Effect of Joule Heating on Titanium Wires for Terahertz Antenna-Coupled Bolometer

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An antenna-coupled bolometer is a viable approach to detect terahertz (THz) waves. For resistive bolometers, the important criterion is the temperature coefficient resistance (TCR) of thermistor material, since it is directly proportional to responsivity (R_v) and inversely proportional to the noise equivalent power (NEP). Especially, the device performances of metallic bolometer directly gets benefit from the improved TCR. The TCR of thin and narrow wires is affected by the presence of defects or grain boundaries, and can be increased by annealing. Therefore, this time we study the effect of Joule heating caused by the large current through the wire. The fabricated titanium (Ti) wire structure and its cross-section are shown in Fig. 1 (a & b). Ti has been selected as a possible candidate for thermistor material due to its large resistivity and small thermal conductance. Ti wire was formed by patterning of electron-beam (EB) evaporated Ti thin film using laser lithography. After that the deep cavity for thermal isolation was formed by CHF_3 RIE and SF_6 plasma etching.

After the device fabrication, the two devices with different lengths (L) of 50 μm and 100 μm and same width (W) of 2 μm were taken for characterization. The basic parameters of device such as electrical resistance (R) and TCR were obtained by DC IV measurement at 240-300 K. The measured resistance (TCR) of devices are 252 Ω (0.202 %/K) and 495 Ω (0.204 %/K), for L = 50 μm and 100 μm, respectively. The sheet resistance estimated from the measured resistance and TCR is shown in Fig. 2 (a). The electrical resistance linearly increases with the temperature. To check the effect of Joule heating, large constant voltage instead of current (to avoid thermal run away) was applied step by step until the 100% rise of resistance is achieved. The change in current and resistance during the Joule heating is shown in Fig. 2 (b & c). Surprisingly, the reversal of the TCR value to negative one and sheet resistance with respect to temperature were observed as a result of Joule heating, as shown in Fig. 2 (d). The measured resistance after Joule heating are 499 Ω and 1.13 kΩ, for L = 50 μm and 100 μm, respectively, which is around 2 times larger than that before Joule heating. The measured TCR value are -0.222%/K and -0.099 %/K, for L = 50 μm and 100 μm, respectively. The absolute value of TCR for the former becomes larger than that before Joule heating. Hence, the results implies that the Joule heating can improves the performance of the device by changing its material property.

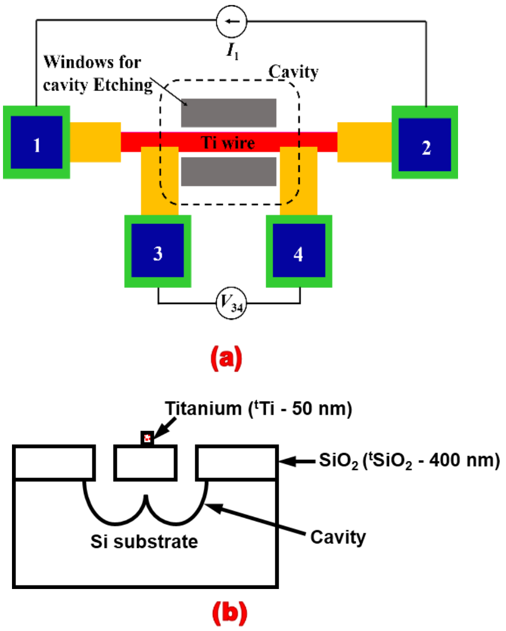

Fig. 1 (a) Fabricated device structure and measurement method for studying joule heating (b) Cross-sectional view of fabricated device effect.

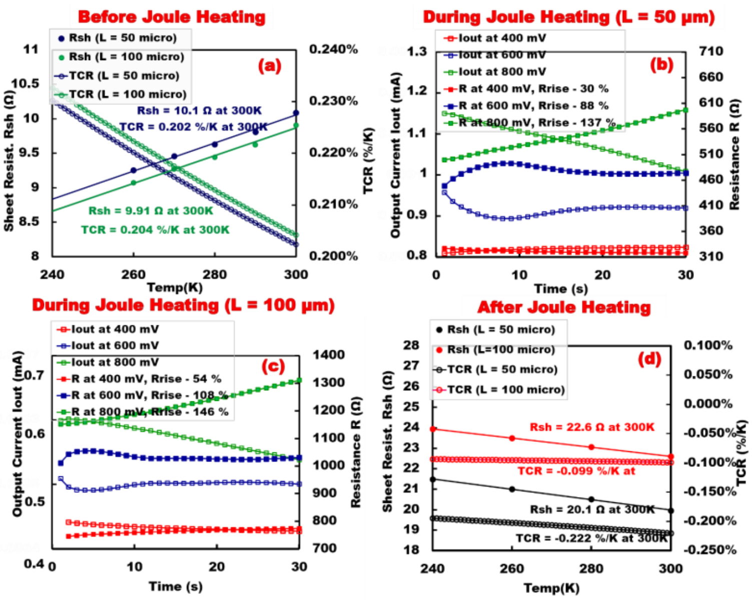

Fig. 2 (a) Measured sheet resistance and TCR before Joule heating (b, c) Change in current and resistance during Joule heating at const. step voltages for L= 50 and 100 μm, respectively. (d) Measured sheet resistance and TCR after Joule heating.