AlGaAs Solar Cells Grown by Liquid Phase Epitaxy for Tandem Solar Cell Applications

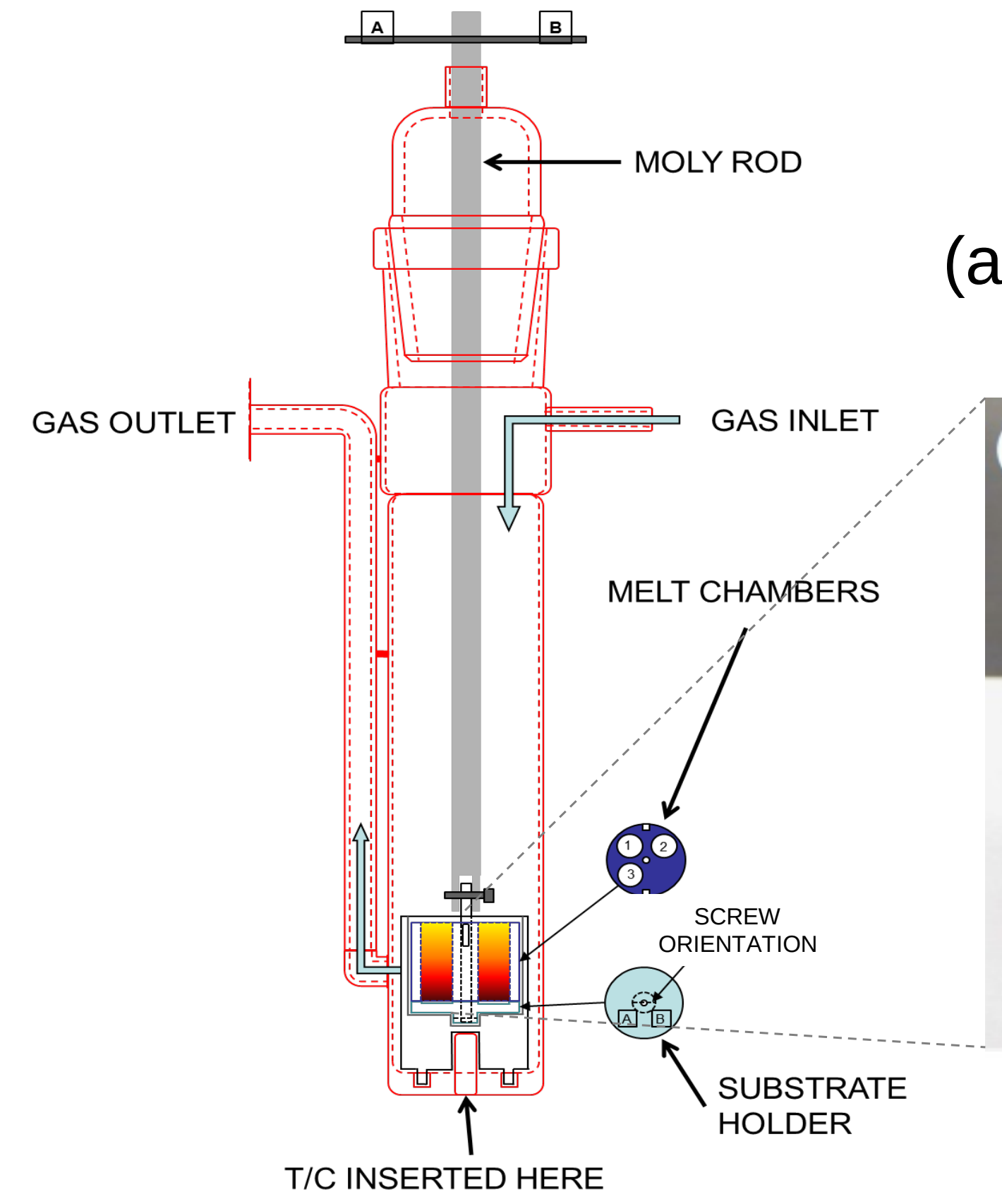
Xin Zhao, Kyle H. Montgomery, and Jerry M. Woodall
Department of Electrical and Computer Engineering, University of California, Davis, CA, 95616, USA

