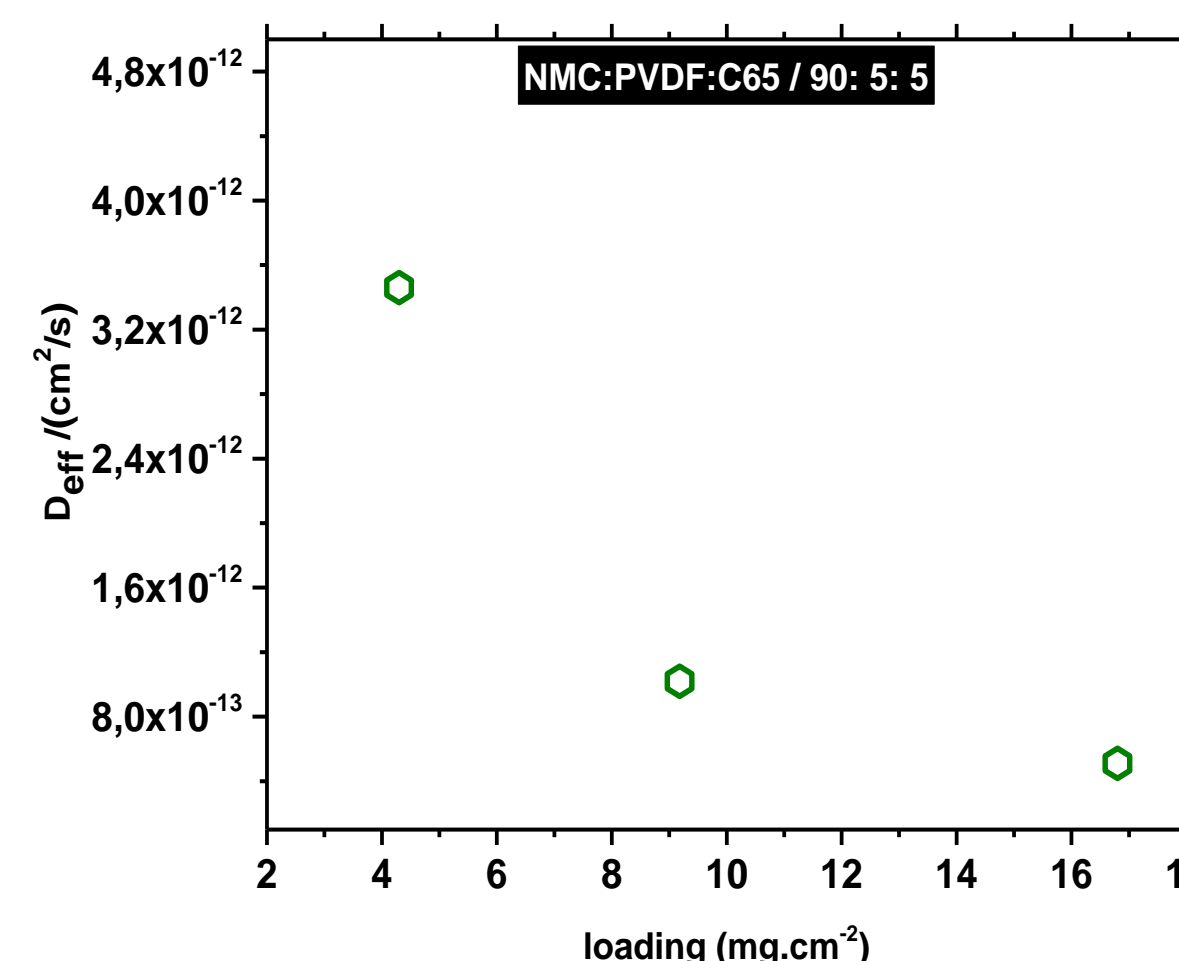


LFP electrode at 20% porosity

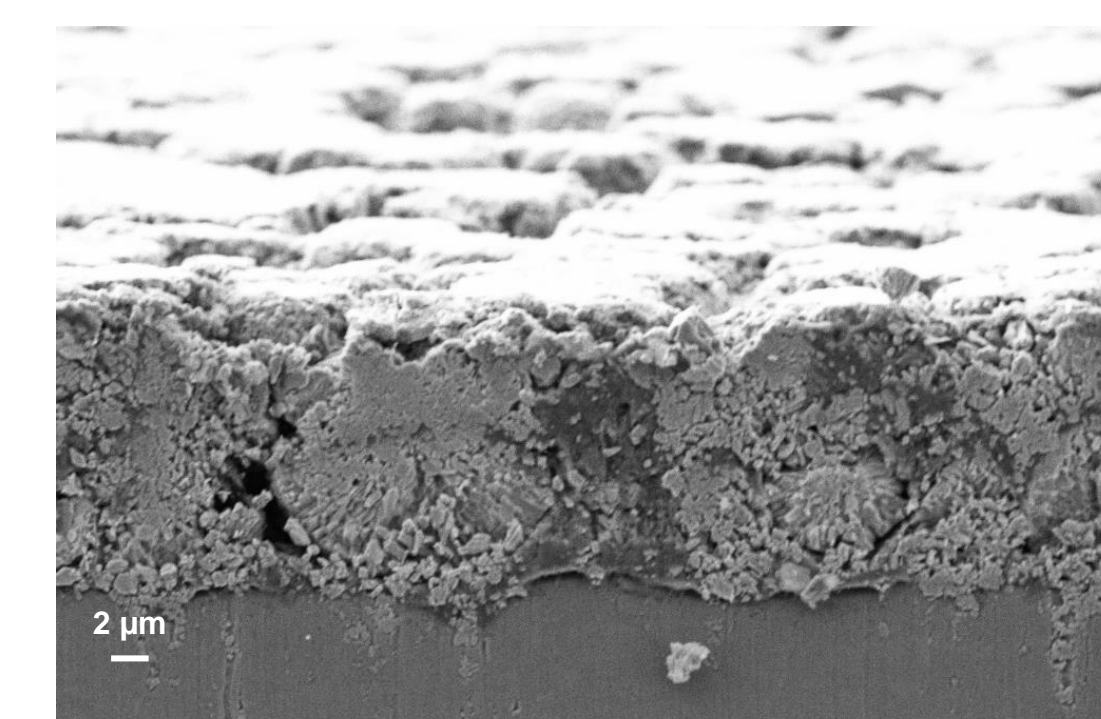
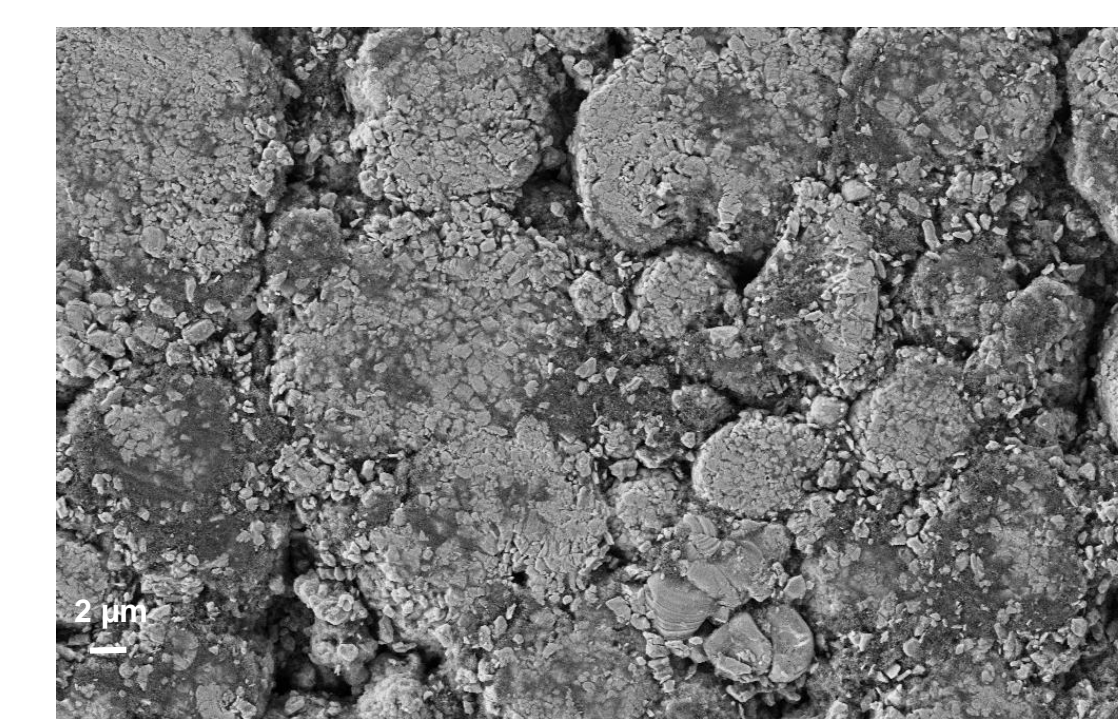
## NMC based electrode

### 1) Loading effect

Loading (mg.cm <sup>-2</sup> )	4	17
$J_{lim}$ (mA.cm <sup>-2</sup> )	20.8	10.1
$D_{eff}$ AM limitation (cm <sup>2</sup> .s <sup>-1</sup> )	$3.4 \cdot 10^{-12}$	$5.1 \cdot 10^{-13}$
$D_{eff}$ electrolyte limitation (cm <sup>2</sup> .s <sup>-1</sup> )	$1.9 \cdot 10^{-6}$	$4.1 \cdot 10^{-6}$



### 2) SEM images



NMC electrode at 20% porosity

- NMC-based electrode shows higher  $J_{lim}$ , compared to LFP one

- Same effect of loading on  $J_{lim}$  and power performance
- 9 and 17 mg.cm<sup>-2</sup> electrodes shows almost similar power performance

## Conclusion

- Quick determination of limiting current density as well as limiting process of power.
- Electrode design (Porosity, loading, microstructure) has a substantial impact on the power performance of the battery
- Figure out a physical interpretation of the impact of design parameters on power performance
- An optimum of all parameters has to be found to maximize power performance

## References

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