MEMS ボロメータの感度に対する梁表面段差構造の影響

Effect of surface step structures on the thermal responsivity of MEMS bolometers

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Terahertz (THz) detectors are one of the crucial components in the THz technologies. Recently, we reported a room temperature, high-speed THz bolometer using a GaAs doubly clamped MEMS beam resonator [1,2]. Figure 1(a) shows a schematic of the device structure. When the doubly clamped MEMS beam is heated by THz radiation, a thermal stress is induced in the MEMS beam and its resonance frequency decreases. We use piezoelectric capacitors on both ends of the MEMS beam to drive and detect the vibration of the beam. The present device detects the frequency reduction induced by heating and works as a very sensitive thermometer. Previously, we found that initial beam deflection reduces the thermal responsivity of the MEMS bolometers. To suppress the initial beam deflection, we preloaded a tensile strain in the MEMS beam [3]. However, we found that although the deflection is reduced, it still remains. In this report we show that a significant part of the residual beam deflection is induced by the step structure on the beam surface.

We have prepared MEMS beam samples with various mesa heights, h, as shown in Fig. 1(a), and investigated how the mesa height affects the responsivity. When a heat is applied, the resonance frequency of the MEMS beam decreases until the MEMS beam is buckled, and then it starts increasing with further heating. The deflection of the MEMS beam can be characterized by the resonance frequency at the buckling point, f_c. For an ideal flat MEMS beam, f_c goes to zero. However, f_c increases with increasing beam deflection. We have prepared 1μm-thick MEMS beams with various mesa heights, h. Figure 1(b) shows the profiles of the sample surface. h was varied from 0 to 183nm. A 100nm-thick Au electrode was deposited on the 183 nm mesa. Other samples had 17nm-thick NiCr film electrodes. We applied heat to the MEMS beam and the normalized resonance frequency is plotted in Figure 1(c) as a function of the heating power. With increasing h, f_c increases from $0.24f_0$ to $0.86f_0$, indicating that the estimated effective beam deflection increases from 10 nm to 230 nm. This result shows that high surface step structures on the MEMS beam give an effective beam deflection and reduce the thermal responsivity of the MEMS bolometers.

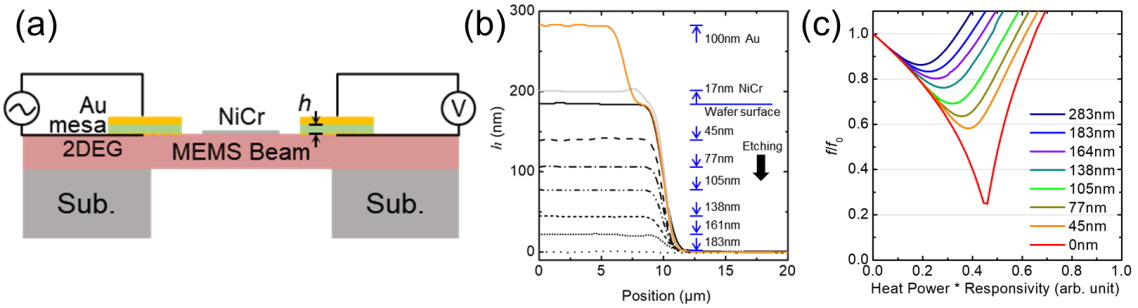

Fig.1 (a) Schematic of MEMS resonator as THz bolometer. Dimension of the MEMS beam is L80μm W26μm H1.0μm. (b) Profile of the sample surface. (c) Resonance frequency shift as function of heating power.

Ref. [1] Y. Zhang, et al., Appl. Phys. Lett. 108, 163503 (2016). [2] Y. Zhang, et al., J. Appl. Phys. 125(15), 151602 (2019). [3] B. Qiu, et al., Appl. Phys. Lett. 117, 203503 (2020).