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Heterogeneous Integration of Materials on Si for Nanophotonics Devices

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Optical interconnects are attractive candidates for achieving communication bandwidth well beyond terabit-per-second for high-performance multi-core microprocessors. Silicon has become a desirable material due to its transparency in the infrared wavelength range and the ease for integrating optical devices at the vicinity of CMOS circuitry utilizing standard processes. While state-of-the-art patterning techniques provide precise dimension control as well as pattern placement, standard doping and metallization steps enable utilization of phenomena such as carrier injection and depletion to render the devices tunable. As a result, large progress has been made on Si-based nanophotonic devices such as modulators, switches, and wavelength division multiplexing (WDM) systems [1, 2]. To make photodetectors, however, a heterogeneous integration of other materials that absorb light in the infrared is necessary. Available in standard front-end CMOS processes for gate strain engineering, Germanium is suitable due to its high absorption coefficient at 1.3μm and 1.5μm wavelengths. Thus, Ge can be directly integrated into the process to fabricate compact photodetectors simultaneously with amplifier circuits in order to make a receiver for an optical network. Nevertheless, the integration of Ge photodetector into the CMOS process flow is very challenging due to process complexity and severe temperature constraints; as a result, photodetectors fabricated only after completing the front-end processes have been previously demonstrated. This talk will discuss Ge waveguide photodetectors that have been integrated into the front-end before the activation of CMOS well implants. By utilizing a lateral seeded crystallization method wherein the Ge waveguides are melted during high-temperature dopant activation, 20μm-long single-crystal Ge-on-insulator waveguides were formed. This approach eliminates the need for selective epitaxial growth of Ge, and avoids high-density misfit dislocations formed due to lattice mismatch when growing Ge on Si substrate. The photodetectors operate at low applied bias voltages (0.5-1V) with bandwidth exceeding 40GHz.

[1] W.M.J. Green et al, “Ultra-compact, low RF power, 10 Gb/s silicon Mach–Zehnder modulator,” Opt. Express 15, 17106 (2007).

[2] Y. A. Vlasov et al, “High-throughput Silicon Nanophotonic wavelength-insensitive switch for On-chip Optical Networks,” Nature Photonics 2, 242 (2008).