Comparative Study on Temperature Sensors for Antenna-Coupled Bolometers: MOSFET, PN Junction Diode and Resistor

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Temperature sensor is the most important element in bolometers, and many kinds of sensors, such as resistor (thermistor), pn-junction diode, FET, etc., have been reported. However, there is a tradeoff between responsivity and output noise, and fair comparison has not been made among different devices and materials. This time, we systematically compare the performances of MOSFETs (n- and p-channel), pn-junction diodes (with and without body doping) and resistors with different materials (n^+ and p^+ single-crystal Si, and n^+ polycrystalline Si) by assuming the 1-THz antenna-coupled bolometer that allows the area of 15 μm × 15 μm for the integrated heater and the temperature sensor.

As shown in Fig 1, the temperature sensor and the heater together with the insulation layer between them are placed at the center of the antenna. Assumed device dimensions are given in Table 1. The constant current load of 10 μA is considered for the estimation of the responsivity and noise equivalent power (NEP). For simplicity, the antenna-coupled structure is shown only for MOSFET and resistor, but the same structure is assumed also for diode. I-V and noise measurements have been performed for FET (L=1 μm, W=5 μm), diode (L=2μm, W=50 μm) and resistor (L=100 μm, W=1 μm), then the data is converted for assumed device dimension. Thermal resistance parameters are also extracted from experimental data, and the temperature rise is calculated for the estimation of the responsivity. Table 2 shows the performance comparison of the studied devices. N-channel MOSFET shows the largest responsivity of 338 V/W. NEP, which is inversely proportional to the responsivity, is estimated from the output noise voltage at 10Hz. The comparison table interestingly shows the resistive bolometer of polysilicon has an NEP comparable to that of n-channel MOSFET due to the small noise, although the responsivity is not high.

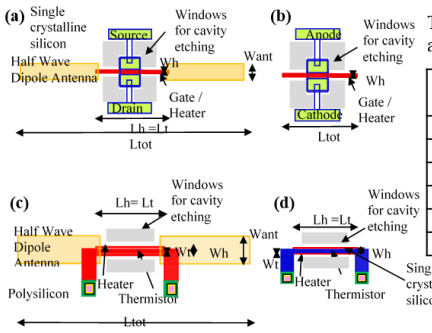

Fig 1. (a) Antenna-coupled MOSFET bolometer, (b). Diode bolometer, (c). Antenna-coupled resistive bolometer (polycrystalline thermistor), (d). Resistive bolometer (single crystalline thermistor)

Table 1. Dimensions of assumed devices

Parameter	Dimension (μm)
Ltot	50
Lh	15
Lt	15
Wh	1
Wt	0.6
Want	5.2

Table 2. Performance comparison of various bolometers

Device	Voltage Noise (at 10Hz) V/(Hz)$^{1/2}$	Responsivity (V/W)	NEP W/(Hz)$^{1/2}$
N MOSFET	7.47E-08	338	2.21E-10
P MOSFET	7.72E-08	73.6	1.04E-09
Diode (without body doping)	2.08E-07	134	1.54E-09
Diode (with body doping)	2.26E-07	135	1.68E-09
Resistor n+	2.69E-08	53.7	5.01E-10
Resistor p+	7.71E-08	222	3.47E-10
Resistor Polycrystalline Si	1.77E-08	71.4	2.48E-10