



**HAL**  
open science

## Analysis of limiting Processes within Li-ion Batteries

Mohamed Raghibi, Laureline Lecarme, Didier Devaux, R. Bouchet

### ► To cite this version:

Mohamed Raghibi, Laureline Lecarme, Didier Devaux, R. Bouchet. Analysis of limiting Processes within Li-ion Batteries. Journées d'électrochimie Mons, 2022, Jul 2022, Mons, Belgium. <hal-04230808>

**HAL Id: hal-04230808**

**<https://hal.science/hal-04230808v1>**

Submitted on 6 Oct 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC0 1.0 - Universal - International License

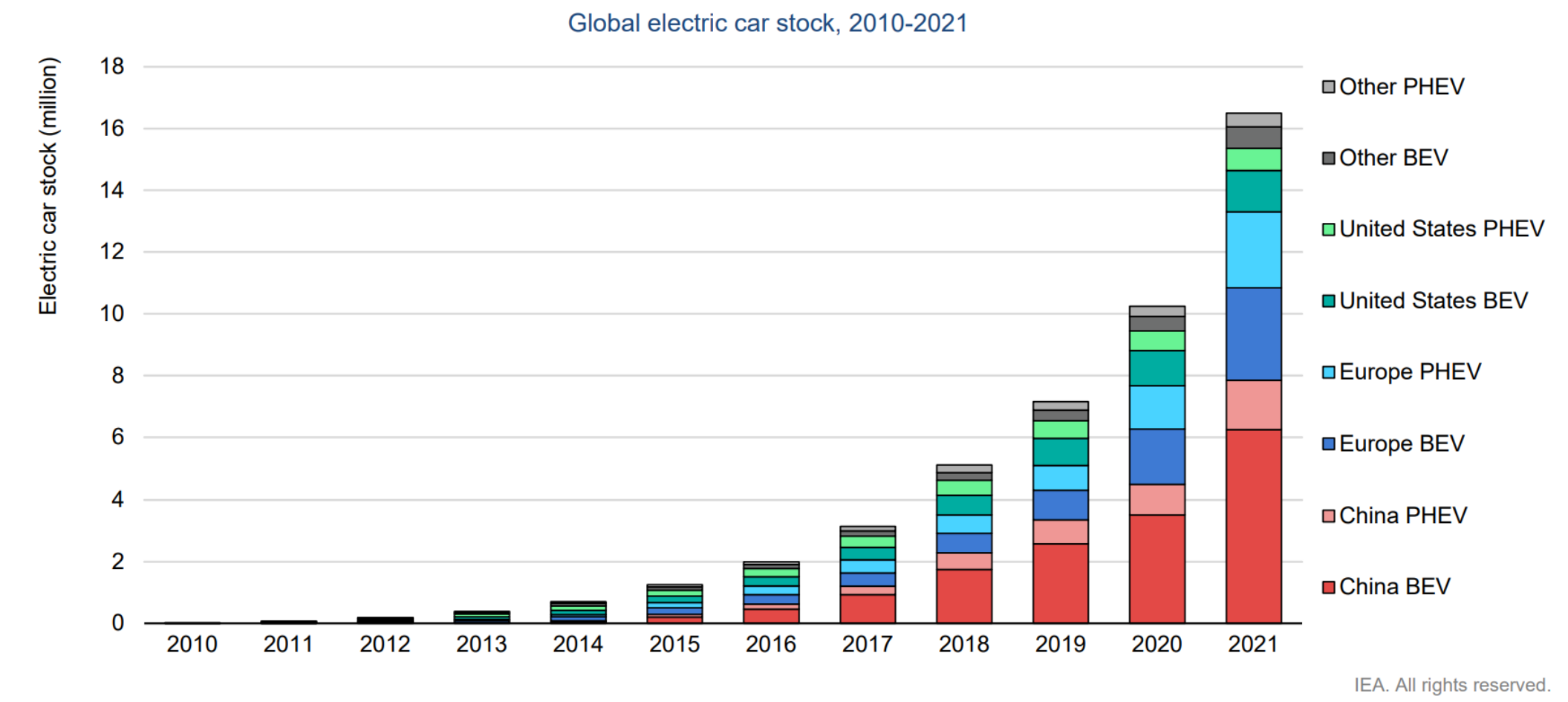
# Analysis of Limiting Diffusion Processes within Li-ion Batteries

Raghibi Mohamed (a)\*, Lecarme Lauréline (a), Devaux Didier (a), Bouchet Renaud (a)

(a) Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, Grenoble INP\*\*, LEPMI, 38000 Grenoble, France

\*\*Institute of Engineering and Management Univ. Grenoble Alpes

\*mohamed.raghibi@grenoble-inp.fr



## 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

### Electrode formulation

Active materials: **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 85/ 7,5/ 7,5	2-17	0,4-2,7	23-50	10°C-40°C
NMC / C65 / PVDF	90/ 5 / 5	4-16	0,8-3,4	20-25	10°C-40°C

