World Academy of Science, Engineering and Technology
International Journal of Electrical and Information Engineering
Vol:10, No:03, 2016

Miniaturization of Germanium Photo-Detectors by Using Micro-Disk Resonator

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Abstract : Several Germanium photodetectors (PD) built on silicon micro-disks are fabricated on the standard Si photonics multiple project wafers (MPW) and demonstrated to exhibit very low dark current, satisfactory operation bandwidth and moderate responsivity. Among them, a vertical p-i-n Ge PD based on a 2.0 μm-radius micro-disk has a dark current of as low as 35 nA, compared to a conventional PD current of 1 μA with an area of 100 μm2. The operation bandwidth is around 15 GHz at a reverse bias of 1V. The responsivity is about 0.6 A/W. Microdisk is a striking planar structure in integrated optics to enhance light-matter interaction and construct various photonics devices. The disk geometries feature in strongly and circularly confining light into an ultra-small volume in the form of whispering gallery modes. A laser may benefit from a microdisk in which a single mode overlaps the gain materials both spatially and spectrally. Compared to microrings, micro-disk removes the inner boundaries to enable even better compactness, which also makes it very suitable for some scenarios that electrical connections are needed. For example, an ultra-low power (≈ fJ) athermal Si modulator has been demonstrated with a bit rate of 25Gbit/s by confining both photons and electrically-driven carriers into a microscale volume.In this work, we study Si-based PDs with Ge selectively grown on a microdisk with the radius of a few microns. The unique feature of using microdisk for Ge photodetector is that mode selection is not important. In the applications of laser or other passive optical components, microdisk must be designed very carefully to excite the fundamental mode in a microdisk in that essentially the microdisk usually supports many higher order modes in the radial directions. However, for detector applications, this is not an issue because the local light absorption is mode insensitive. Light power carried by all modes are expected to be converted into photo-current. Another benefit of using microdisk is that the power circulation inside avoids any introduction of the reflector. A complete simulation model with all involved materials taken into account is established to study the promise of microdisk structures for photodetector by using finite difference time domain (FDTD) method. By viewing from the current preliminary data, the directions to further improve the device performance are also discussed.

Keywords : integrated optical devices, silicon photonics, micro-resonator, photodetectors
Conference Title : ICCSSP 2016 : International Conference on Circuits, Systems, and Signal Processing
Conference Location : Singapore, Singapore
Conference Dates : March 03-04, 2016