GaAs MEMS テラヘルツボロメータの応答スペクトルに対する Reststrahlen 効果とフォノン吸収の影響

Effect of Restrahlen band and phonon absorption on the response spectra of GaAs-based MEMS terahertz bolometers

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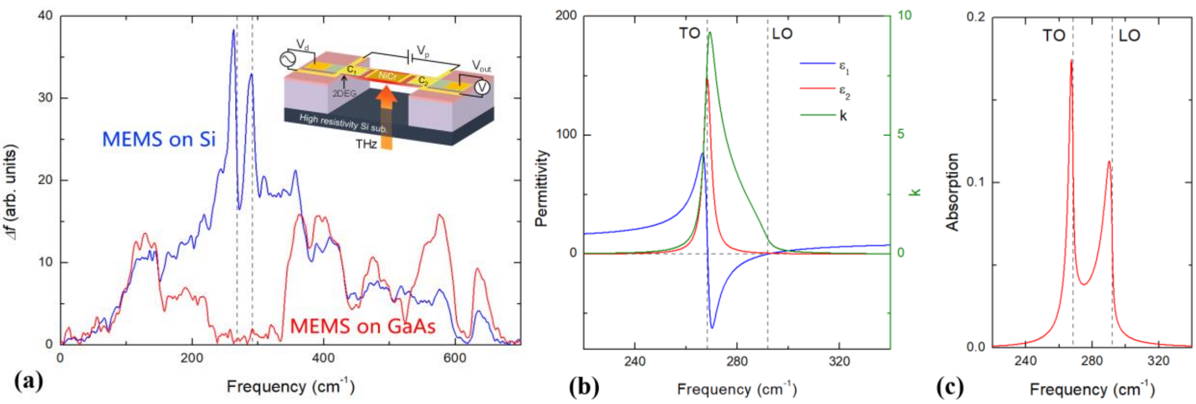
We proposed and realized a room-temperature operated, all electrically driving and detecting, sensitive and fast thermometer structure using a doubly clamped microelectromechanical (MEMS) resonator for bolometer applications [1]. When a terahertz (THz) radiation is incident on a NiCr film absorber deposited on the MEMS beam surface, a stress is generated in the beam due to thermal expansion, leading to a reduction in the mechanical resonance frequency. The MEMS detects the shift in its resonance frequency caused by heating and works as a very sensitive bolometer [1]. In order to achieve a broad and continuous response spectrum in the THz range, we fabricated the MEMS bolometer on a high-resistivity Si substrate, using a wafer-bonding technique [2]. In this presentation, we will discuss how the responsivity spectra of the GaAs MEMS bolometers are affected by the substrate effect.

Fig. 1(a) shows responsivity spectra of the MEMS bolometers fabricated on an insulating GaAs substrate (red trace) and a high-resistivity Si substrate (blue trace). As seen in the figure, the MEMS sample on Si (blue) exhibits a large responsivity in the range of 230-330 cm^{-1}, where the responsivity vanishes in the standard MEMS bolometers fabricated on a GaAs substrate. This is a great advantage of using Si substrates for the THz range. However, we have found that two sharp peaks appear near the TO and LO phonon frequencies. To understand the origin of the new responsivity peaks, we have theoretically calculated the absorption spectrum of a 1-μm-thick GaAs film, using the Drude-Lorentz dispersion model [3];

$$\bar{\epsilon} = \epsilon_1 - i\epsilon_2 = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)\omega_t^2}{\omega_t^2 - \omega^2 + i\Gamma\omega}, \tag{1}$$

where ϵ_0 and ϵ_∞ are respectively the GaAs permittivity at low and high frequencies. Γ is the damping factor of the dipole oscillation. ω_t is the TO resonance frequency in GaAs. As shown by the red curve in Fig. 1(b), the imaginary part of the permittivity, ϵ_2, has a sharp peak at the TO frequency, leading to a large absorption. At the same time, the real part, ϵ_1, becomes negative between the TO and LO frequencies (the Reststrahlen band), leading to a strong reflection of THz radiation. As a result, the responsivity spectrum of the MEMS bolometer fabricated on a Si substrate exhibits a double peak structure, as shown in Fig. 1(c).



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