Covering all optical communication bands using strain-relaxed $Ge_{0.96}Sn_{0.04}$ photodetectors

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As the demand for bandwidth-intensive applications, such as Big Data, Artificial Intelligence, and Internet-of-Things (IoT), increases the telecom industry faces new technological challenges due to limited channel capacity within a single fiber pair [1,2]. To meet this challenge, there is a revived interest in optimizing current wavelength bands and exploring the adjacent L-band and 2 µm-band. To implement these new optical communication platforms, it is critical to establish all active and passive components for photonic integrated circuits (PICs) operating deeper in the infrared beyond the traditional telecom bands. One of the indispensable components is the silicon-integrated high-speed photodetectors, which serve as the optical to electrical converter. This range of the electromagnetic spectrum is currently served by detectors made of compound semiconductors, which are costly and may require cooling in addition to facing manufacturing and scalability challenges as they can be incompatible with silicon processing [3,4]. These limitations hinder their use in intra-chip and inter-chip communications. One promising technology to circumvent these challenges is germanium (Ge) on silicon (Si) photodetectors, which are efficient in the C-band region and Si-compatible [5,6]. However, their efficiency degrades greatly in the L-band and beyond. To counter this problem, herein we introduce germanium-tin (GeSn) semiconductors, which have attracted a great deal of interest due to its bandgap tunability via Sn concentration. By increasing Sn content, it is possible to extend the operational wavelength range to the mid-infrared (MWIR)[7], thus covering all telecommunication bandwidth from the O-band up the to the 2 µm-band, while providing a true monolithic integrated platform, making this solution scalable[8].

In this work, material development and optoelectrical properties of a set of devices made of GeSn/Ge/Si with low Sn content are presented demonstrating the extended device operation in the L-band range. The investigated materials are grown by chemical vapor deposition on silicon wafers using GeH_4 and $SnCl_4$ as precursors. The material quality properties and its potential application in photodetectors are discussed. For instance, at a low Sn content (below 5 at.%), we found that GeSn-based photoconductive devices display unexpectedly a low dark current and exhibit a room-temperature cutoff wavelength around 1.85 µm, with a responsivity of 0.52 A/W at 1.55 um. Additionally, capacitance devices are fabricated to extract unintentional doping concentrations from CV measurements. Finally, ex situ doping of GeSn is investigated toward lateral PIN diodes for high-speed applications.

References

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