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Materials and Optical Devices Based on Group IV Quantum Wells Grown on Si-Ge-Sn Buffered Silicon

The ability to manufacture high quality Sn-Ge and Si-Ge-Sn alloys has significant industry value for various reasons; however, existing techniques have failed to produce sufficiently high quality alloys to allow for effective use of these alloys in device applications. Specifically, the ability of Sn-Ge alloys to transition from indirect- to direct-gap semiconductors may ultimately allow for a direct-gap semiconductor to be fully integrated with Si technology. Subsequently, arbitrarily thick Sn-Ge layers deposited on Si can function as ?virtual substrates? or ?buffer layers? to allow for the growth of Ge-Si-Sn ternary analogs. By using these alloys in conjunction with Si, it is possible to decouple, and therefore, independently manipulate strain and band gap to engineer unique device structures based entirely on group IV materials.

Researchers at Arizona State University have developed a device quality semiconductor structure comprising a single quantum well (SQW) Ge-Si-Sn/Ge-Si heterostructure that is grown strain-free on Si(100) via a Sn-Ge buffer layer using chemical vapor deposition (CVD). It is possible to specifically design these alloy systems to display quantum confinement Stark effects (QCSE), the response to an applied electric field in which the exciton absorption peaks in a quantum well shift. Consequently, the SQWs can operate as building blocks to fabricate multi-quantum well (MQW) modulator structures with band gaps covering the 1.4 ? 1.9 µm range.

Potential Applications

- Directly Integrated Optical & Optoelectronic Materials/Devices with Si-Based Electronics
- Strain-Engineered Direct Band Gap Optical & Optoelectronic Devices (e.g. MQW Lasers, Photodetectors, Emitters, Modulators, etc.)

Benefits and Advantages

- Provides Device Quality Sn-Ge & Si-Ge-Sn Alloys
  - Allows Full Integration of these Materials with Si
  - Allows Production of Photonic Devices Based Entirely on Group IV Materials - operates over a wide range of IR wavelengths 1.4 ? 1.9 µm including the 1.55 micron communication wavelength
  - Allows for Independent Strain and Band Gap Engineering ? in some devices, such as detectors and modulators, the ability to manipulate the electronic structure in a wide range of alloys gives rise to superior device performance
- Operates with Inherently High Speed ? incorporated physical effects are inherently fast in nature

- Enables Substantial Size Reduction ? design optimization can provide significant size reductions over existing Si-based devices