Enhanced thermal sensitivity of a microelectromechanical bolometer by introducing preloaded strain in the beam structure

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Previously, we reported a room temperature, sensitive terahertz (THz) bolometer using a doubly clamped microelectromechanical (MEMS) resonator [1], which detects a shift in the resonance frequency caused by heating due to radiation. For bolometer applications, it is highly desirable to increase the thermal sensitivity of the device. When a heating power is applied to a NiCr film placed on the MEMS beam surface, as schematically shown in Fig. 1(a), we observed a reduction in the resonance frequency when the heating power was smaller than 1 mW, as seen in Fig. 1(b). However, as the heating power was further increased, the resonance frequency started to increase, which is because of the buckling of the beam when the internal stress exceeds the critical load. We found that the positive slope is 2~3 times steeper than the negative slope, suggesting that an enhanced thermal sensitivity is obtained when a small buckling is introduced in the MEMS beam.

Therefore, we have introduced a preloaded compressive strain in the beam by using the lattice mismatch between $In_xGa_{1-x}As$ ($x = 0.0013$) and GaAs, as shown in Fig. 1(c). Two devices of the same dimensions (120L×30W×1.2H μm^3) have been fabricated with $In_xGa_{1-x}As$ and GaAs beam structures, respectively. The GaAs device shows a frequency responsivity of 120 W^{-1}, whereas the $In_xGa_{1-x}As$ device shows an enhanced frequency responsivity of nearly 300 W^{-1}, as shown in Fig. 1(d), demonstrating that the introduction of buckling is useful for achieving higher thermal sensitivity for MEMS detectors.

Ref. [1] Y. Zhang, Y. Watanabe, S. Hosono, N. Nagai, K. Hirakawa, Appl. Phys. Lett. 108, 163503(2016).

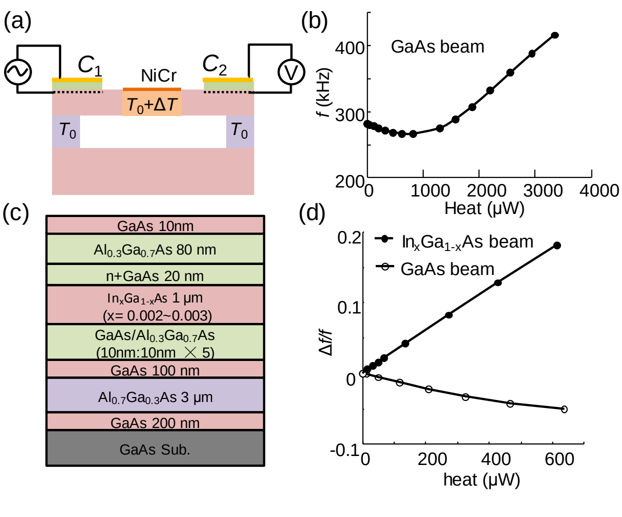

Fig.1 (a) Schematic illustration of the THz MEMS bolometer. (b) The shift in the resonance frequency with increasing heating power for a GaAs beam resonator. (c) The wafer structure of an $In_xGa_{1-x}As$ beam resonator. (d) Normalized frequency shift plotted as a function of the heating power for the $In_xGa_{1-x}As$ beam and the GaAs beam, respectively.