Introduction

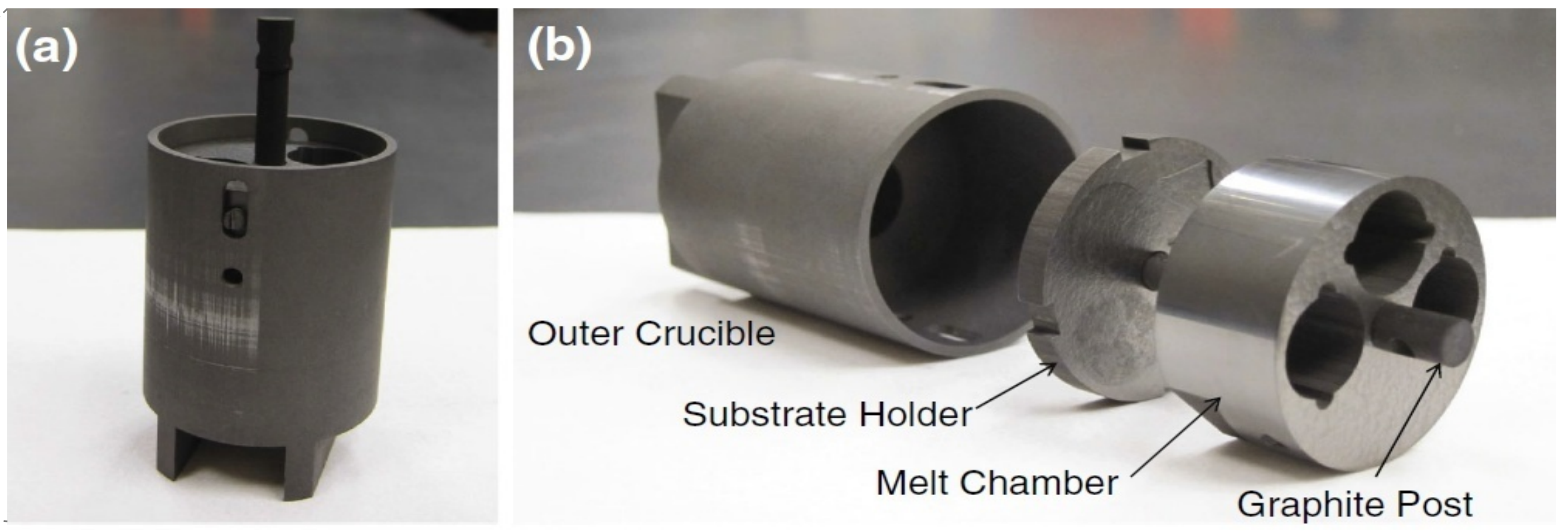
Theoretically, for a dual junction device, a top sub-cell bandgap of ~1.75eV enables a near-optimal power conversion efficiency of more than 38% under AM1.5G condition, assuming an optimized c-Si bottom sub-cell [1]. With a direct bandgap covering 1.42 – 2 eV, AlGaAs is a candidate for the top sub-cell material. AlGaAs can be grown lattice-matched on a GaAs substrate first, and then be bonded to a Si bottom sub-cell with the native substrate subsequently removed [2]. Direct liquid phase epitaxial (LPE) growth of AlGaAs on GaP/Si superstrates is also feasible because efficient electroluminescence has been observed from LPE-grown AlGaAs on GaP [3]. The growth of Al-rich AlGaAs by alternative growth techniques such as molecular beam epitaxy (MBE) or metalorganic chemical vapor deposition (MOCVD), however, are typically plagued by oxygen incorporation. Since LPE is known for its capability of growing high-purity AlGaAs due to its liquid-solid growth interface, it was used for our study of AlGaAs epilayers and solar cells.

This poster will cover the behavior of various dopants (Sn and Te as n-type dopants, and Ge and Zn as p-type dopants) in Al$_x$Ga$_{1-x}$As (x ~ 0.23). Also included are dark IV, light IV and EQE results of AlGaAs solar cells.