### Cell Assembly

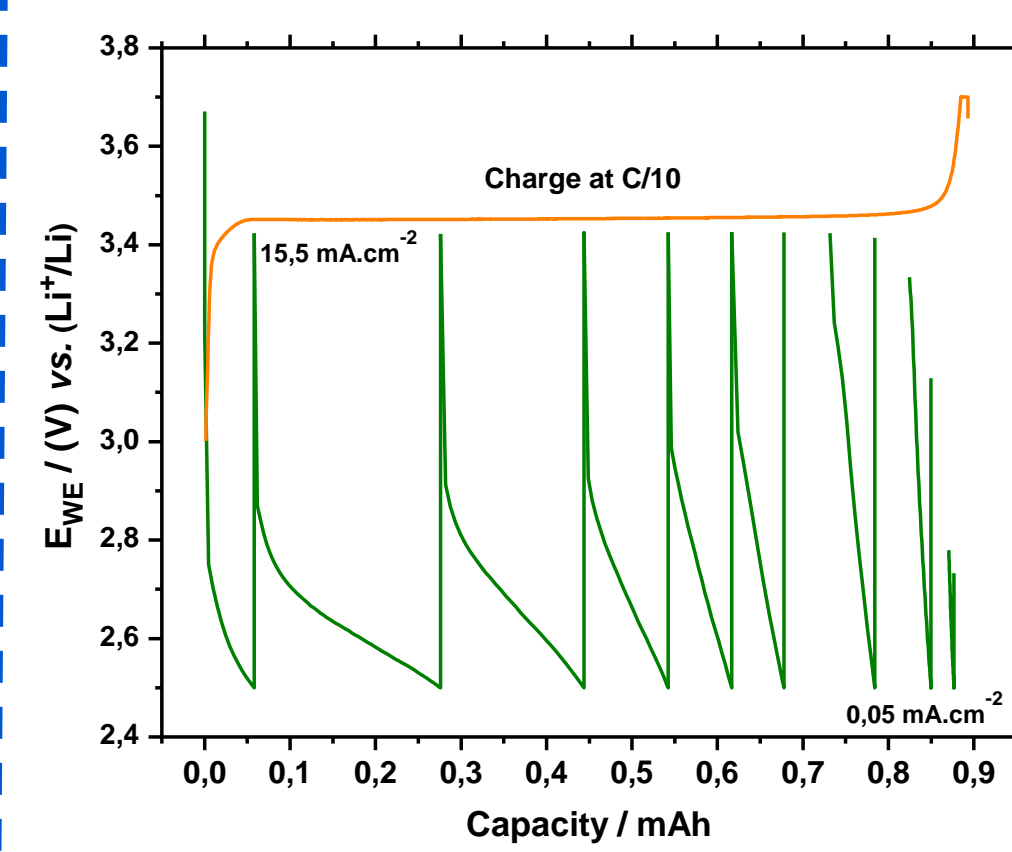
Coin cell CR2032

Electrode//LP30//Li

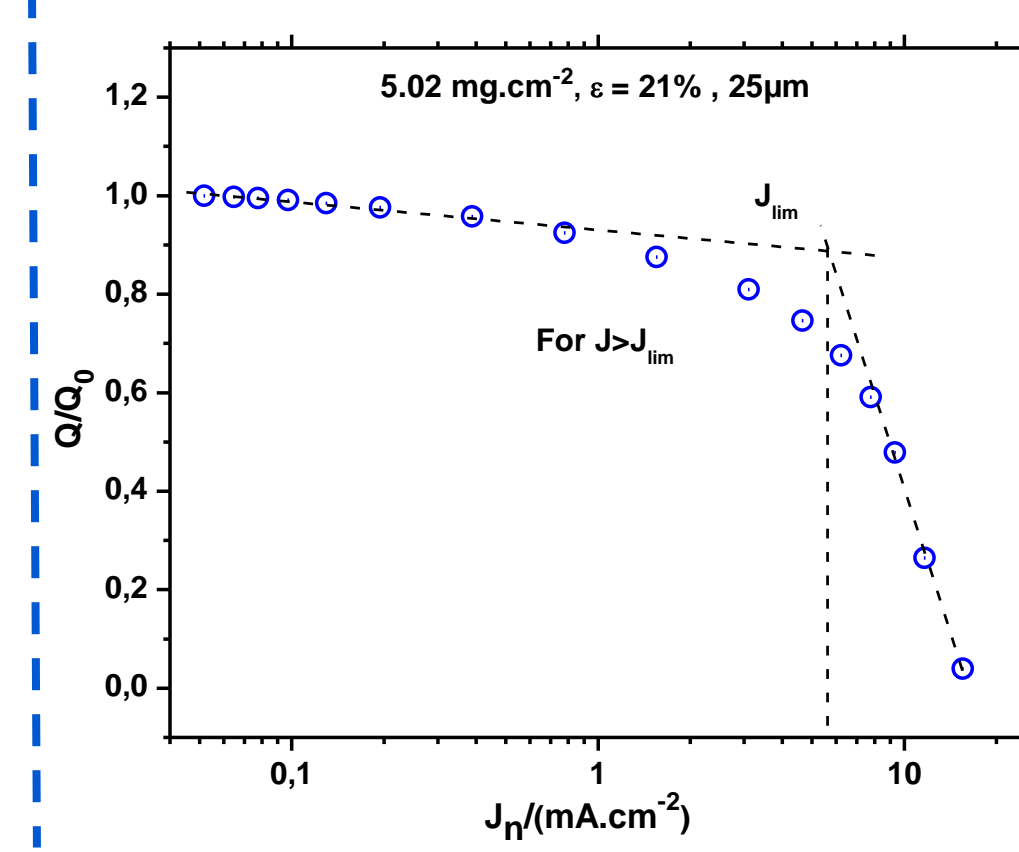


## Methodology

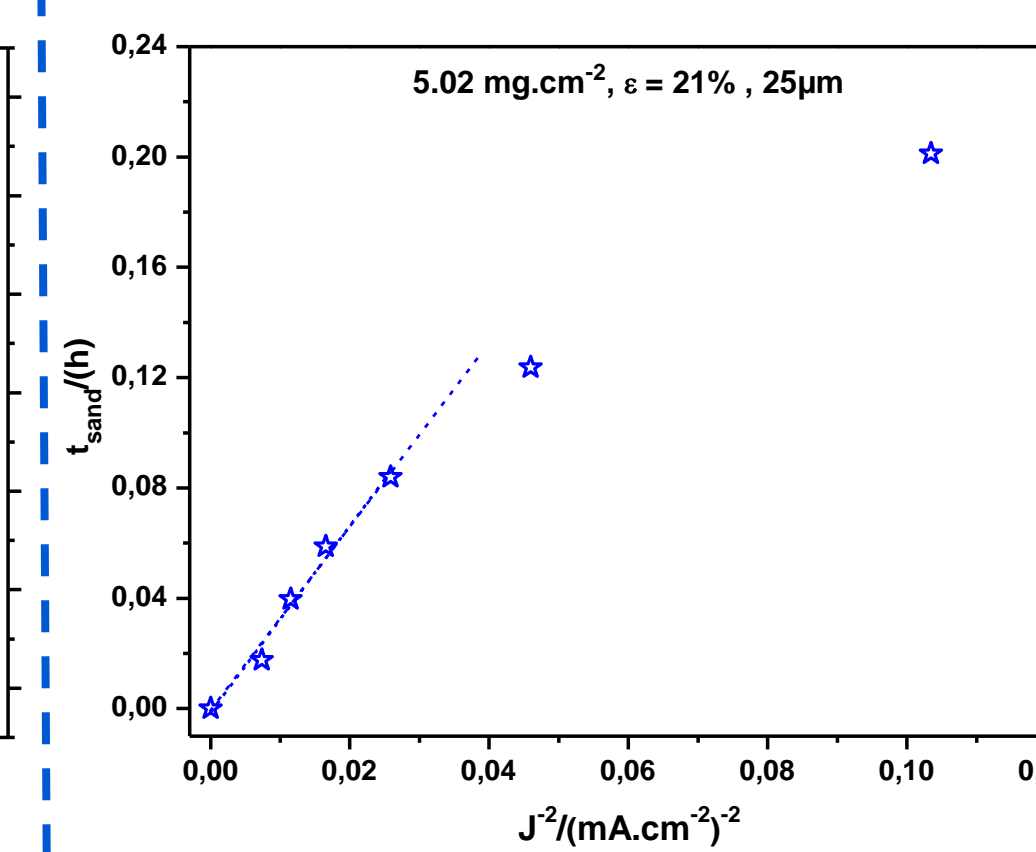
