Abstract #407, 223rd ECS Meeting, © 2013 The Electrochemical Society

The Significance of Tortuosity for the Performance of Lithium-Ion Batteries

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The power capability of lithium-ion cells is strongly influenced by the transport properties of the electrochemically active components. However, independently of the specific material, the transport properties are controlled by its volume fraction and microstructure characteristics. Among all, the tortuosity of both electrodes and of the separator always reduces the conductivities and diffusivities. Whether tortuosity is of a critical size for a specific component or not, depends on its transport properties compared to the other relevant phases.

One way to determine the tortuosity τ is to use microstructure reconstructions from micro x-ray or FIB tomography (1). The calculation of τ uses the effective conductivity trough the structure which is obtained by a finite element simulation on the reconstruction as model geometry (see fig. 1)

First, a discussion of critical points arising during application of this method is given. This will cover the geometry and the mesh as well as the boundary conditions applied for the simulation.

Second, the approach by FEM simulations is compared to other common methods to estimate tortuosity (2,3). This includes the well-known Bruggemann equation and related approaches, as well as geometrical estimations. Also a comparison to measurements will be given.

Finally, the importance of the derived values for cell modeling using homogenized electrode models will be discussed.

References

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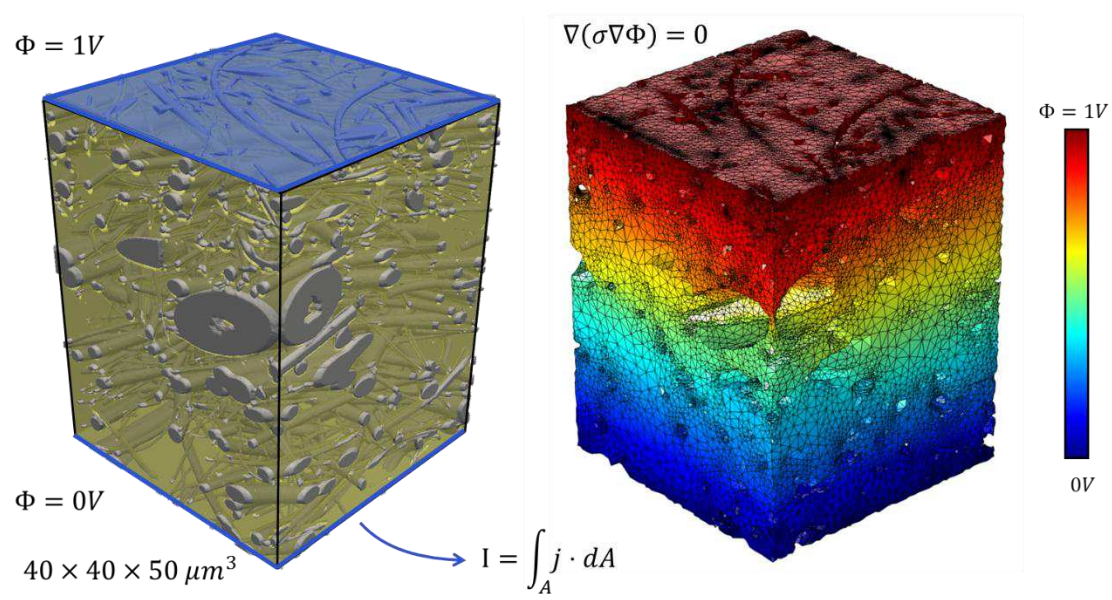

Figure 1: Model geometry of a glass fiber separator used for lithium-ion cells. The simulation result shows the potential distribution inside the porosity. From this, the flux through the structure can be calculated. With the effective conductivity and the actual conductivity set in the model, the tortuosity is calculated.