Characteristics of THz waves and carrier scattering in boron-doped epitaxial Si and $Si_{1-x}Ge_x$ films

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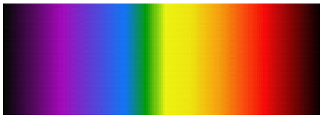

The latest issue of Journal of Applied Physics (Vol. 95, No. 10, pp. 5301–5304) publishes the work of S. K. Ray and a group of scientists who demonstrated absorption and reflection characteristics of boron-doped silicon and silicon-germanium alloys in the frequency range from 1.6 to 60 THz. They found that absorption increases with doping concentration, in agreement with free carrier effects, however, saturates for wavelengths longer than about 20 µm. As compared to silicon, the attenuation increases with the Ge fraction in the alloy.

The visible and infrared diode lasers are at the core of information technology, and at the other end of the spectrum, microwave and radio-frequency emitters enable wireless communications.
However, the terahertz region (1–10 THz; 1 THz = 10^{12} Hz) between these ranges has remained largely underdeveloped, despite the identification of various possible applications—for example, biological and chemical detection, astronomy and medical imaging.

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Recently, the potential applications of THz radiation have led to tremendous research interests in the fabrication of compact far-infrared sources and detectors. A lot of attention is paid to SiGe/Si-based multiquantum well semiconductor heterostructures, as being compatible with Si planar integration technology and the absence of the reststrahlen absorption band that is present in III–V and II–VI compound semiconductors.

The critical issue for device design at these frequencies that has not been addressed before is the interaction of free carriers with photons in the far-infrared. The reflectance, which is strongly frequency dependent in the THz range, may also play an important role for guided waves in THz components. Most of the previous absorption studies in doped silicon were limited to the mid-infrared wavelength (l

For the first time, the paper presents the absorption and reflection of THz radiation in boron-doped epitaxial Si and SiGe films in the frequency range from 1.6 to 60 THz. Terahertz reflectance data has been analyzed to study the doping dependent plasma-edge frequency, which may play an important role for the design of emitters, detectors, and plasmon waveguides. The best fitting of the experimental data with Drude theory has been used to extract the hole scattering relaxation time in doped silicon. The results have been utilized to explain the doping-dependent attenuation characteristics of the THz radiation.

The paper provides valuable results for the optimum design of group-IV-based THz active and passive devices. The hole relaxation time, that is useful for the transport modeling of the devices, has been calculated from the free-carrier absorption data, which explained the doping-dependent attenuation characteristics of THz radiation.

Read full paper at: Journal of Applied Physics

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