### Cycling protocol (3)(4)



### Power performance



### Sand Plot



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

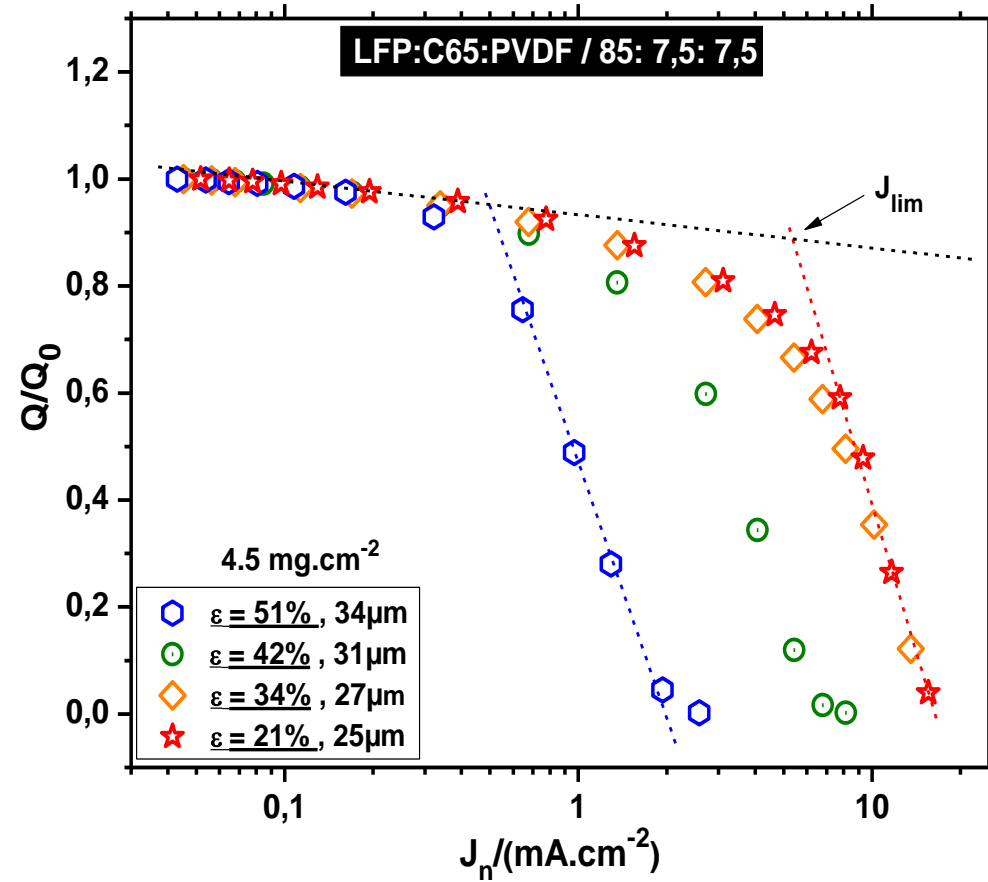
Sand Equation (4)(5)

