Mathematical Modelling of Lithium-Ion Batteries

Wolfgang Dreyer

Weierstrass Institute for Applied Analysis and Stochastics (WIAS),
Mohrenstr. 39, 10117 Berlin, Germany

wolfgang.dreyer@wias-berlin.de

Reversible storage systems serve to store electrical or chemical energy for later use. They are of key importance in modern energy technologies. In this study we consider storage systems that consist of an ensemble of many interconnected storage particles that particularly appear in lithium-ion batteries. During charging and discharging of a battery, one observes a phase transition and hysteretic behaviour. There are two regimes for fast and slow charging with extremely different mathematical models. However, the voltage-charge plot is qualitatively the same in the two regimes.

The appropriate model of the fast charging regime is a viscous Cahn-Hilliard model with mechanical coupling. It describes a free boundary problem in a single storage particle. In this regime the particles of the ensemble are simultaneously charged.

If the time to approach equilibrium in a single storage particle is much smaller than the time for full charging of the ensemble, we are in the slow charging regime where we meet a totally different scenario. In this regime the particles are charged according to the rule *one after the other*. Here the phase transition is a many-particle effect and happens in the ensemble instead within a single particle. Its evolution is modelled by a nonlocal and nonlinear conservation law of Fokker-Planck type. There are two parameter that control if the ensemble transits the 2-phase region along a Maxwell line, along a hysteresis path, or if the ensemble shows the same behaviour as its constituents.