Conversion Materials for Energy Storage

Maximilian Fichtner

The lecture will start with an introduction to the problem of energy storage. Chemical methods offer the highest energy density for storing energy; they are the most interesting option for high energy and high power applications such as automobiles and for seasonal storage of electric energy from renewables.

For storage of hydrogen or lithium, today´s systems are based on intercalation materials. However, as the energy density shall be improved by a factor of two (H storage materials) or five (battery materials), a paradigm change is necessary in the materials development in order to be able to reach these goals. From the current knowledge, only systems based on the conversion principle offer such high energy densities.

Conversion materials are based on solid state chemical reactions where several reaction partners may be involved depending on whether the material is charged or discharged. The systems undergo a massive reconstruction of their structures, which is different in intercalation based systems.

Standard thermodynamics can be used in order to preliminary assess the potential of such reactions. Rate limiting kinetic steps are nucleation and growth in most cases. Hence, the mobility on the nanoscale is essential for the performance of such systems and catalytic amounts of additives have been successfully applied to mobilize certain species in the nanocomposite. For battery materials, electronic transfer from and to the active components is an important precondition which has to be established and maintained during cycling. This can be achieved by mechanical alloying with conductive agents such as nanocarbon for example. Moreover, the use of electronic nonconductors as active materials requires small particle diameters in order to be able to transfer electrons to and from the material and, thus, making the electrochemical conversion possible. The design and the stability of the nanostructure of such functional nanocomposites are essential for the performance and cyclic behavior of the whole system.

Several examples from H storage materials and battery research will be presented and discussed, and current directions of research in these fields will be outlined.