テラヘルツ領域における超薄メタマテリアルの共振特性に対する基板フォノン吸収の影響

Effects of Substrate Phonon Absorption on the Resonance Properties of Ultrathin Metamaterials in the Terahertz Range

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Recently, we have developed a sensitive, fast THz bolometer that uses a doubly clamped MEMS beam resonator [1]. For active THz imaging together with a THz quantum cascade laser, we need a high-absorption, narrowband absorber at a well-defined frequency on the MEMS beam. In a typical metal-insulator-metal (MIM) MMA configuration [2], the MM pattern layer is the topmost layer and light is incident from the top side. However, when we integrate the MMA on the THz MEMS bolometer, THz radiation needs to be incident from the substrate side. Here, we have investigated effects of substrates on the resonance spectra of ultrathin MIM MMAs in the THz frequency range.

The top-incidence MIM MMAs studied in this work consist of an array of gold rectangular patches and a gold ground plane separated by a SiO_2 insulation layer (thickness = 1600 nm), as shown in Fig. 1 (a). The typical size of each patch was 23 μm×8 μm. The polarization of the normal incident light was set to be along its long side. Figures 1(b) and 1(c) show the bottom-incidence MIM MMAs for a semi-insulating GaAs substrate and a high-resistivity Si substrate, respectively. As shown in Fig. 2, for the top-incidence MMA (red curve), the first resonant mode has a 92% absorption and a 0.4 THz FWHM at 3 THz. However, when THz is incident on the MMA through a GaAs substrate, the resonant mode is completely washed out (black curve). This is due to strong THz absorption by acoustic phonons in GaAs. In contrast, when the GaAs substrate is replaced with a high-resistivity Si substrate, the first resonance mode is recovered and a sharp absorption peak as large as 63% is observed at 2.4 THz (blue curve). Compared with the top-incidence MMA, the decrease in the absorption is due to the reflection on the back surface of silicon substrate. A large absorption and a narrowband spectrum make the Si-based bottom-incidence MMA to be a good candidate for the MM integration with THz MEMS bolometer.

Fig. 1

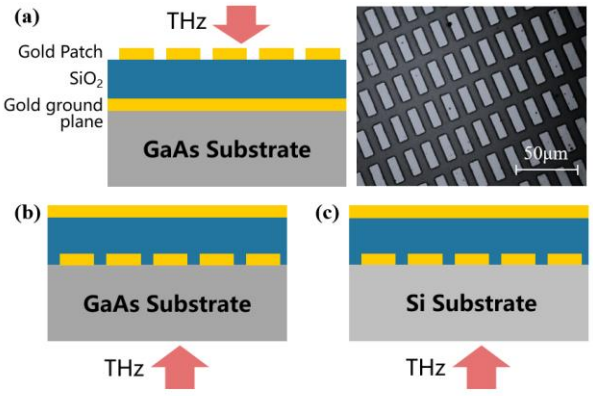
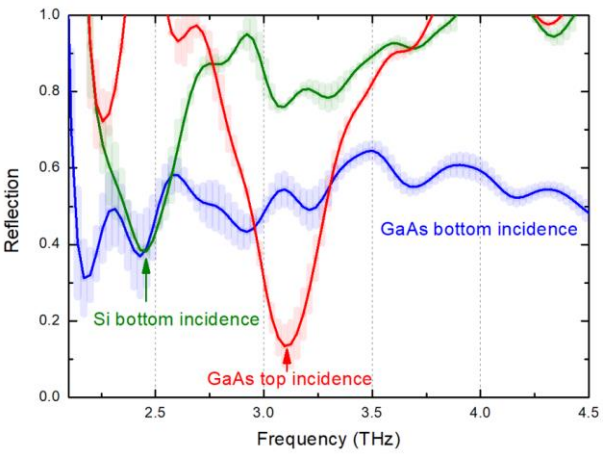


Fig. 2



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