SMALL SILICON THERMISTORS AS HOT-ELECTRON BOLOMETERS

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We discuss a new type of direct detector, a silicon hot-electron bolometer, for measurements in the far-infrared and submillimeter spectral ranges. Semiconductors with partially compensated doping levels just below a metal-insulator transition can make highly sensitive thermistors at sub-kelvin temperatures. Silicon thermistors have been used successfully as the thermometer element in x-ray microcalorimeters and FIR bolometer arrays. In such arrays, the weak thermal conductance is engineered by supporting the radiation absorber and thermometer on a thin membrane or bridge. However, the electron-phonon thermal conductance in doped silicon can be made the dominant thermal isolation from the cryogenic bath, potentially allowing a smaller thermal conductance and a more sensitive bolometer for low-background photometric and spectroscopic applications. Another key feature is that, while the dc resistance of a silicon thermistor film is very high, its surface impedance at terahertz frequencies is conveniently low, making feasible efficient antenna coupling of radiation into the hot electron system. The temperature independent high dielectric constant predicted by theory is observed by us directly in fourier transform spectrometer measurements, and its frequency dependent loss fits a relaxation time model with physically reasonable parameters. To test for deviations from simple scaling of the electron-phonon conductance with volume, we made small silicon thermistors with linear dimensions 1-10 μm approaching the typical variable range hopping distance responsible for electrical conduction at temperatures of order 100 mK. While deviations were observed, a hot-electron model still works well with a conductance that is only a few percent of typical values for ordinary metals. In a 10 μm $\times$ 10 μm $\times$ 1.4 μm device, we measured a thermal conductance as small as 0.4 pW/K at 100 mK (still decreasing with temperature), which corresponds to a thermal fluctuation limited Noise Equivalent Power (NEP) of 5×10^{-19} W/$Hz^{0.5}$.

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