THE MUSIC PROJECT

Materials for sUstainable Sodium-Ion Capacitors

Deliverable 5.4 100 F Pouch cell fabrication

María Arnaiz
CICE

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Horizon Europe. Neither the European Union nor the granting authority can be held responsible for them. No 101092080

Grant agreement Number	Project 101092080 — MUSIC	
Deliverable No.	D5.4	
Related WP	WP5. Electrode development and prototype fabrication	
Deliverable Title	100F Pouch cell fabrication	
Deliverable Date	2025-06-30	
Deliverable Type	REPORT	
Dissemination level	Public (PU)	
Written By	María Arnaiz (CICE)	2025-06-30
Checked by	Jon Ajuria, Elena Dosal (CICE)	2025-06-30
Reviewed by (if applicable)	Juan Pablo Badillo (ELYTE)	2025-06-27
Approved by	Jon Ajuria (CICE)	2025-06-30
Status	Final	2025-06-30

Disclaimer / Acknowledgment

This project has received funding from the European Union's Horizon Europe programme for research and innovation under grant agreement No. 101092080. This document reflects the views of the author and does not reflect the views of the European Commission. While every effort has been made to ensure the accuracy and completeness of this document. the European Commission cannot be held responsible for errors or omissions. whatever their cause.

Publishable summary

This deliverable reports the fabrication and electrochemical evaluation of a 100F sodium-ion capacitor (SIC) prototype, developed within the framework of the MUSIC project. Building upon the formulations and processing strategies reported in D5.2, the prototype device integrates previously optimized hard carbon (HC) and activated carbon (AC-$Na_2C_4O_4$) electrodes, both fabricated in a double-sided configuration using roll-to-roll (R2R) processing.

The cell was assembled in a multilayer pouch format under dry room conditions, employing a Generation 0 electrolyte composed of 1 M $NaPF_6$ in ethylene carbonate:propylene carbonate (1:1 vol.) and tested at room temperature. Careful mass balancing between the positive and negative electrodes was applied to ensure optimal charge storage, including the use of a sacrificial sodium salt to enable pre-sodiation. Electrochemical characterization confirmed successful cell design. The results demonstrate both the scalability and viability of the developed sodium-ion capacitor concept.

This work represents a key milestone in the MUSIC project's objective to develop sustainable and high-performance sodium-based hybrid energy storage systems.

Contents

List of Figures

List of Tables

Abbreviations

SYMBOL	SHORTNAME
AC	Activated Carbon
EC	Ethylene Carbonate
Gen0	Generation 0
GCPL	Galvanostatic Cycling with Potential Limitation
HC	Hard Carbon
PC	Propylene Carbonate
RT	Room Temperature
SEI	Solid Electrolyte Interphase
SIC	Sodium Ion Capacitor
S/N	Serial Number
WP	Work Package

1 Introduction

1.1 Objective

The aim of this Deliverable is to develop a 100 F sodium-ion capacitor using previously selected materials and electrode formulations developed in D5.2. This work focused on cell design, ensuring proper mass balance between electrodes to meet performance targets. Double-side electrodes, previously fabricated, were essential to achieve the required capacitance in a compact format. The device was assembled in pouch cell configuration using a Gen0 electrolyte consisting of 1 M $NaPF_6$ in ethylene carbonate:propylene carbonate (EC:PC, 1:1 vol.), and all tests were conducted under room temperature conditions. This deliverable serves as a proof-of-concept, demonstrating the scalability and practical viability of the developed components for sodium-ion capacitors.

2 Methods and Results

2.1 Electrode fabrication

The fabrication of double-sided electrodes for both positive (activated carbon, AC-$Na_2C_4O_4$) and negative (hard carbon, HC) electrodes was carried out using the formulations and methods described in D5.2.

