Introduction for the Group-IV Photonics feature

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Silicon-based photonics technology, which has the DNA of silicon electronics technology, promises to provide a compact photonic integration platform with high integration density, mass-producibility, and excellent cost performance. This technology has been used to develop various photonic devices based on silicon, such as waveguides, filters, and modulators. In addition, germanium photodetectors have been built on a silicon-based photonic platform. These photonic devices have already been monolithically integrated, and a group-IV photonic platform based on silicon and germanium, or standard group-IV materials, has been established. Moreover, photonics–electronics convergence is now being pursued based on this platform. These emerging compact photonics–electronics convergent modules will have the potential to be used in the construction of energy-efficient, cost-effective systems for various applications, such as communications, information processing, and sensing. Hence, silicon- and germanium-based photonic devices, their integration, and convergence with electronics can be the short- and mid-term topics of this feature issue. For these topics, we have four papers, including two invited.

As mentioned above, the group-IV photonic platform based on silicon and germanium has the potential for compact and energy efficient photonics–electronics convergence. Considering the material characteristics and difficulties in microfabrication technology, however, silicon and germanium by themselves are not necessarily ideal materials for the ultracompact, ultrahigh-density, ultralow-energy photonics–electronics convergent platform of the future. For example, silicon is not suitable for light-emitting devices because it is an indirect transition material. In addition, the operation speed of silicon-based optical modulators is limited by the carrier mobility of silicon, which is significantly lower than that of III–V semiconductors. Moreover, the size reduction of the modulators is limited by a weak photon–carrier interaction in silicon. For similar reasons, germanium photodetectors also have some performance limitations. The resolution and dynamic range of silicon-based interference devices, such as wavelength filters, are significantly limited by fabrication errors in microfabrication processes.

For further performance improvement, various assisting technologies should be implemented on the standard group-IV photonic platform. These technologies are categorized into *intelligence assists* and *material assists*. Intelligence assists are aimed at compensating for performance deficiencies, such as bandwidth limitations in modulators and detectors, by using the electronic circuits that are now being developed for digital coherent transmission systems. Material assists are designed to improve performance by introducing the right materials for the right functions. The materials to be implemented are III–V materials such as indium phosphide, rare-earth materials such as erbium for light emission, and exotic group-IV materials such as highly strained germanium and graphene. Fortunately, the group-IV photonic platform is robust physically, chemically, and mechanically; therefore, these heterogeneous material integrations can be achieved on this platform. Hence, heterogeneous materials integration on the group-IV photonic platform and their novel functionalities are the mid- to long-term research topics of this feature issue. For these topics, we have four papers, including two invited.

We believe these excellent works in this feature issue will significantly contribute to supporting sustainable growth in the world.

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