Transient Hot-Bridge Thermal Transport-Properties Meter

Ulf Hammerschmidt [C, S] and Vladislav Meier
Physikalisch-Technische Bundesanstalt, Braunschweig, Niedersachsen, Germany

"When reporting the result of a measurement of a physical quantity, it is obligatory that some indication of the quality of the result be given so that those who use it can assess its reliability." This introductory sentence of ‘The Guide to the Expression of Uncertainty in Measurement’ (ISO GUM), stimulated us to design and set up an instrument that not only measures thermal transport properties but also assesses related GUM uncertainties. The instrument simultaneously determines thermal conductivity (0.02 to 100 W/(m K)) and thermal diffusivity (0.05 to 10 mm^2/s) at uncertainties of typical 3 % and 6 %, respectively. The allowed working temperature (-40 to 200 °C) of a material under test is also monitored continuously. The key-component of the Thermal Transport-Properties Meter is a transient hot-bridge (THB-) sensor that is sandwiched between the sample halves. Looking like a thin heater-foil, the sensor consists of four parallel Nickel-strips that simultaneously act as heat sources and resistance thermometers. Each strip is segmented into two parts of different lengths to effectively compensate for the perturbing end-effect. All strips are switched to form a symmetric bridge that minimizes any bias. Owing to this special arrangement, there is no need for balancing prior to a run and for guessing the end of this transient event. The THB sensor is operated fully automatically by a System-Sourcemeter (Keithley 2612). This device consists of a voltmeter, a current source and a timer. Its customer-programmable processor runs our complete software package including data acquisition and evaluation as well as the assessment of GUM uncertainties. A built-in expert-system proposes initial values for the sensor’s input parameters: electrical current and duration of a run. The same system controls the respective uncertainties at the end of each run as an indication of the quality of the results. Whenever an uncertainty is higher than the above mentioned typical value, the user is informed to initiate a second or third run at ever optimized parameters proposed by the instrument itself. So far, sample-specific components of the uncertainty like, e.g., abnormal high thermal contact resistances, are not taken into account. We plan to incorporate such systematic deviations as well since this room for improvements actually exists. The sensor’s exemplary output function is known well so that major characteristic departures can be detected, identified and notified to the user.