The mechanics of batteries: open issues and future perspectives

Prof. Alberto Salvadori

DIMI, Università degli Studi di Brescia, Brescia, Italy

Date	**18 June 2024**
Time	**10.30–11.30**
Room	**2R, DICAM, Mesiano**

Although the development of next generation of batteries is a prominent subject of the electrochemistry research, mechanics is well known to play a fundamental role in the response of energy storage systems. The primary focus of this seminar is discussing open issues and future perspectives, either in lithium-based solid-state batteries or in sodium-batteries.

A rigorous modelling approach should account for the large deformations involved during lithium deposition, a surface growth process that often triggers dendritic growth. The impossibility of defining a stress-free and kinematically compatible reference configuration is an unsolved quest in the Lagrangian finite strain mechanics of surface growth. Eulerian formulations, which have been proposed to circumvent the need of the reference configuration, raise complementary open challenges such as the need of tracking the deposition front.

Dendrite nucleation is connected to non-homogeneous deposition during plating. While it may not be feasible to entirely prevent the initiation of dendritic cracks, short circuits over numerous cycles may be prevented by either inhibiting crack propagation or restricting the overall growth of Li dendrites within pre-existing dry cracks. Highly deformable visco-plastic Li can in fact penetrate pre-existing fractures in the brittle SE, giving rise to high internal pressures and driving crack growth.

Sodium-ion batteries have emerged as a promising alternative to lithium-ion batteries in the pursuit of sustainable and high-capacity energy storage systems, owing to the abundant availability of sodium. Nevertheless, the development of sodium-ion batteries is impeded by obstacles, particularly the expansion of electrode materials and the resulting fragmentation. Tin-based anodes possess significant potential as they can create binary alloys with sodium, resulting in the formation of compounds with high capacity. Unlike carbon anodes, tin's alloying process with sodium causes phase transformations, which may lead to electrode degradation.

Our research aims at developing a model for the mechanical and chemical characteristics of phase transformations occurring in the anode. Hence, we employ a dual methodology integrating viscoplasticity, to model the mechanical stresses and strains, and the Cahn-Hilliard equation, to simulate the chemical diffusion processes at finite strains. The geometry of the model is derived from imaging techniques, including Scanning Electron Microscopy (SEM) and synchrotron X-ray tomography, providing 2D and 3D views of the anode's microstructure. Preliminary findings, particularly from the constitutive theory aspect, have shed light on the material behavior underlying the volumetric change and plastic deformation in anode materials.

The seminar is organized by the Solid and Structural Mechanics Group [D. Bigoni, F. Dal Corso, L. Deseri, D. Misseroni, M.F. Pantano, A. Piccolroaz, N.Pugno, R. Springhetti]