2.2 100F sodium ion capacitor fabrication

The assembly of a multilayer pouch cell involves several key steps to ensure optimal performance. First, the positive and negative electrodes are fabricated, followed by drying, calendaring, and cutting into desired shapes. These electrodes are then stacked alternately with cellulose separator in a dry room to prevent moisture contamination. The stack is connected to external terminals via ultrasonic welding of tabs. After insertion into an aluminium laminate pouch, the cells are filled with electrolyte, and the pouches are vacuum sealed to eliminate air pockets. A large empty area was kept in the pouch cells to accommodate the gas evolution during initial charge step (*i.e.,* pre-sodiation), which later is removed for the appropriate further characterization of the device (see **Figure 1**).

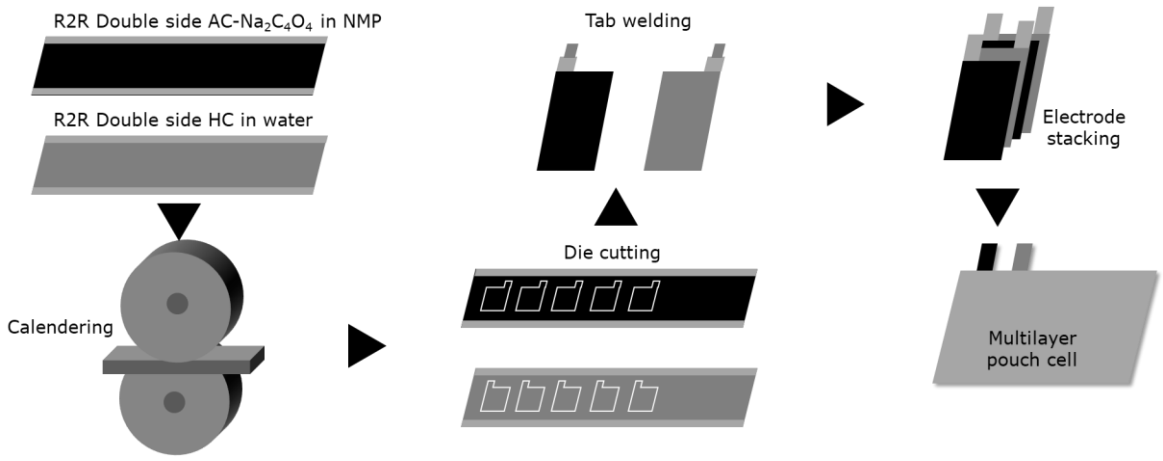

Figure 1. Schematic illustration of multilayer pouch cell assembly process.

The R2R processing of double side HC negative electrodes and AC-Na2C4O4 positive electrodes, make possible the fabrication of multilayer SICs utilizing a sacrificial salt as extra sodium agent. Two single side HC electrodes in the terminals were combined with eight double side AC- $Na_2C_4O_4$ and seven double side HC electrodes to build a 100 F multilayer SIC prototype. All electrodes were ~20 cm^2 size and cells were assembled by the Z-holding technique with cellulose separator. They were immersed in a certain amount of 1 M $NaPF_6$ (ethylene carbonate:propylene carbonate, 50:50 vol.%). After cell assembly, a 24h wetting period was established to guarantee full electrolyte penetration throughout the electrodes and separator.

2.3 100F sodium ion capacitor characterization

After the necessary wetting period, the cell undergoes initial formation cycles where the oxidation sacrificial salt is oxidized and becomes the responsible of creating a stable solid-electrolyte interphase (SEI). This process is crucial for producing high-performance cells with excellent electrochemical properties.

