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Optical properties and time resolved THz spectroscopy of ion-implanted GeSn films

Simonas Driukas,[1] Chia-Ming Mai,[2] Ričardas Norkus,[1] Bronislavas Čehavičius,[1] Ignas Nevinskas,[1] Shang-Hua Yang,[2, 3, 4, 5] and Gintaras Valušis[6]

1)Department of Optoelectronics, Center for Physical Sciences and Technology, Saulėtekio Ave. 3, LT-10257, Vilnius, Lithuania
2)Institute of Electronic Engineering, National Tsing Hua University, Hsinchu City 300, Taiwan
3)Department of Electrical Engineering, National Tsing Hua University, Hsinchu City 300, Taiwan
4)Terahertz Optics and Photonics Center, National Tsing Hua University, Hsinchu City 300,Taiwan
5)College of Semiconductor Research, National Tsing Hua University, Hsinchu City 300, Taiwan
6)Institute of Photonics and Nanotechnology, Faculty of Physics, Vilnius University, Saulėtekio Ave. 3, LT-10257, Vilnius, Lithuania
Email: simonas.driukas@ftmc.lt

Among the emerging optoelectronic materials needed for the growing chip-integrated photonics industry, GeSn has attracted considerable attention due to its compatibility with existing CMOS fabrication processes and silicon-on-insulator technology, as well as its tunable bandgap enabling to reach 1.55 μm wavelength. While pure Ge is an indirect semiconductor, the incorporation of 7-9% Sn lowers the energy of the Γ conduction valley, leading to a direct bandgap GeSn material. [1] The alloy has already demonstrated strong potential for photodetectors, light-emitting diodes, and laser devices [2], however, its ultrafast performance at terahertz (THz) frequencies remains relatively unexplored. For THz applications and high frequency wireless data transfer, post-growth processing is required to reduce carrier lifetimes.

In this work, conventional structural characterization techniques and a range of THz spectroscopic methods are employed to investigate the structural, optical, and electrical properties of ion-implanted GeSn layers with varying implantation energies and ion doses. Structural characterization reveals a threshold beyond which implantation-induced damage becomes significant, while lower implantation parameters preserve the crystallinity of the material. Surface THz emission spectroscopy reveals THz emission at longer optical excitation wavelengths than those observed in the Ge substrate, indicating the Sn-induced bandgap reduction. Furthermore, optical-pump THz-probe spectroscopy unveils complex carrier dynamics governed by intervalley scattering and ion-induced defect states. A more than one order-of-magnitude reduction in carrier lifetime is achieved in ion-implanted samples, decreasing from 132 ps to 4.5 ps for an implantation dose of 5×10^{12} cm^{-2} and an implantation energy of 100 keV.

These results provide new insights into effects caused by ion implantation in GeSn alloys, enabling the identification of optimal implantation parameters for ultrafast optoelectronic applications.

REFERENCES

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