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

Quick access to the effective diffusion coefficient

## Results & discussions

### LFP based electrode : 1) Porosity effect

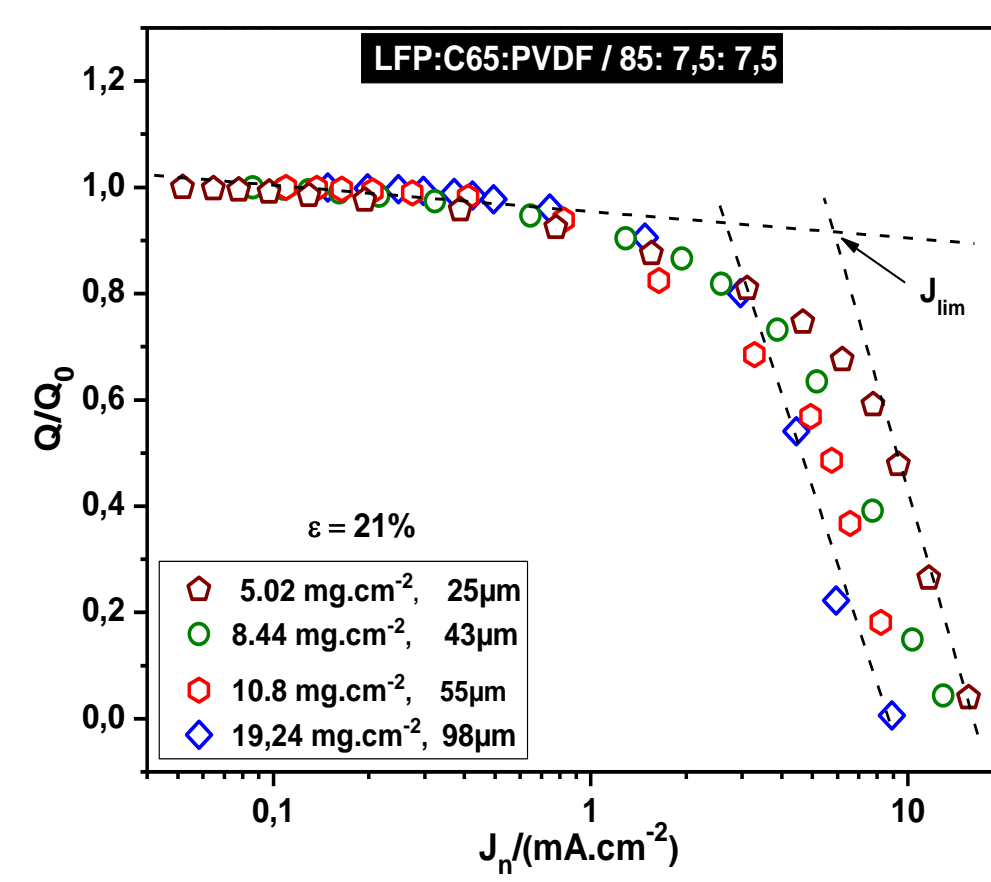


- Lower porosity results in higher  $J_{lim}$ , and higher operating C-rates

→ Calendering enhances contact particle-particle and particle-current collector

Porosity (%)	53	22
$J_{lim}$ (mA.cm <sup>-2</sup> )	0,7	5
$D_{eff}$ (cm <sup>2</sup> .s <sup>-1</sup> )	2,2.10 <sup>-15</sup>	1,7.10 <sup>-14</sup>

