Acoustic Measurements in Gases: Applications to Thermodynamic Properties, Transport Properties, the Temperature Scale, and Flow

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Cylindrical acoustic resonators developed at NIST are routinely used to measure the speed-of-sound in gases with uncertainties less than 0.01%. The speed-of-sound data are fitted by virial coefficients having the temperature dependencies of model intermolecular potentials to obtain gas densities and ideal-gas heat-capacities with uncertainties on the order of 0.1%. These techniques have been applied to more than 20 pure gases and mixtures. The corrosive and toxic gases that are used in semiconductor processing are now under study.

Two novel acoustic resonators are described elsewhere in this conference. One is the Greenspan acoustic viscometer that is capable of measuring the viscous diffusivity $D_v \equiv \eta/\rho$ of gases with an imprecision of 0.1% or less. Our goal is to achieve an absolute accuracy of 0.1% which is competitive with the best alternative methods of gas viscometry. A second novel acoustic resonator was designed to measure the Prandtl number Pr of gases. ($Pr \equiv D_v/D_t$, where D_t is the thermal diffusivity. The Prandtl number is used to correlate heat transfer from a solid to a flowing fluid.) When the results from this resonator are combined with the results from the Greenspan viscometer, D_t of the gas is determined.

Spherical acoustic resonators are used when the highest possible accuracy is needed. A spherical resonator was used at NIST to measure the universal gas constant R with a fractional standard uncertainty of 1.7×10^{-6}. This work is now being extended at NIST and in Great Britain to measure imperfections in the internationally accepted temperature scale (ITS-90) in the range 200 K to 700 K. In effect, very accurate measurements of speed of sound in argon will be used to calibrate other thermometers.

Acoustic resonators respond only weakly to uniform flows and to slow, unsteady flows such as buoyancy driven convection. Thus, resonators make poor flow meters. NIST is developing non-resonant acoustic techniques to calibrate meters used in semiconductor processing to measure low flow rates in corrosive gases.