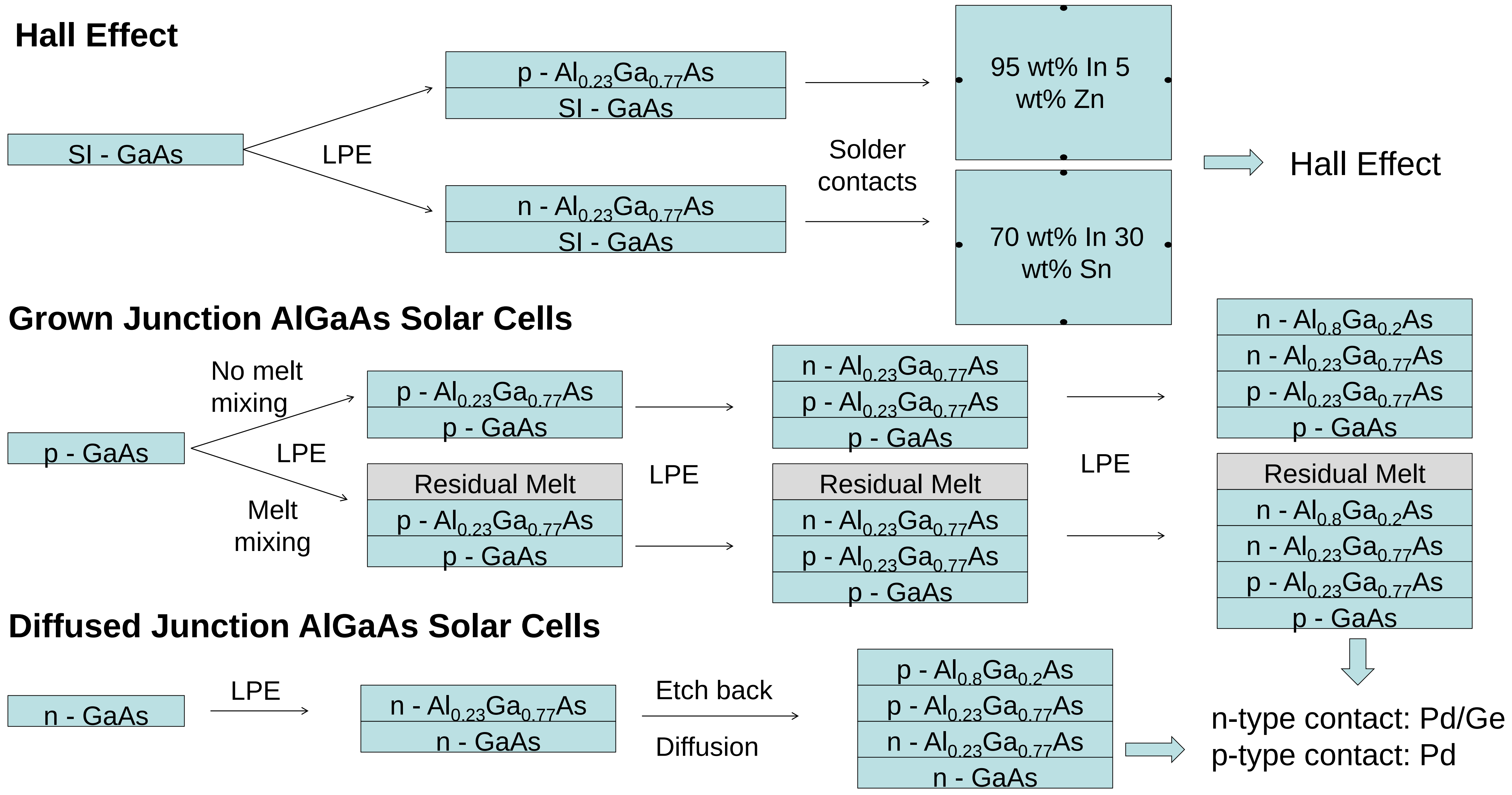
LPE Apparatus



(a) Assembled view and (b) exploded view of graphite apparatus



Methods



Hall Effect

SI - GaAs

LPE

p - Al$_{0.23}$Ga$_{0.77}$As
SI - GaAs

n - Al$_{0.23}$Ga$_{0.77}$As
SI - GaAs

Solder contacts

95 wt% In 5 wt% Zn

70 wt% In 30 wt% Sn

Hall Effect

Grown Junction AlGaAs Solar Cells

p - GaAs

LPE

No melt mixing

p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

Melt mixing

Residual Melt
p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

LPE

n - Al$_{0.23}$Ga$_{0.77}$As
p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

Residual Melt
n - Al$_{0.23}$Ga$_{0.77}$As
p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

LPE

n - Al$_{0.8}$Ga$_{0.2}$As
n - Al$_{0.23}$Ga$_{0.77}$As
p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

Residual Melt
n - Al$_{0.8}$Ga$_{0.2}$As
n - Al$_{0.23}$Ga$_{0.77}$As
p - Al$_{0.23}$Ga$_{0.77}$As
p - GaAs