### 2) Loading effect

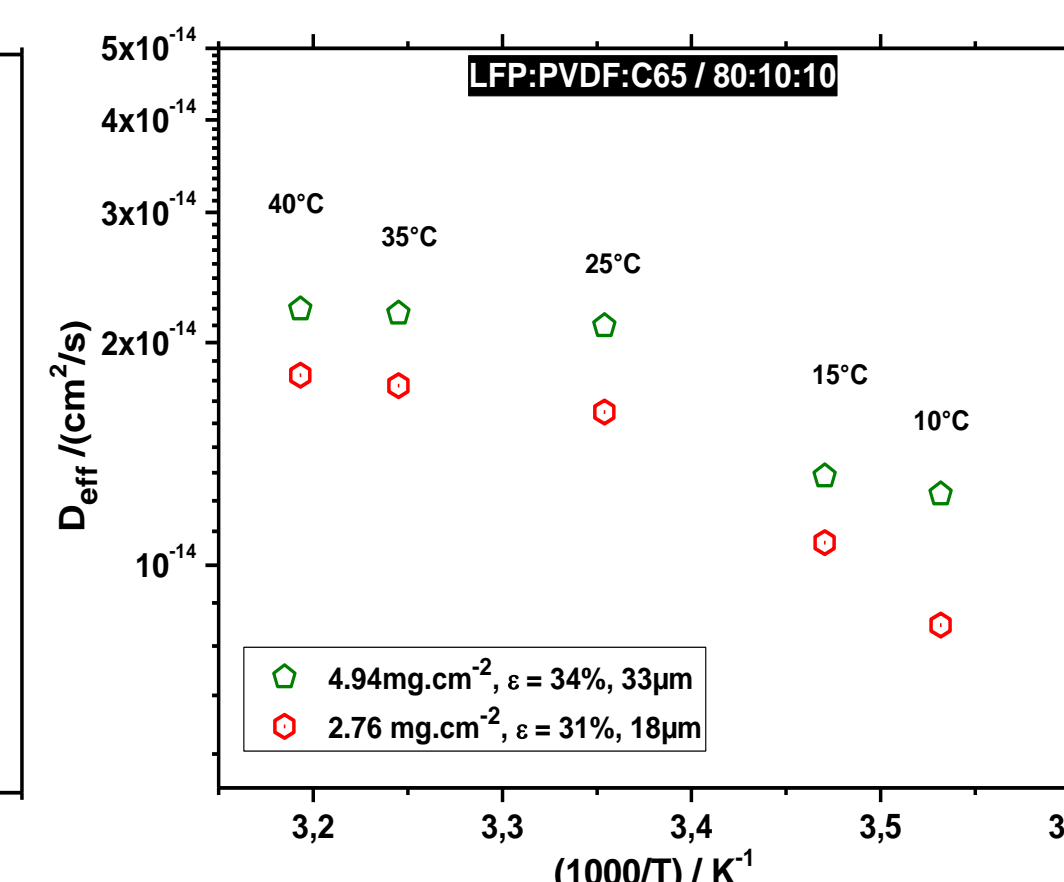
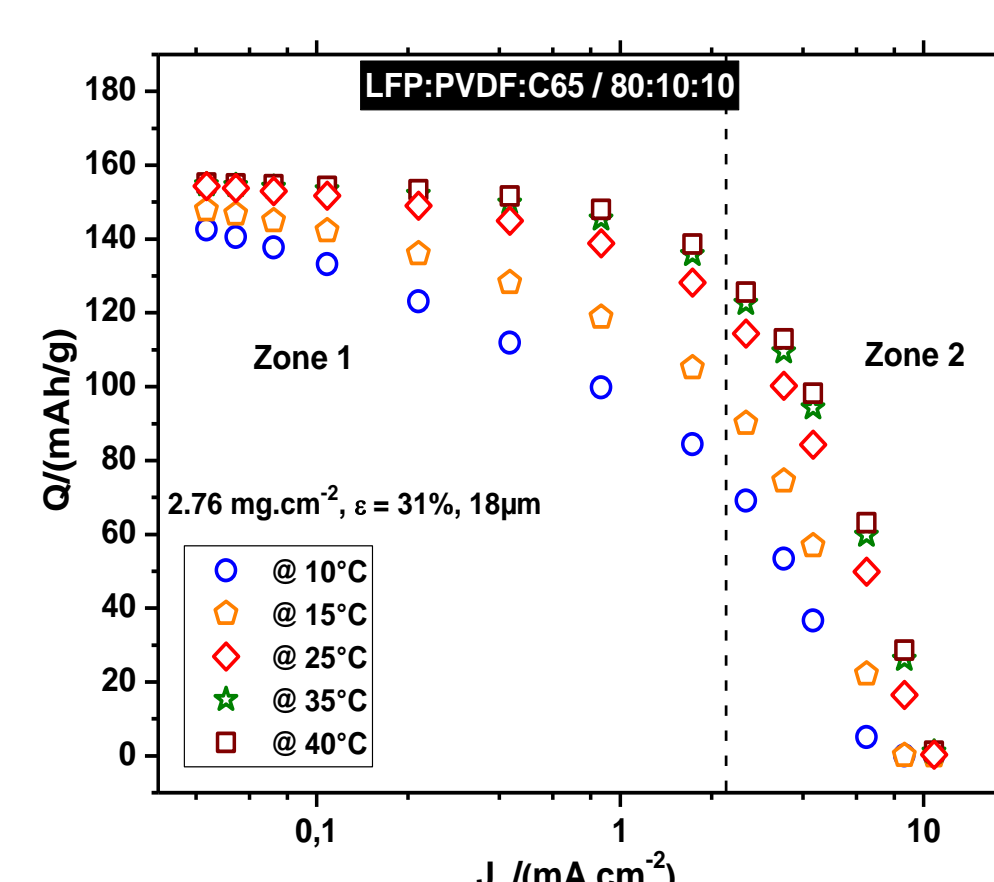


- Thicker is the electrode; lower is  $J_{lim}$

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

Loading (mg.cm <sup>2</sup> )	5	19
$J_{lim}$ (mA.cm <sup>-2</sup> )	5	2,5
$D_{eff}$ AM limitation (cm <sup>2</sup> .s <sup>-1</sup> )	1,7.10 <sup>-14</sup>	2,5.10 <sup>-15</sup>
$D_{eff}$ electrolyte limitation (cm <sup>2</sup> .s <sup>-1</sup> )	5,2.10 <sup>-7</sup>	1,1.10 <sup>-6</sup>

