



Semiconductor Materials for Multijunction Photovoltaic Applications

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Intellectual Property Status

Patent Pending

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Background

The most efficient solar cells currently in production utilize lattice matched Ge/InGaAs/InGaP triple-junctions grown on bulk Ge substrates. While these architectures average 30% efficiency and can achieve close to 40% by using solar concentrators, incorporating a fourth junction could provide substantial improvements in efficiency. The material in this fourth junction should be lattice-matched to Ge and have a band gap of ~ 1 eV; however, prior to recent advances that make it possible to grow device-quality Ge, GeSn, and GeSiSn alloys on Si substrates, there had been no materials reasonably suitable to meet these requirements. The emergence of the GeSiSn system provides the opportunity to incorporate these alloys as fourth junctions in solar cells as a result of the independently and widely adjustable band gap at a fixed lattice constant identical to that of Ge. Most importantly these materials can be grown directly on low cost, large wafer size Si platforms.

Invention Description

Researchers at Arizona State University have developed a method to incorporate GeSiSn alloys in a multi-junction Ge/GeSiSn/InGaAs/InGaP cell grown on a Si substrate. The technique uses a chemical vapor deposition (CVD) to grow the corresponding Ge films with high thickness (up to and above 5 microns) and record low defect densities ($<10^4$ - 10^5 /cm²). The resulting solar cells, grown on Si substrates, offer considerable cost reductions over traditional devices. Meanwhile, the method allows for development and optimization of hybrid group IV/III-V tandem designs with theoretical efficiencies reaching as unprecedented high values.

Potential Applications

- Commercial Electronic Devices
- Satellites, Spacecraft, Space Probes
- Remote and Grid-Tied Power Generation
- Remote Radiotelephones and Water Pumps

Benefits and Advantages

- **Offers Substantial Cost Reductions** (Unique Ge/Si(100) hybrid platforms developed at ASU replace the expensive Ge substrate with Si)
 - Ge substrate constitutes 1/2-1/3 of the cost of contemporary solar cells
 - Si wafers are considerably cheaper
 - Si possesses more superior mechanical properties than Ge: lesser brittleness of Si allows for thinner substrates; availability of Si in larger sizes (300 mm diameter) accommodates the same number of solar cells with larger individual dimensions - imposes less severe constraints on the concentrator optical design; Si substrates are lighter - particularly relevant for space applications
- **Provides Substantial Efficiency Improvements** (Four-Junction Solar Cells)
 - GeSiSn alloys exhibit independently and widely adjustable lattice constants and band gaps
 - Developments in Hybrid Group IV/III-V tandem solar cells allow for theoretical efficiency limits as high as 70.7% compared to the average 30% ($\approx 40\%$ maximum) provided by best existing solar cells