Diffused Junction AlGaAs Solar Cells

n - GaAs

LPE

n - Al$_{0.23}$Ga$_{0.77}$As
n - GaAs

Etch back

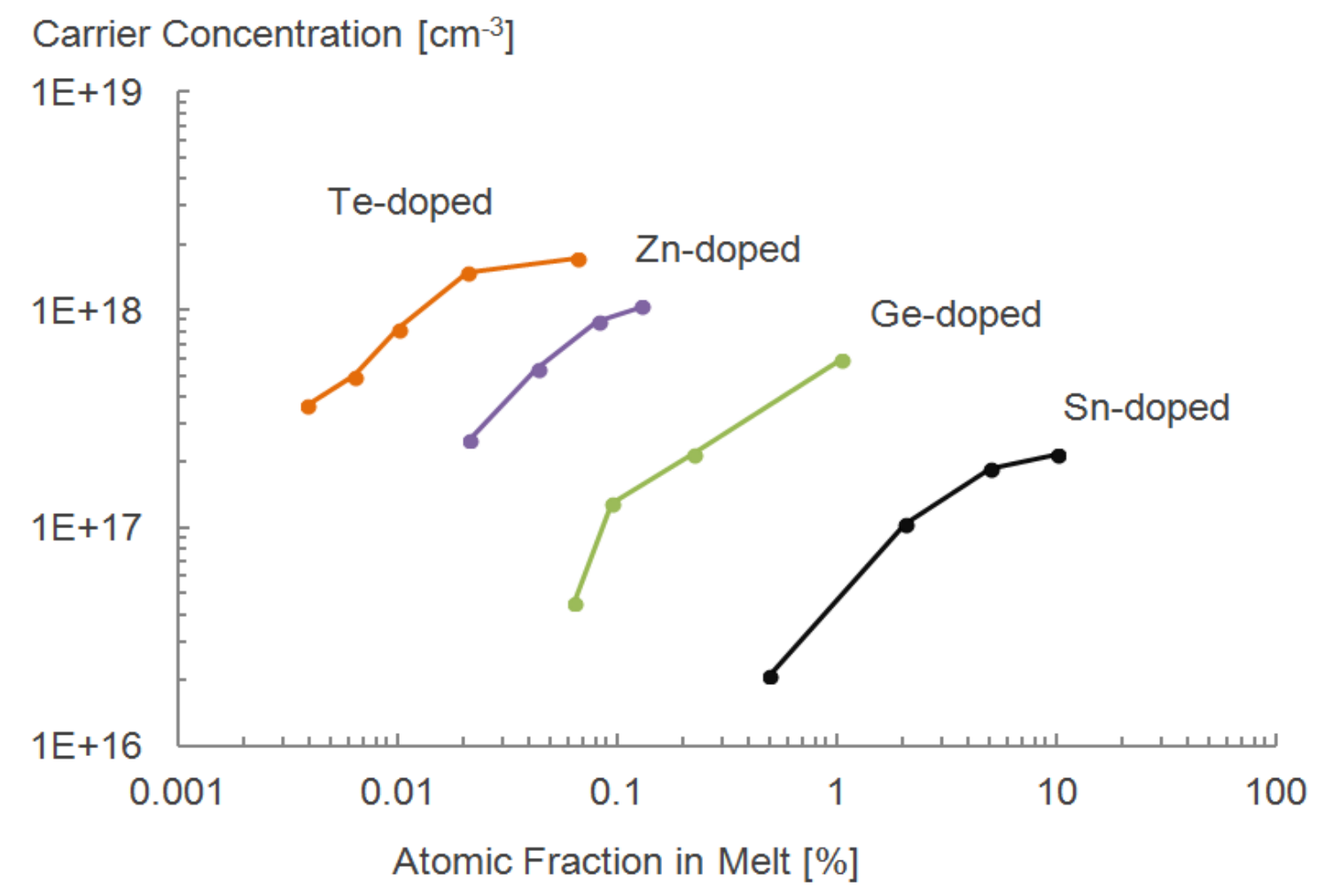
Diffusion

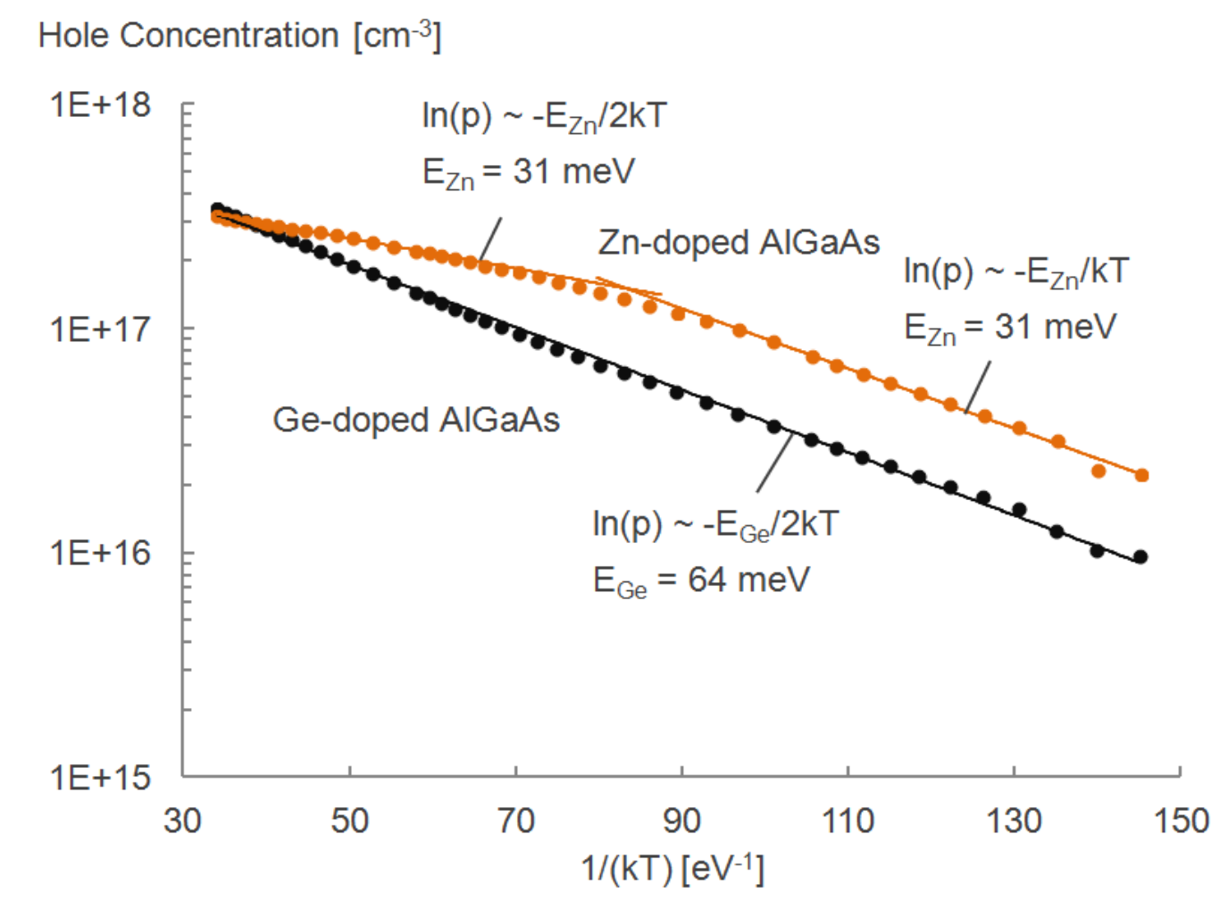
