Silicon-dominant anodes: how the TRL level can influence the production process

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The manufacturing of Li-ion Battery cells (LIBs) can be divided into different levels depending on how close a new technology is to commercialization, depending on the final TRL (Technology Readiness Level) achieved: from laboratory scale (TRL 3-4) to pilot-line scale (TRL 5-6). This evidences the need of implementing new processes or optimizing the use of new materials at the pilot-line level.
Scaling up the electrode production process is heavily dependent on the chemical composition of the materials used. The current state-of-art regarding the anode materials is well-known and the water-based graphite anodes are already on the market. However, for silicon-dominant anodes, the road is still long. This is because the production process needs to be reoptimized depending on the different physical-chemical properties of the silicon surface that affect the interaction with the other components, leading to varying result. Furthermore, silicon has the significant disadvantage of undergoing substantial volume expansion during charge and discharge cycles that leads to the pulverization of the electrode and to the overall performance decay. To mitigate this issue, many different composite, micro or nanometric forms have been proposed in literature and some of them are already commercialized, such as the E-Magy micro-sized nanoporous silicon used in this work.
The starting composition of the anode was 80% of E-Magy nanoporous silicon, mixed with 5% of graphite, 5% of conductive additive and 10% of polyacrylic acid as binder, using water as solvent. Starting with the mixing step, at laboratory lever the slurry was mixed with a Dispermat device: this facility produced a highly homogeneous slurry with all the components very well dispersed, as confirmed by FESEM-EDX analysis. However, moving toward the higher TRL level, the planetary mixer required much more effort to optimize the mixing procedure: the different blade shapes greatly affected the homogeneity of the slurry causing significant aggregation and sedimentation phenomena. After the mixing step, the coating step is strictly related to the properties of the slurry, thus, if the mixing step is not optimized at the best, neither is the coating, both at laboratory level using a simple tape casting like the doctor blade, both at pilot-line level using a more automated roll-to-roll machine.
Our research seeks to optimize the production process for these silicon-dominant electrodes and understand how each production process at TRL 5-6 can affect the final electrode properties. To do so, electrochemical tests with a capacity control protocol were conducted on the electrodes. For mass loading of about 1.5 mg cm^{-2}, a stable capacity of 1000 mAh/g can be reached with both the production methods as well as a stable coulombic efficiency of over 99% for more than 200 cycles.

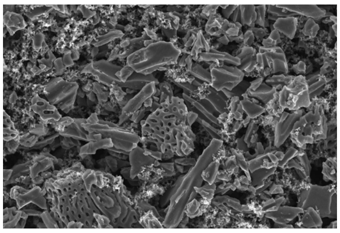

Figure 1 - FESEM analysis of the electrode produced with E-Magy silicon, with a magnification of 10kX

Acknowledgment
This publication is part of the project PNRR-NGEU which has received funding from the MUR – DM 352/2022
This study was carried out within the Sustainable Mobility Center (CNMS) and received funding from the European Union Next Generation EU with grant agreement no. CN_00000023. This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.