### 3) Temperature effect



- For  $J > J_{lim}$  (zone1), the slope  $Q$  vs  $J$  increases when T decreases

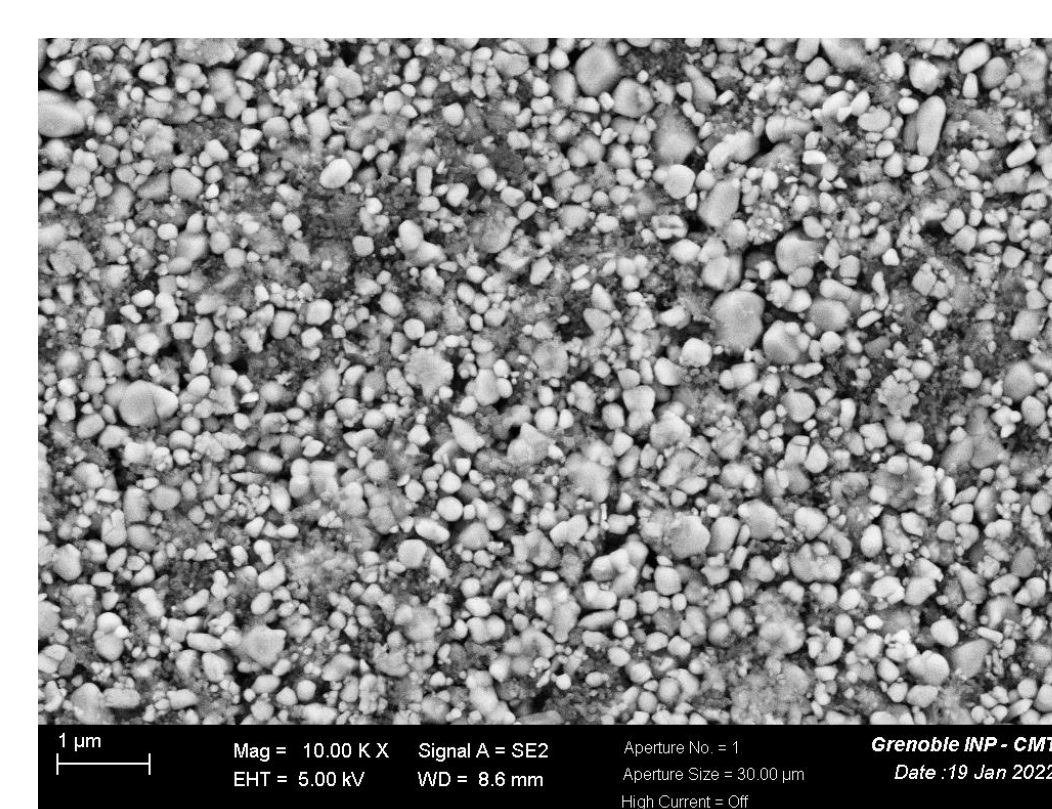
- The variation of  $D_{eff}$  with  $1/T$  shows two linear portions

