Determination of Load Dependent Thermal Conductivity of Porous Adsorbents

O. Kraft[1], J. Gaiser[1], M. Stripf[1]

[1]University of Applied Sciences, Karlsruhe, Baden-Würtemberg, Germany

Abstract

Standard measuring techniques for thermal conductivity cannot be readily applied to determine the load-dependent thermal conductivity of porous adsorbents, because the local ad- and desorption inside the specimen and the thickness of the specimen are not considered. Hence, in this work a new measuring procedure combining the transient hot bridge (THB) technique (Hammerschmidt and Meier V. (2006)) with a finite element model set up in COMSOL Multiphysics® software for postprocessing is presented. An easy to use COMSOL application is evolved to determine the load-dependent thermal conductivity considering the local ad- and desorption processes and the specimen geometry. The results of this new procedure can be used for detailed system simulations of ad- and desorption processes, e.g. regenerative filters or adsorption heat pumps.

The measurement set-up of the THB method is made up of the THB sensor which is clamped between two equivalent specimens. For the measurement of adsorbents, the measurement set-up is located in a chamber in which the vapor pressure of the working fluid is controllable. The sensor itself consists of a structured nickel film forming the conducting paths between two polyimide sheets. Its layout is shown in Figure 1. The eight meander shaped conductors are arranged symmetrically for an equal-resistance Wheatstone bridge. During measurement, the constant electric current IB flows through the sensor and establishes an inhomogeneous temperature profile which changes the bridge voltage UB(t). The measured time-dependent bridge voltage is used to compute the thermal conductivity. In Figure 2 the qualitative measurement signal UB(t) is shown.

The three dimensional finite element model of one specimen, one polyimide sheet with the printed circuit paths of half the film thickness and a symmetry boundary condition form the basis of the COMSOL application (Figure 1b). In order to simulate the voltage signal, the COMSOL physics interface Electric Currents is used to specify the electric current IB as well as the ground for measuring the bridge voltage. In the model, all of the supplied power is converted into heat within the strips. To calculate the heat transfer within the specimens, the physics interface Heat Transfer in Porous Media is used and supplementary, a partial differential equation is inserted to describe the adsorption kinetics. Furthermore, the Transport of Diluted Species in Porous Media interface is used to describe the mass transfer of the working fluid. An optimization algorithm finally adjusts the simulated thermal conductivity systematically, until the computed slope of the bridge voltage corresponds to the measured one and the thermal conductivity is found.

The first tests with the new measuring techniques were successfully performed with the working pair active carbon and methanol. The computed effective thermal conductivity increases with rising methanol load due to the growing proportion of the thermal

conductivity of the adsorbed phase. The results are shown in Figure 3. The computed value of the dry carbon complies to measurements with standard techniques.
The new technique extends the range of application of the transient hot bridge method and sheds light on the physics that influences the thermal conductivity of porous media.

Reference

[1] U. Hammerschmidt and V. Meier, New Transient Hot-Bridge Sensor to Measure Thermal Conductivity, Thermal Diffusivity, and Volumetric Specific Heat, International Journal of Thermophysics 27.3, S. 840–865 (2006)

Figures used in the abstract

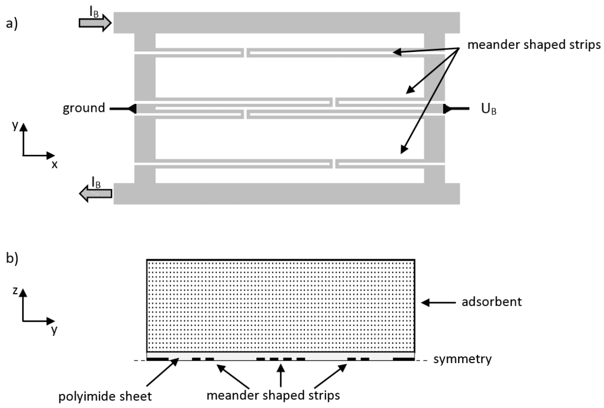

Figure 1: Transient hot bridge method: a) schematic construction of the sensor b) measurement setup in the simulation.

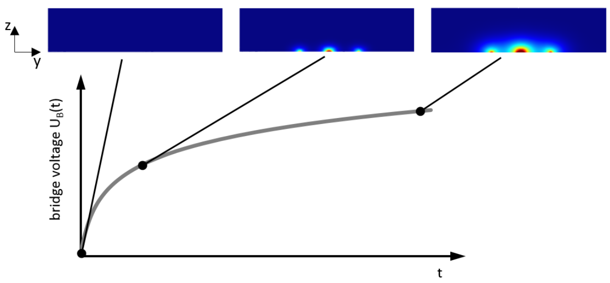

Figure 2: Qualitative laps of UB(t) and the temperature plot.

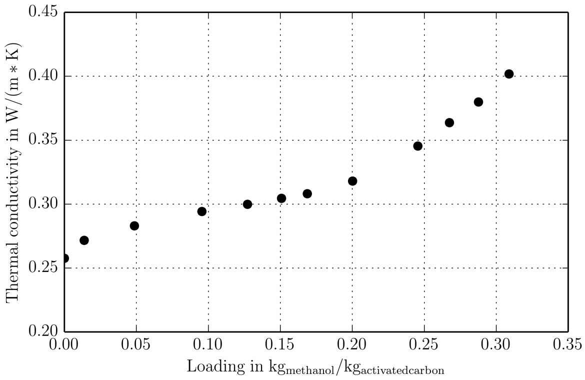

Figure 3: Load dependent thermal conductivity of activated carbon/methanol.