An Ultrafast Multiple-Wire Microchip to Measure the Thermal Conductivity and Thermal Diffusivity of Gases

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Based on a silicon microchip, a miniaturized thermal transport-properties sensor was constructed. It allows the measurement of thermal conductivity and thermal diffusivity of less than 1 ml gas within a few milliseconds at a very low heating power. The microchip contains a 2000-µm-wide 300-µm-deep channel that is spanned by a series of thirteen unsupported bridges. These serve as one hot and twelve cold wires, acting respectively, as the heat source and the thermometers of the sensor. The cold wires are arranged symmetrically to the center hot wire at six different distances between ±50 µm and ±500 µm. To ensure high signal resolution, each thermometer is switched to its own Wheatstone-bridge circuit of the external IO-unit. The thermal conductivity is determined using the quasi-steady-state (QSS-) technique [1]. Here, a step pulse of a few milliseconds is applied to the hot wire while measuring the quasi-stationary response of selected pairs of thermometers. Their individual differences in temperature furnish the measurand on a redundant basis. The thermal diffusivity results from a time-of-flight measurement: a 100-µs-pulse is fed to the hot wire from where the resulting heat pulse propagates through the gas, in both ways passing one cold wire after the other. For each one of them, the arrival of the temperature maximum is detected. Again on a redundant basis, the thermal diffusivity is evaluated from all these points in time. A preliminary assessment reveals standard uncertainties for both measurands mentioned to be well below 5 %.

References

[1] U. Hammerschmidt, A Quasi-Steady State Technique to Measure the Thermal Conductivity, Int. J. Thermophys. 24:1291 (2003).