Manufacturing of lithium-ion battery prototypes through environmentally friendly processes

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The current environmental situation of the world calls for the increasing use of renewable energies to decrease the dependency on fossil resources. However, renewable energies are intermittent and therefore require efficient large-scale storage systems. Such storage systems could be of electrochemical nature. More precisely, lithium-ion batteries could be good candidates due to their high energy density and long life cycle. In addition, lithium-ion batteries have already proven their worth in the field of portable devices.

A lithium-ion battery is composed of a positive and a negative electrode isolated from each other by a separator and in contact with an electrolyte. The lithium-ion battery works on the principle of insertion and deinsertion of lithium ions within the electrode materials and the role of the electrolyte is to transport lithium ions as efficiently as possible between both electrodes. In commercial lithium-ion batteries, the electrolyte is either a liquid or a liquid trapped in a polymer matrix. The classical liquid electrolyte is composed of a lithium salt dissolved in an organic solvent which is a mix of carbonates. The lithium salt present in the electrolyte is highly reactive when put in contact with moisture and this leads to the formation of toxic gaseous components. Concerning the mix of carbonates, it is highly flammable. Even if this classical electrolyte leads to very good electrochemical performances of lithium-ion batteries, the significant safety issues associated cannot be ignored, especially at large-scale.

The objective of this Master thesis was to investigate two safer and greener alternatives to the classical liquid electrolyte for lithium-ion batteries. The first alternative was a semi-solid electrolyte called gel polymer electrolyte, composed of a non-flammable ionic liquid trapped in a polymer matrix. This electrolyte allows to avoid the potential leaks of electrolyte and the associated safety issues. The second alternative investigated was an aqueous electrolyte called water-in-salt electrolyte. It is composed of a highly concentrated lithium salt in water, which allows to widen the electrochemical stability window of water. This aqueous electrolyte therefore discards the safety issues associated to the organic solvent.

The classical liquid electrolyte and the two alternatives were studied from the electrochemical point of view. First, the stability of each electrolyte was investigated. Then, the electrolytes were characterised in combination with $LiFePO_4$ and $Li_4Ti_5O_{12}$ electrodes produced with a water-based manufacturing process. Half-cell and full-cell configurations were assembled and subjected to electrochemical tests. The final objective was to compare the electrochemical performances of the classical liquid electrolyte to those of the gel polymer electrolyte and of the water-in-salt electrolyte.

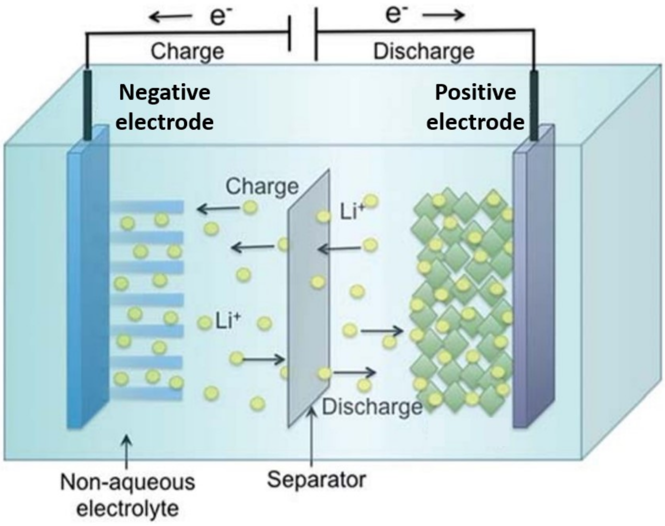

Figure 1: Representation of the charge and discharge of a lithium-ion battery, modified from [1].

[1] Roy, P. & Srivastava, S.K., 2015. Nanostructured anode materials for lithium ion batteries. *Journal of Materials Chemistry A*, 3, 2454-2484. https://doi.org/10.1039/C4TA04980B