Growth and activation of group IV semiconductors for application in infrared detectors and photovoltaics

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Bandgaps in group IV semiconductors such as $Ge_{1-y}Sn_y$ and $Ge_{1-x-y}Si_xSn_y$ are tunable by varying the material composition. The tunable bandgaps make these materials with potential applications in photodetectors, modulators, waveguiders, lasers and photovolatics.

This presentation reports significant improvements of the low-temperature chemical vapor deposition (CVD) process leading to growth of device quality $Ge_{0.98}Sn_{0.02}$ films with thickness over 500 nm. Highly controlled and efficient doping protocols were also developed to obtain facile substitution and complete activation of dopant atoms at levels $10^{17} – 10^{19}$ cm^{-3} via both conventional and custom built molecules. $Ge_{0.98}Sn_{0.02}$-based PIN structures were subsequently fabricated and characterized. Results show that the incorporation of only 2% of Sn extends the infrared performance of $Ge_{1-y}Sn_y$ based optoelectronic devices to the entire range of transmission windows for telecom applications.

Meanwhile, a new approach to high quality $Ge_{1-x-y}Si_xSn_y$ ternaries grown directly on both Ge(100) and Si (100) substrates was established based on commercially available sources such as trisilane, digermane and stannane. The soft chemistry process was extended to fabricated p- and n-type layers on Si, and their optical and electrical properties were determined. Characterizations indicate that the properties of GeSiSn are independent of the platform on which they are grown including Si, Ge or GeSn/Si. First-principles calculations show that mixing entropy thermodynamically stabilizes SiGeSn in contrast to GeSn analogs with the same Sn content, in good agreement with experimentally observation.

In addition, InGaAs films were fabricated on SiGeSn/Ge/Si templates to demonstrate the application of SiGeSn in high efficiency, low cost solar cells. The resultant heterstructures show high crystalline quality to serve as platforms for the subsequent creation of complete four-junction photovoltaic devices under conditions fully compatible with Si CMOS processing.