p - Al$_{0.8}$Ga$_{0.2}$As
p - Al$_{0.23}$Ga$_{0.77}$As
n - Al$_{0.23}$Ga$_{0.77}$As
n - GaAs

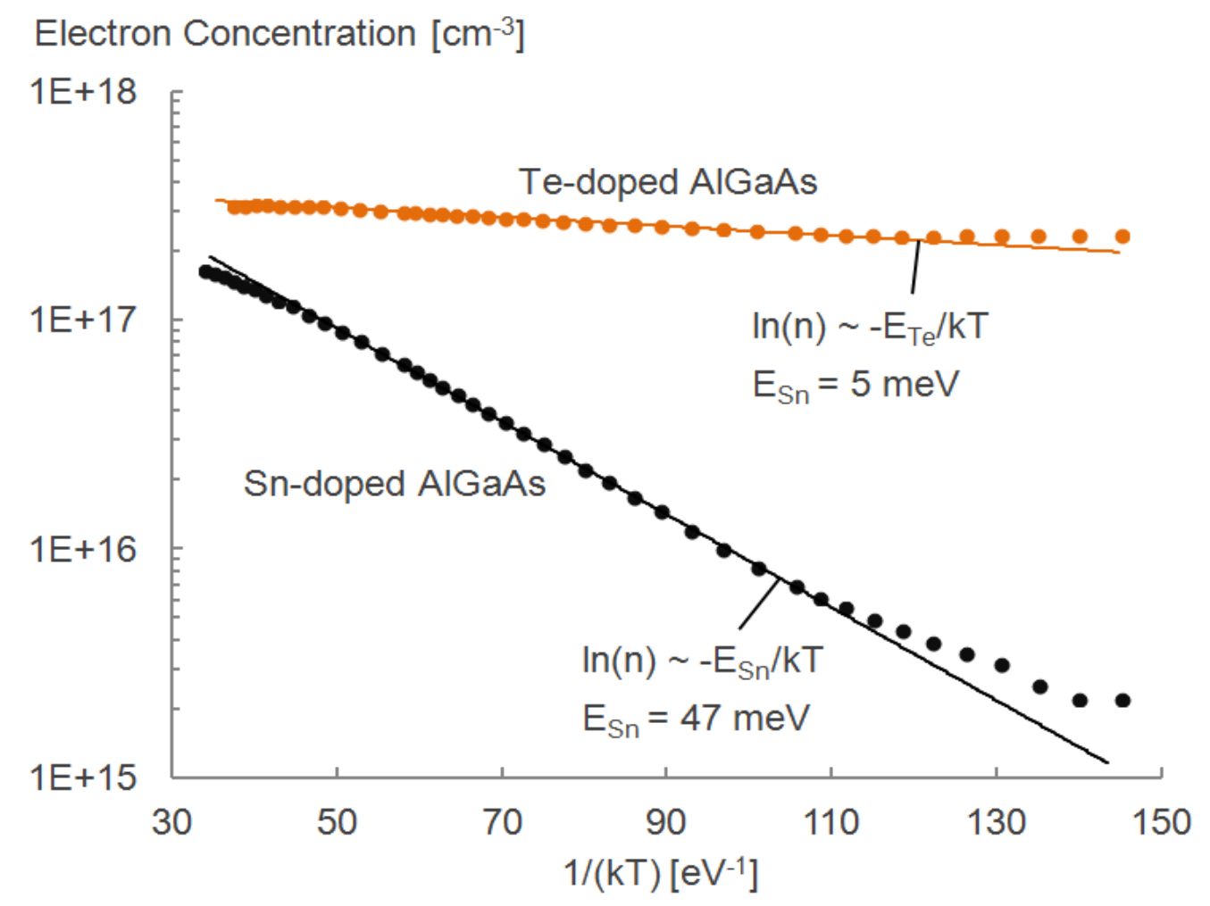
n-type contact: Pd/Ge
p-type contact: Pd

