Synthesis of nanostructured energy storage materials from end-of-life lithium-ion batteries

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The recycling of end-of-life (EoL) Li-ion batteries (LIBs) is mandatory to sustain the demand for the critical and strategic raw materials required to produce new energy storage devices. Electrode materials including strategic or critical raw materials such as graphite, Co, Li, Ni, and Mn, which account for more than 50% of the LIB cost, need to be recovered and recycled to the energy storage devices manufacturing chain. Currently, hydrometallurgical recycling processes can be implemented ensuring the complete recovery of the different metals composing the electrodic materials into separate streams. The major bottleneck reducing the economic and environmental sustainability of hydrometallurgical processes is represented by the numerous and costly stages performed to separate the different metals. An effective strategy for overcoming these limitations is the integration of hydrometallurgical recycling processes by the production of new energy storage materials. The solution obtained by leaching the electrodic powder of spent LIBs in the hydrometallurgical recycling process can be directly used to “resynthesize” new energy storage materials, thus excluding the downstream costly and complex separation of the different metals.

In order to directly produce high-performance and low-cost electrodes, strategies allowing for the morphology-controlled synthesis of transition metal oxides nanostructures must be integrated into the recycling chain.

In this perspective, different synthesis routes that rely on the implementation of chemical and electrochemical methods will be discussed. In particular, the synthesis of electrodes based on transition metal oxide nanowires produced by electrodeposition will be illustrated. The role of impurities coming from EoL LIBs was in-depth evaluated on the electrochemical performances of the nanowires electrodes when tested as anodes in LIBs and positive electrodes in pseudocapacitors. An integrated chemical synthesis of mixed oxide cathodes ($Li_aNi_bMn_cCo_dO_2$, a+b+c+d=2) with the simultaneous production of graphene will be presented as an innovative closed-loop LIBs recycling process.