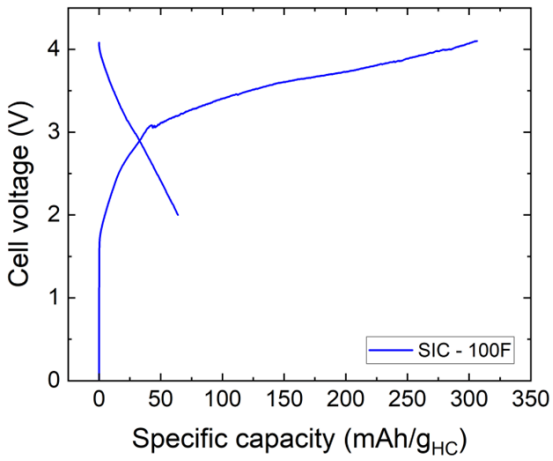

Figure 2 describes the first charge step of the SIC up to the upper voltage of 4.1 V to complete the pre-sodiation step, where in the positive electrode, the sacrificial salt is reversibly oxidized and those sodium ions are inserted in the negative electrode, being part of the SEI formation agents. Before continuing the characterization of the cell, a degassing step (*i.e.*, after the pre-conditioning/pre-sodiation step) must be followed in order to eliminate the gas generated along the oxidation of the sacrificial salt.

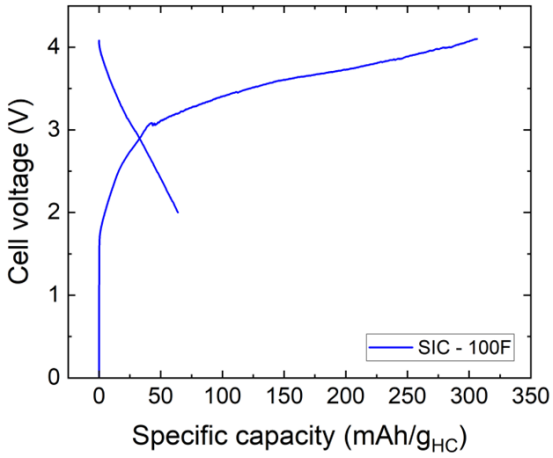

Figure 2. Electrochemical characterization of multilayer SIC pouch cells: first charge step in terms of specific capacity

Afterwards, the multilayer SIC has been characterized between 2.2 and 3.8 V at different current densities. **Figure 3** shows capacitance, energy, and power values obtained from these galvanostatic charge/discharge measurements. As shown in **Figure 3a** the targeted 100F were obtained until discharge times of 8 minutes. The internal resistance might be the main responsible for the decrease in capacitance, and therefore, energy output. Thus, the same behaviour can be observed in **Figure 3b** in terms of energy and power density. At the power density of 147 W kg^{-1}_{AM}, 40 Wh kg^{-1}_{AM} energy density was obtained, whereas at higher power density of 437 W kg^{-1}_{AM}, 30 Wh kg^{-1}_{AM}.

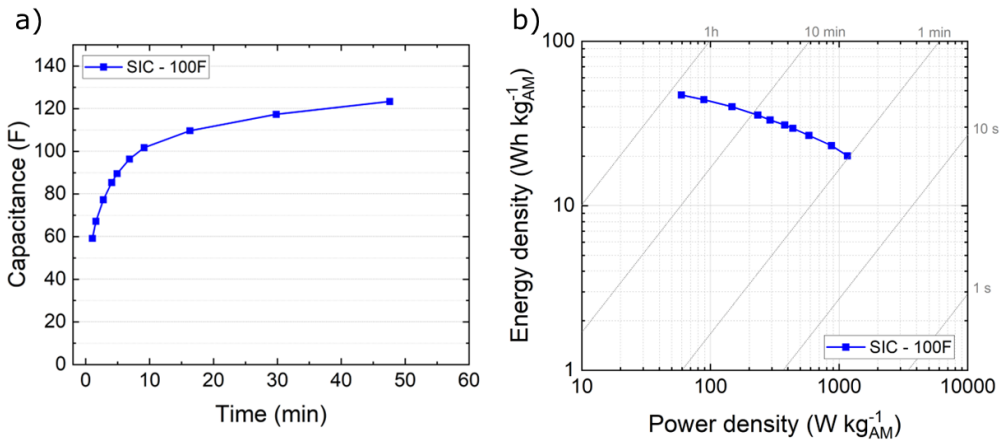

Figure 3. Electrochemical characterization of multilayer SIC pouch cell: a) capacitance at different discharge times, b) Ragone plot.

