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Non-Graphitic Anodes for Lithium-Ion Batteries

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Abstract

Despite the unique combination of exceptional energy and power density, making lithium-ion batteries the state-of-the-art electrochemical energy storage technology for small- and large-scale applications [1], further improvement is needed for realizing high energy density batteries to achieve electric vehicles extended driving ranges. Likewise most battery chemistries, the performance of Li-ion batteries (LIBs) is affected by external environmental conditions. In particular, the low temperatures experienced in country with extremely cold winters, such as northern Europe, Russia, USA and Canada, can sensibly reduce the energy storage capability of LIBs based on the current graphite-metal oxide technology. The major responsible for such limitation is the graphite negative electrode, where the lithium intercalation becomes sluggish below 0°C. Besides hampering the utilization of the full LIB capacity (that cannot be entirely recharged), the poor electrochemical performance of graphite at low T can cause severe safety hazards. In fact, in such conditions, the probability of plating lithium metal on the negative electrode during fast charge or regenerative braking increases substantially.

In this work, we propose two classes of negative electrode materials as advanced LIB negative electrodes both based on the use of zinc, an environmentally benign and low cost metal. Porous copper-zinc (Cu-Zn) alloys, based on a different storage mechanism (alloying rather than intercalation), provide impressively enhanced performance at temperatures as low as -30°C, while maintaining a safe operational voltage that minimizes the risk of lithium plating [2]. These novel binder- and carbon-free negative electrodes are easily

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produced by electrodeposition in aqueous solution (dynamic hydrogen bubble template method, i.e., DHBT), thus having a potentially low environmental fingerprint. This adds further appeal to the growing interest on Zn-based materials, which, by replacing graphite, could boost the volumetric capacity of next generation LIBs.

Making use of the same metal (Zn), we developed an additional class of anode materials, combining the alloying and conversion lithium storage mechanisms in a single compound, i.e., conversion/alloying materials (CAMs) [3]. Herein, a comprehensive overview on this new material class will also be provided, starting from a brief summary of the major strengths and issues related to pure alloying and conversion electrodes, subsequently introducing the two approaches to realize CAMs while highlighting some recent results, before finally summarizing their potential advantages and the remaining challenges.

[1] B. Scrosati, J. Garche, J. Power Sources. 195 (2010) 2419.

[2] A. Varzi, L. Mattarozzi, S. Cattarin, P. Guerriero and S. Passerini, Adv. Energy Mater. 2017, 1701706 (DOI: 10.1002/aenm.201701706).

[3] D. Bresser, S. Passerini and B. Scrosati, Energy Environ. Sci. DOI:10.1039/c6ee02346k (2016).

Speaker`s profile

Prof. Stefano Passerini leads the Electrochemistry for Batteries group at the Karlsruhe Institute of Technology, Helmholtz Institute Ulm (Ulm, Germany), since 2014. His research activities are focused on electrochemical energy storage in batteries and supercapacitors.

Co-author of more than 450 scientific papers (Scopus H-Index: 67, >3,300 citations in 2017), a few book chapters and several international patents.

He has been awarded in 2012 the Research Award of the Electrochemical Society Battery Division.

Since 2015 he has been appointed as Editor-in-Chief of the Journal of Power Sources.

The language of the presentation is English