Sustainable Conversion and Alloying Composite Anodes for Li- and Na-ion Batteries

Leonardo Sbrascini[1], Luca Bottoni[1], Antunes Staffolani[1], Hamideh Darjazi[1], Francesco Nobili[1]

[1]*Department of Chemistry, UNICAM - Universita' degli Studi di Camerino, Via S.Agostino 1 - 62032 Camerino, Italy*

leonardo.sbrascini@unicam.it

The market of rechargeable batteries is progressively moving towards a circular economy perspective and environmental sustainability [1]. Although Li-ion batteries are considered to be the best candidates for applications in the automotive sector, the long-term utilization of lithium might be limited due to the low abundance of the element, thus the research on Na-ion systems is still very open, at least for large-scale stationary applications [2,3]. Graphite, the state-of-the-art anode material for commercial batteries, is no longer able to sustain the energetic demand of the advancing technology, especially for automotive applications; additionally, it cannot be used as the anode material for Na-ion batteries in stationary applications, because of the larger ionic radius of the alkali metal relative to the Li counterpart and its low thermodynamic intercalation stability [4,5]. On one hand, amorphous hard carbons possess similar characteristics to graphite and are still the most promising candidates to be used as anodes for Na-ion batteries [6]; on the other hand, alloying and conversion materials have attracted particular interest in both Li-ion and Na-ion systems because of their higher sustainability and higher theoretical capacities, but their application is limited due to the huge volume expansion and structural rearrangement upon cycling [7]. In this regard, the combination of carbon materials as conductive and buffering matrices and the high energy densities of alloying and conversion materials may be very attractive for both types of electrochemical systems. Moreover, a further improvement of performance and sustainability could be obtained by the use of green binders with a high content of polar functional groups and the possibility to have crosslinking for a better particle cohesion [8,9]. In this work, we present a preliminary optimization of some composite electrodes based on Si and SnO_2 dispersed in a Hard Carbon matrix for Li-ion cells; analogously, a preliminary optimization has also been carried out for SnO_2/C and Fe_3O_4/rGO composites in Na-ion cells.

Acknowledgments

"Piano Triennale di Realizzazione 2019-2021, Accordo di Programma Ministero dello Sviluppo Economico" – ENEA and "New generation of electrochemical energy storage systems".

[1] S. Xiong, J. Ji, and X. Ma, "Environmental and economic evaluation of remanufacturing lithium-ion batteries from electric vehicles," Waste Manag., vol. 102, pp. 579–586, 2020.

[2] D. Larcher and J. M. Tarascon, "Towards greener and more sustainable batteries for electrical energy storage," Nat. Chem., vol. 7, no. 1, pp. 19–29, 2015.

[3] M. Sawicki and L. L. Shaw, "Advances and challenges of sodium ion batteries as post lithium ion batteries," RSC Adv., vol. 5, no. 65, pp. 53129–53154, 2015.

[4] D. Kundu, E. Talaie, V. Duffort, and L. F. Nazar, "The emerging chemistry of sodium ion batteries for electrochemical energy storage," Angew. Chemie - Int. Ed., vol. 54, no. 11, pp. 3432–3448, 2015.

[5] A. Franco Gonzalez, N.-H. Yang, and R.-S. Liu, "Silicon Anode Design for Lithium-Ion Batteries: Progress and Perspectives," J. Phys. Chem. C, vol. 121, no. 50, pp. 27775–27787, Dec. 2017.

[6] X. Dou et al., “Hard carbons for sodium-ion batteries: Structure, analysis, sustainability, and electrochemistry,” Mater. Today, vol. 23, no. March, pp. 87–104, 2019.

[7] J. Y. Li, Q. Xu, G. Li, Y. X. Yin, L. J. Wan, and Y. G. Guo, “Research progress regarding Si-based anode materials towards practical application in high energy density Li-ion batteries,” Mater. Chem. Front., vol. 1, no. 9, pp. 1691–1708, 2017.

[8] C. Erk, T. Brezesinski, H. Sommer, R. Schneider, and J. Janek, “Toward silicon anodes for next-generation lithium ion batteries: A comparative performance study of various polymer binders and silicon nanopowders,” ACS Appl. Mater. Interfaces, vol. 5, no. 15, pp. 7299–7307, 2013.

[9] L. Shen, L. Shen, Z. Wang, and L. Chen, “In situ thermally cross-linked polyacrylonitrile as binder for high-performance silicon as lithium ion battery anode,” ChemSusChem, vol. 7, no. 7, pp. 1951–1956, 2014.