Lignin-Derived Vacuum Pyrolysis Hard Carbon for Sodium Batteries

Pietro COLUCCI - *ENEA, Casaccia Research Centre*

Relying on more abundant materials, Sodium Ion Batteries (SIBs) provide a promising alternative to Lithium Ion Batteries (LIBs) for energy storage applications where the energy density is not crucial. Despite the substantial similarities between SIBs and LIBs, many challenges remain to be addressed. One of the main differences between the two battery chemistries is the anode materials, being Hard Carbon (HC) in SIBs, instead of graphite used in LIBs, as Na^+ ions do not intercalate into graphite due to their size and solvation shell. HC is a disordered carbonaceous material that is non-graphitizable and is normally obtained from the pyrolysis of organic precursors at temperatures above 1000°C under inert atmospheres. HC offers advantages such as low working electrochemical potential, a high specific capacity, and thus a high specific energy density. The electrochemical properties of HC rely heavily on the processing conditions and carbon source used. If the pyrolysis process is not properly optimized, it may result in low yield and/or a high surface area of the HC, leading to a significant capacity loss during the first cycle and reduced coulombic efficiency. This is partly attributed to the instability and high solubility of the passivation layer that forms at the HC electrode/electrolyte interface (SEI) in an SIB, which also accelerates electrolyte decomposition, reducing cycle life.

In this study, a set of HCs have been produced from lignin, as carbon source, through by mean a vacuum pyrolysis process at high temperature. The synthesis was investigated toward the process set-up optimization to obtain high quality anode material for SIBs.

If compared with pyrolysis processes in the atmospheric environment, the oxygen-free environment and high temperatures conditions in a vacuum chamber increase the compactness of the produced HC, allowing to obtain a higher energy density anodic material. Moreover, by testing different vacuum pyrolysis conditions, it has been possible to tune the material structural properties in terms of interplanar distance, graphitization degree, porosity and surface area.

The HC were characterized by X-ray diffraction and Raman spectroscopy, physisorption and thermal analysis, and by SEM for the morphological characterization. HC were tested as anode material for SIBs by galvanostatic cycling.

The experimental results for HC obtained at low pyrolisis time present the best electrochemical performances due to the better graphene-graphene interlayer distance. On the contrary, by increasing the pyrolysis time, an increase in the graphitization degree is evident examining the Raman spectra.

The interplanar distance is a parameter which depends both on the pyrolysis conditions and on the purity and characteristics of the precursor used; therefore, the use of highly purified and selected precursors as lignin can help to obtain a lower interplanar distance.

This work aims at contributing to the development of sustainable and cost-effective anode materials for SIB promoting the utilization of lignin as a valuable renewable resource.