Table 1 summarizes the key specifications of the fabricated 100 F sodium-ion capacitor demonstrator. These parameters reflect the configuration used for device assembly and characterization.

Table 1. Specifications of the fabricated 100F SIC demonstrator.

S/N	Parameter	Values
1	Capacitance	100 F
2	Energy at Power	0.13 Wh at 0.49 W
3	Specific Energy at Specific Power	40 Wh/kg$_{AM}$ at 147 W/kg$_{AM}$
4	Energy at Power	0.10 Wh at 1.45 W
5	Specific Energy at Specific Power	30 Wh/kg$_{AM}$ at 437 W/kg$_{AM}$
6	Mass, active materials	3.315 g
7	Total mass, device	18.19 g
8	Cell voltage	2.2 - 3.8 V

3 Discussion and Conclusions

This development successfully demonstrated the scalability and effectiveness of the pre-sodiation strategy used in the fabrication of a 100F sodium-ion capacitor (SIC). The fabrication process involved the preparation of double-sided electrodes (AC-$Na_2C_4O_4$ for the positive electrode and HC for the negative electrode) and the assembly of multilayer pouch cells, incorporating a sacrificial salt ($Na_2C_4O_4$) to aid in the pre-sodiation of the negative electrode. The sacrificial salt played a crucial role in forming a stable SEI during the initial cycles, which is essential for long-term electrochemical performance.

Overall, the results confirm the viability of the pre-sodiation strategy and electrode configuration for sodium-ion capacitors, offering a promising path for future energy storage applications, particularly in hybrid and large-scale energy systems.

4 Recommendation

Electrode Formulation Optimization: Future work should focus on refining the formulation of the electrodes, particularly by adjusting the active material, and sacrificial salt:HC ratios. These activities will be covered by WP5/WP6 in the following months.

Electrolyte Composition: Further exploration of alternative electrolytes developed in WP3 is recommended.

Long-Term Cycling Tests: To better understand the long-term stability of the SIC, further testing should be performed at extended cycles. These activities will be covered by WP5 in the following months.

5 Risk register

Table 2. Risk Register

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[2]	Solutions to overcome the risk
R1	High Internal Resistance	2	2	Optimize electrode formulation and processing to improve contact and reduce resistance.
R2	Long-Term Stability Issues	2	2	Conduct extended cycling tests to assess performance over time.

6 References

[1] Probability risk will occur: 1 = high, 2 = medium, 3 = low

[2] Effect when risk occurs: 1 = high, 2 = medium, 3 = low

7 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Table 3. Project partners

#	PARTICIPANT SHORT NAME	PARTNER ORGANISATION NAME	COUNTRY
1	CICE	CENTRO DE INVESTIGACION COOPERATIVA DE ENERGIAS ALTERNATIVAS FUNDACION. CIC ENERGIGUNE FUNDAZIOA	Spain
2	EUR	CLANCY HAUSSLER RITA	Austria
3	KIT	KARLSRUHER INSTITUT FUER TECHNOLOGIE	Germany
4	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France
4.1	IMN	NANTES UNIVERSITE (Affiliated)	France
5	UPS	UNIVERSITE PAUL SABATIER TOULOUSE III	France
6	FSU	FRIEDRICH-SCHILLER-UNIVERSITAT JENA	Germany
7	IRT-JV	INSTITUT DE RECHERCHE TECHNOLOGIQUE JULES VERNE	France
8	ELY	E-LYTE INNOVATIONS GMBH	Germany
9	BYD	BEYONDER AS	Norway
10	BCARE	BATTERYCARE S. L.	Spain
12	TALGO	PATENTES TALGO SL	Spain
13	UPC	UP CATALYST	Estonia

This project has received funding from the European Union's Horizon Europe programme for research and innovation under grant agreement No. 101092080.