Results

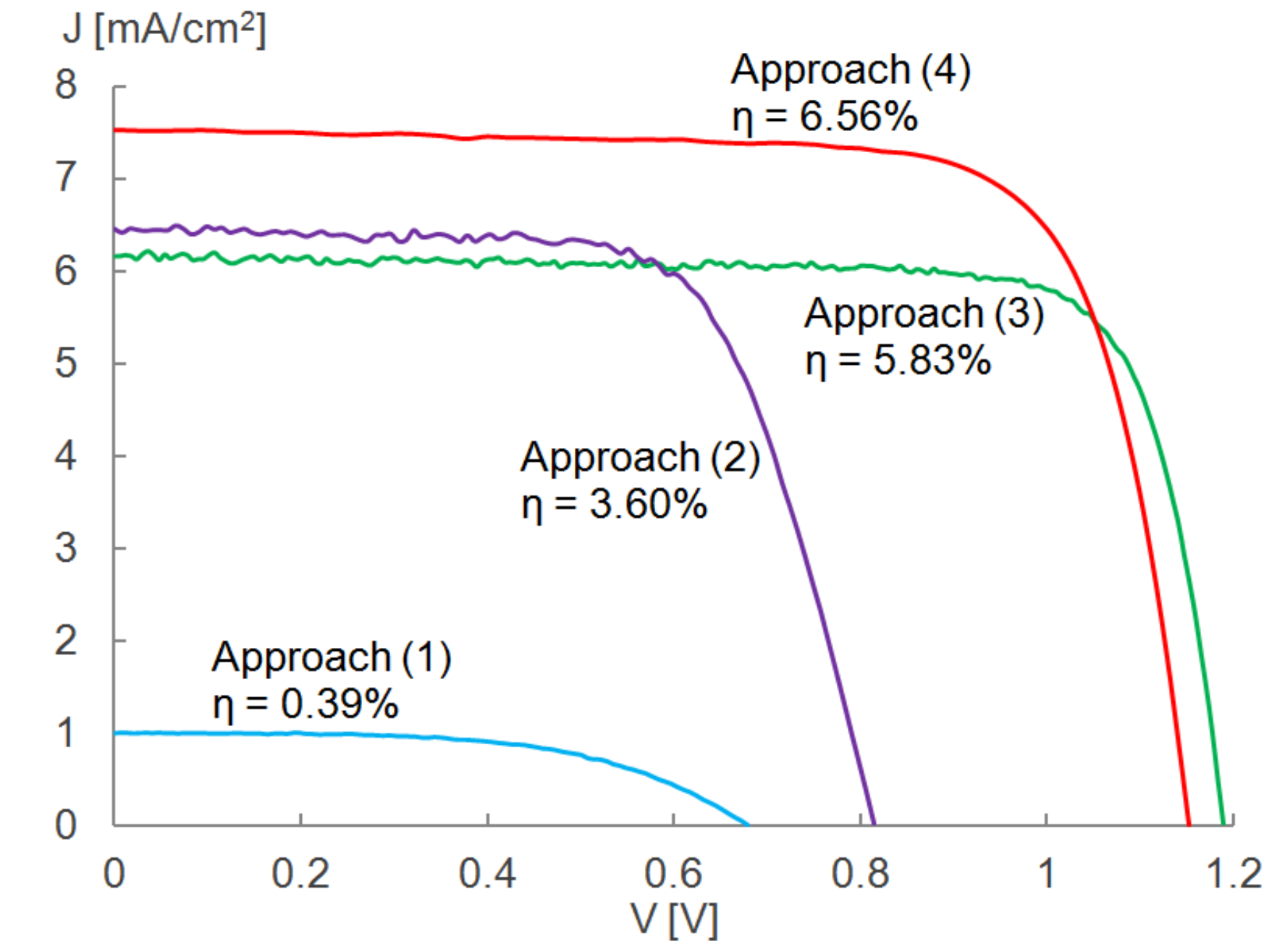
Hall Effect







AlGaAs Solar Cells

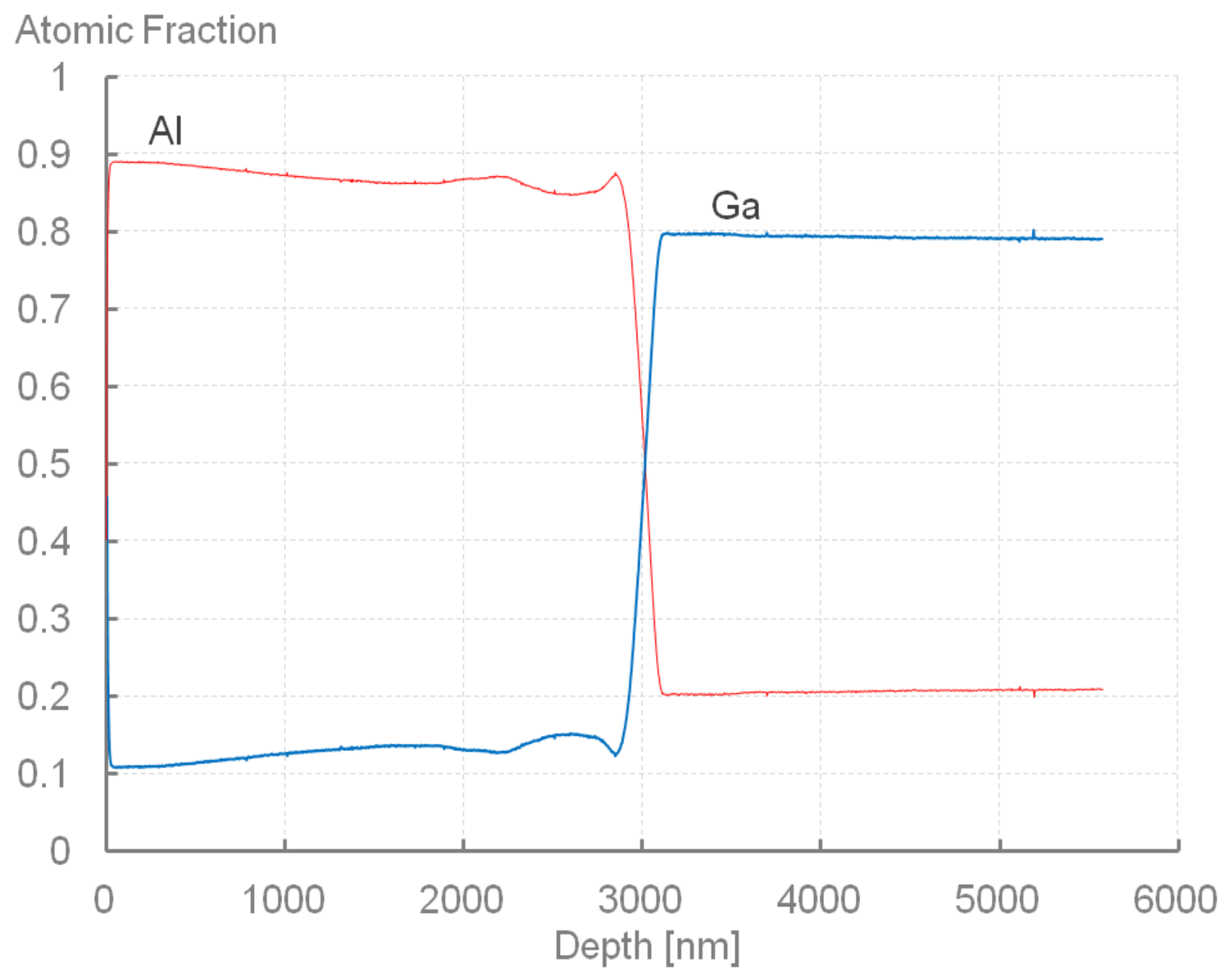


Approach (1): grown junction

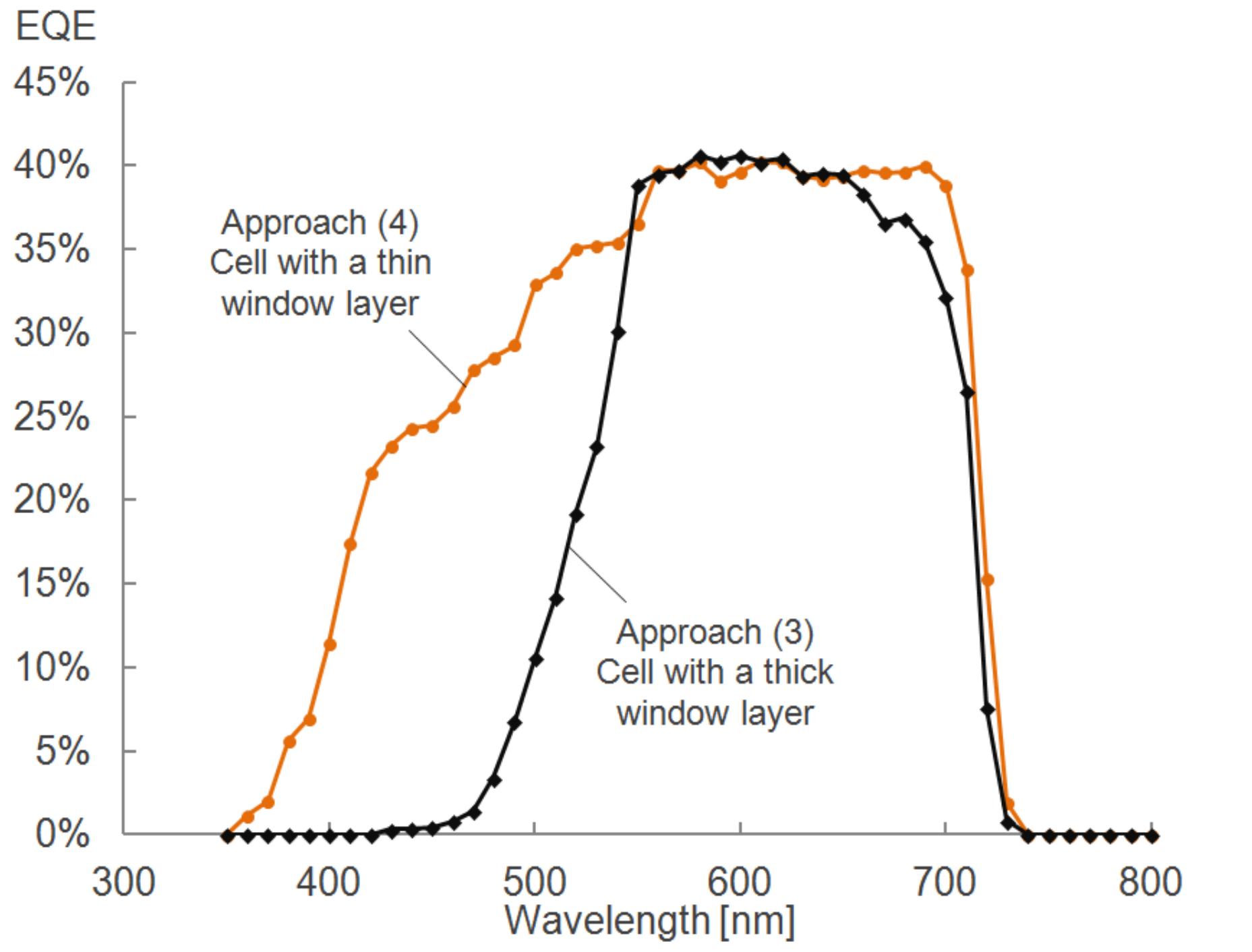
Approach (2): diffused junction without melt carry-over

Approach (3): diffused junction with melt carry-over

Approach (4): diffused junction with melt carry-over followed by window layer etching



SIMS depth profiling of solar cell surface obtained from approach (3)



EQE of solar cells obtained from approach (3) and approach (4)

Conclusion

We have performed Hall effect studies on ~1.75eV AlGaAs, and, based on the results, fabricated AlGaAs solar cells for tandem solar cell applications. The diffused junction cells generally performed better than grown junction cells. Using melt carry-over technique to preserve the solid-liquid interface, which prevents the surface of the sample from being oxidized by the ambient gas, led to improved V_{OC}. J_{SC} improvement was achieved by etching away the thick window layer resulting from the growth from the carry-over melt during system cooling.

References

[1] S. R. Kurtz, P. Faine, and J. M. Olson, "Modeling of two-junction, series-connected tandem solar cells using top-cell thickness as an adjustable parameter," *Journal of Applied Physics,* vol. 68, no. 4, pp. 1890-1895, 1990.

[2] K. Tanabe, K. Watanabe, and Y. Arakawa, "III-V/Si hybrid photonic devices by direct fusion bonding," *Scientific Reports*, vol. 2, pp.1-6, 2012.

[3] J. M. Woodall, R. M. Potemski, S. E. Blum, and R. Lynch, “Ga$_{1-x}$Al$_x$As LED Structures Grown on GaP Substrates,” *Applied Physics Letters,* vol. 20, pp. 375, 1972.

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