Autonomous Self-Healable Silicon Anode for Next Generation Lithium-Ion Batteries

Self-healing is a measure of material's ability to repair damage. Physical and chemical processes have been used to obtain self-healing polymers for various applications. Different approaches are involved for these systems, such as shape-memory effects, covalent-bond reform, heterogeneous systems, diffusion and flow, and the dynamics of supramolecular chemistry. Different approaches are used to achieve self-healing polymers, in particular, the role of the healing system in chemistry is highlighted, which enables thermal transients, damage repairing and reconnection. Moreover, self-healing systems and their energy storage applications are currently getting great importance. Inspired by the dynamic network structure of animal dermis, in which collagen fibril (rigid and strong) and elastin fibril (soft and elastic) crosslink through supramolecular interactions to form a sturdy and flexible material we hypothesized that the combination of a rigid conductive polymer with a soft hydrophilic polymer through proper supramolecular interactions would yield a strong and robust polymer binder.

According to the literature, the external stimulus such as heat, light, pH and redox initiate the healing process. This process is known as non-autonomous self-healing when some additional external stimulus is needed. Considering the battery chemistry, it is the most functional method to choose self-healing structures and batteries with the help of hydrogen bonds in order to make the self-healing process occurs autonomously. In the literature, polymerized β-cyclodextrin (β-CD) has been used as an advanced binder for Si-nanoparticle anodes, and cracks in the electrode can be avoided with its reversible properties through supramolecular cyclodextrin or hydrogen bonding compounds[1]. Dynamic bonds such as hydrogen bonds between composites positively affect the durability of the Si anode performance. For example, the Si anode was coated by the researchers with hydrogen bond-oriented polymer binder layers based on polyimide polymer such as Upy, resulting in electrochemical performance ten times longer than conventional silicon anodes[2].

Horizon projects such as BAT4EVER and HIDDEN under Battery 2030+ initiative have been investigate the integration and optimization of self-healing polymers in Li-ion battery. In the scope of the BAT4EVER project, supramolecular coupling of polyaniline and polyvinyl alcohol via dynamic boronate bond yields polyaniline-polyvinyl alcohol hydrogel with outstanding tensile strength and electrochemical performance. The self-healing chemistry in the Si anode prevents unbalanced volumetric changes and cracks on the electrode surface. Thus, electrochemical performance losses are decreased. The self-healing functionalized components of lithium-ion batteries, which focus on improving and optimizing properties such as high energy density, high voltage, long life, and cycle stability, are of great importance for next-generation batteries [3].

References

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement 957225 (BAT4EVER).