Activation Energy

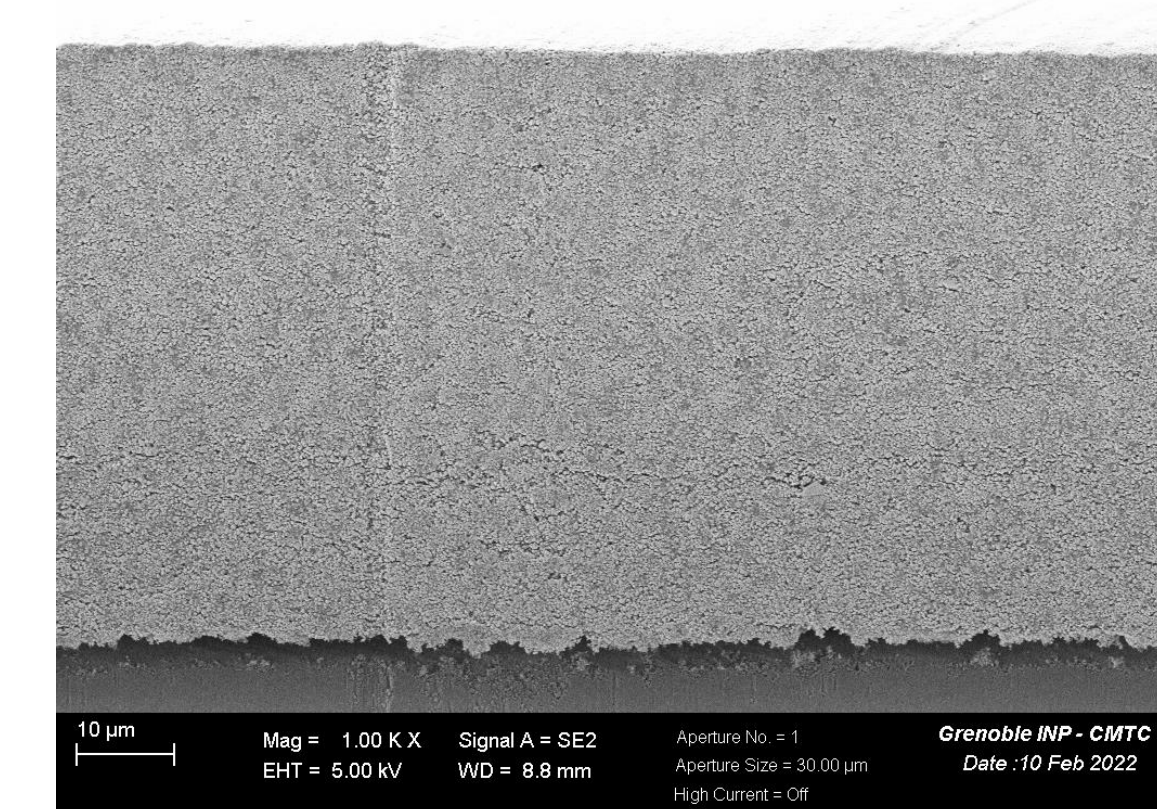
Ea (10-25°) 0,32 eV

Ea (25-40°) 0,06 eV

### 4) SEM images

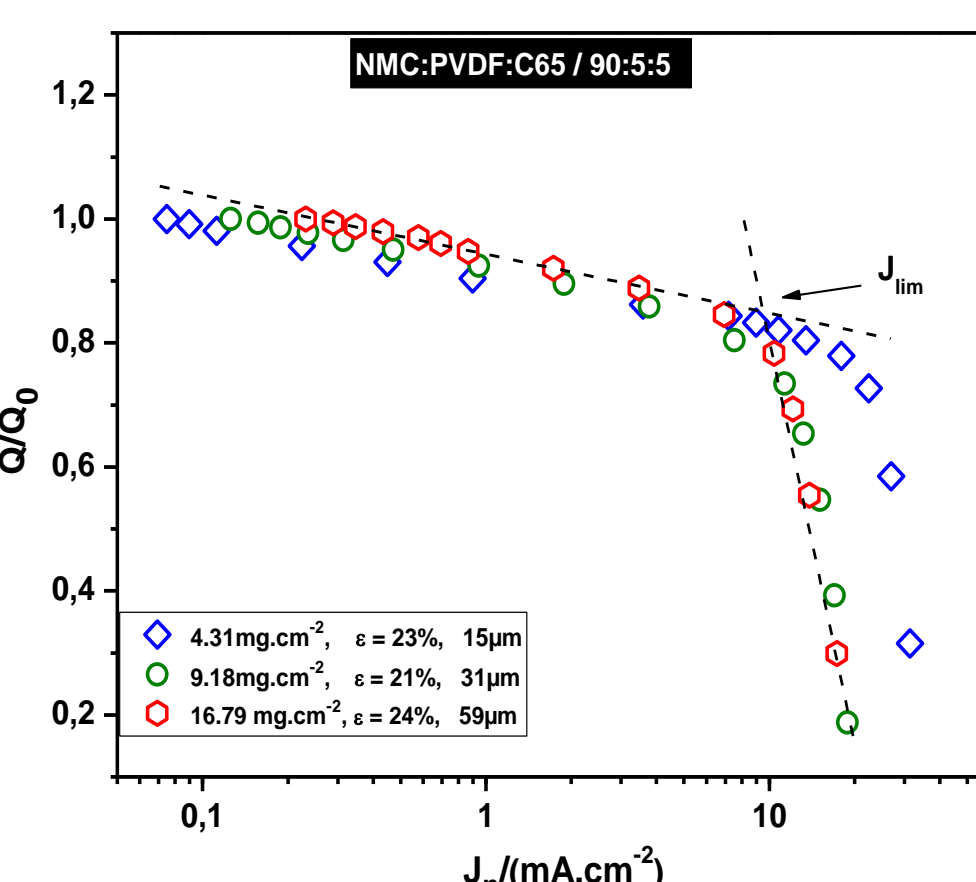


### Cross-section



LFP electrode at 20% porosity

### NMC based electrode : 1) Loading effect

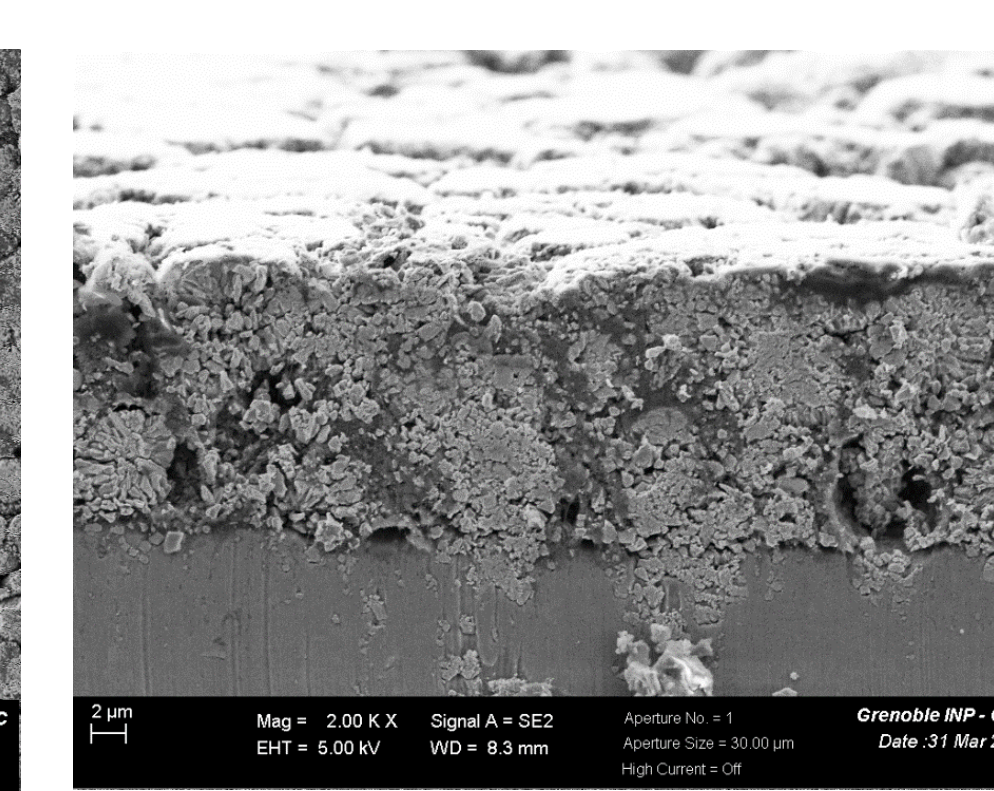
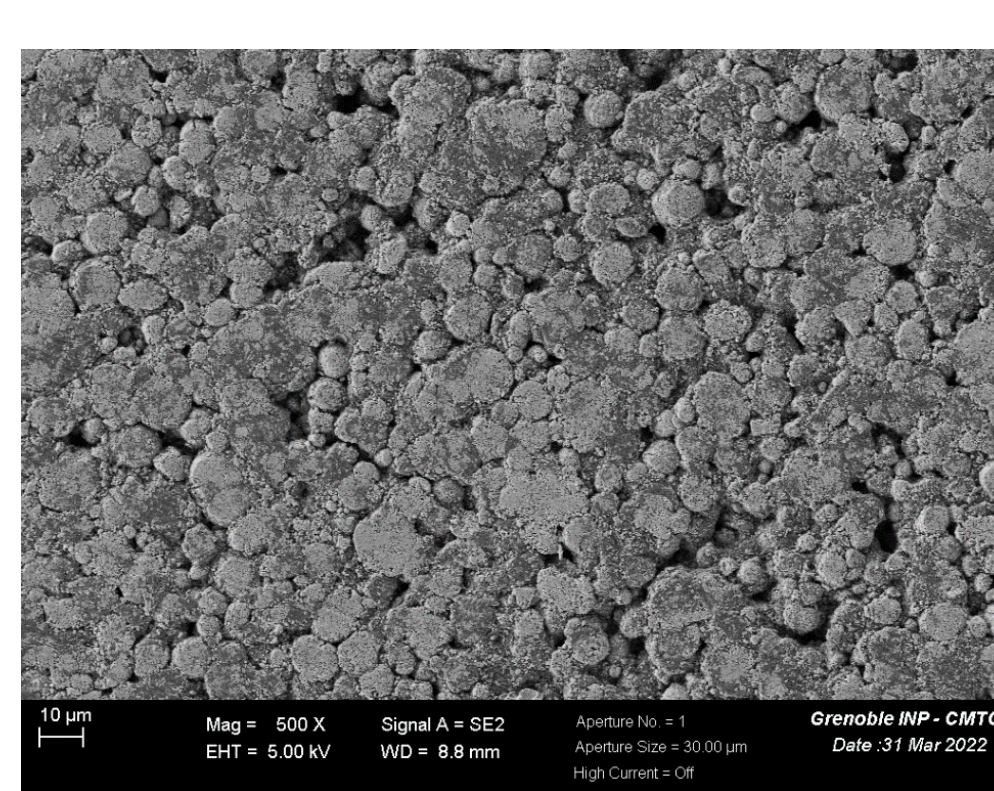


- NMC-based electrode shows higher  $J_{lim}$ , compared to LFP one.

Loading (mg.cm <sup>2</sup> )	4	17
$J_{lim}$ (mA.cm <sup>-2</sup> )	15	10
$D_{eff}$ AM limitation (cm <sup>2</sup> .s <sup>-1</sup> )	3,6.10 <sup>-12</sup>	5,3.10 <sup>-13</sup>
$D_{eff}$ electrolyte limitation (cm <sup>2</sup> .s <sup>-1</sup> )	1,9.10 <sup>-6</sup>	4,4.10 <sup>-6</sup>

- Same effect of loading on  $J_{lim}$  and power performance

### 2) SEM images



NMC electrode at 20% porosity

## 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.

In progress: Find a theoretical correlations

## References

- Armand M *et al.*, Journal of Power Sources, 2020. 479: 228708
- Heubner C *et al.*, Journal of Power Sources, 2019; 419: 119-126
- Doyle. M *et al.*, Journal of Power Sources, 1994. 52(2)
- Devaux. D., *et al.* Frontiers in Energy Research, 2020. 7(168).
- J. E. Baur, Handbook of Electrochemistry, 2007

Acknowledgement

I-MEP<sup>2</sup>  
École Doctorale  
Ingénierie - Matériaux, Mécanique,  
Environnement, Énergétique,  
Procédés, Production