Electrochemistry as a polyvalent tool in the design of an industrially relevant process for recycling of spent lithium-ion batteries

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Lithium-Ion Batteries (LIBs) are ubiquitous electrochemical devices, from portable electronics to electric vehicles. The tight dependence of this technology from some critical materials is forcing the scientific and industrial community to find out effective strategies to recover such materials from the constantly increasing numbers of spent LIBs. Looking at the EU area, to achieve the stringent recovery rate defined by EU regulation for the coming years recyclers still need efficient hydrometallurgical recovery processes.
Despite the relatively simple working principle, plenty of specific features of LIB technologies (crafting process, plenty of cathode chemistries, shapes and dimensions) combined with the lack of standards in manufacturing, entail challenges for the recycling processes. Thus, the development of a robust multi-step process capable of working with batteries, of any types, is up to date the most plausible solution. Besides pre-treatment stage, which may include mechanical and separation steps together with chemicals ones aimed at recovering solvent and/or lithium electrolyte, binders, etc., the core of any hydrometallurgical recycling process employs the dissolution of metal oxides from positive electrode (i.e., leaching stage) and the recovery of the dissolved metals (i.e., precipitation, separation, refining).
In the present applied research project, carried out through a joint collaboration with an engineering company part of the Consortium of the European Battery Innovation project (IPCEI Batterie 2), we are contributing to develop an industrially relevant closed-loop process for LIBs recycling. In particular, after presenting the general flowsheet of the ongoing process, the speech will be focused on discussing the potential of electrochemistry in supporting the technological challenge.
In particular, case studies will be presented demonstrating application of electrochemistry to face at both analytical and synthetic practical issues. The discussion will be focused on:

- development of a *in operando* electrochemical protocols for the on-line monitoring of both i) leaching stage and ii) metal recovery stage;
- waste-stream recovery through a DoE study of an electrodialysis cell operating at intermediate scale between benchtop and pilot-scale one.

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