臨界圧縮応力を用いた MEMS ボロメータの熱感度増大効果
Enhancement in thermal responsivities of MEMS bolometers by introducing a critical buckling strain

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Terahertz (THz) detector is 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]. Fig. 1(a) shows schematic of the device. 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. The present device detects the frequency reduction induced by heating and works as a very sensitive thermometer. The thermal responsivity, R, can be improved by modifying the MEMS beam dimensions. A longer MEMS beam accumulates more heat and shows a higher thermal responsivity. However, its response time increases. In this report we propose a new method to improve R without deteriorating the detection speed, by introducing a preloaded compressive strain in the MEMS beam. Fig. 1(b) shows the relationship between the resonance frequency and the compressive force applied to the MEMS beam. The slope of the curve gradually increases as the force approaches the critical buckling point. This indicates that the thermal stress due to radiation heating gains a higher R when a compressive strain near the critical buckling point is preloaded in the MEMS beam.

In this work, we use a lattice mismatch between GaAs and InGaAs to induce a compressive strain in the MEMS beam. We have prepared samples of doubly clamped MEMS beam resonators with various beam lengths, L, by using strained $In_xGa_{1-x}As$ (x = 0.0015) as the beam materials on GaAs substrates. Since the critical buckling strain, by which the compression in Fig. 1(b) is normalized, is proportional to L^{-2}, we can approach the critical buckling point by changing L instead of increasing In composition in the wafer. Fig. 1(c) plots R of the InGaAs and reference GaAs samples as a function of L. For the reference GaAs samples, R is proportional to L^3, which results from the increase in the thermal time constant. On the other hand, the InGaAs samples show higher R and R increases faster than L^3. This difference is due to the steeper slope in Fig. 1(b) when the compression approaches the critical point. This result indicates that, by introducing compressive strain, we can dramatically increase thermal responsivity of the MEMS beams without deteriorating the detection speed.

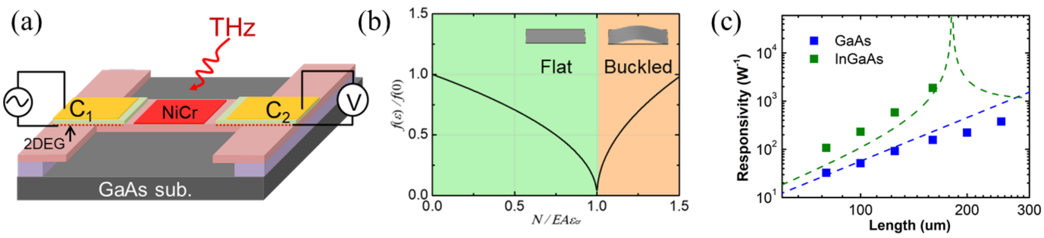

Fig.1 (a) Schematic of MEMS resonator as THz bolometer. (b) Resonance frequency shift as function of compression normalized by critical buckling strain. (c) Responsivity as function of beam length. Dots: experiment data, lines: theory.

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