Progress Towards a Primary Pressure Standard Based on the Dielectric Permittivity of Helium

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NIST is developing a primary pressure standard based on measuring the temperature and the dielectric permittivity, ε, of helium gas in the pressure range 0.5 MPa < p < 7 MPa. The standard will rely on ab initio calculations of the molar polarizability, the density virial coefficients, and the dielectric virial coefficients of helium. We measured [ε(p,T) - 1] of helium near 0 °C and 7 MPa using an ellipsoidal microwave cavity resonator. The shape of the cavity completely lifted the triple degeneracy of a few microwave modes, allowing the corresponding resonance frequencies to be measured with part-per billion precision. The walls of the cavity were copper-plated, maraging steel. Near 7 MPa, the relative uncertainty of the measured value of [ε(p,T) - 1] was 12×10^{6}; this uncertainty was dominated by the uncertain compressibility of the maraging steel, which we determined using resonant ultrasonic spectroscopy.