1.1 eV GaInAs Cell Development for Dual-use Solar and 1075 nm Laser Power Converters

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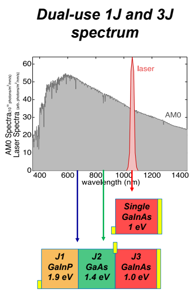
Introduction

- Dual-use PV concept
  - PV: Broad-spectrum energy conversion
  - LPC: High-efficiency single-wavelength conversion
- Benefits
  - Reduce solar panel area and required storage capacity of assets
  - Space applications: satellites, bases, rovers, etc.
- Challenges
  - Metamorphic cell growth, high temps, resistance losses

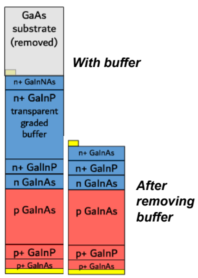
Dual-use 1J and 3J spectrum



Cell Concepts

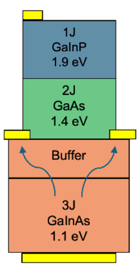
Single Junction Structure

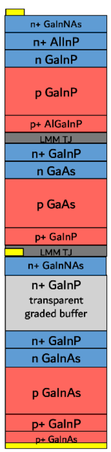
- Two cell concepts
  - MOVPE growth
  - Inverted metamorphic
  - 1.1eV junction to target 1075nm laser
- Single junction
  - Buffer layers removed
  - $Ga_{0.2}In_{0.8}As$
  - Higher LPC efficiency, lower broadband efficiency



Triple Junction Structure

- Triple junction
  - Addition of 1.4eV and 1.9eV junctions
  - Buffer layer not etched off
  - Third contact to collect high current from laser
- Addition of third contact puts more emphasis on lateral current pathways (shown by blue arrows) which is highly dependent on sheet resistance



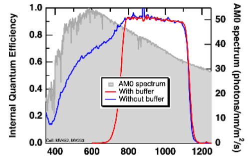


Single Junction Analysis

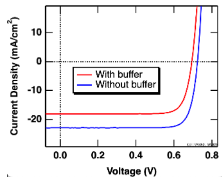
Solar Performance

- QE shows broadband absorption of solar spectrum
- 1.1eV ideal for 1075nm wavelength (1.15eV)
- Characterized for AM0 spectrum
- Without contact layer & buffer, GaInP window layer is still partially absorbing
- JV curve shows improvement to J_{sc} after removing buffer layer
  - Almost no effect to V_{oc}

Quantum Efficiency



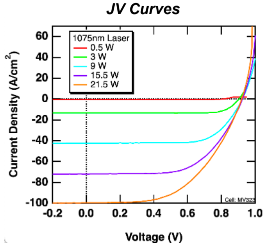
JV curves



	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	Eff (%)
Buffer	0.68	19.2	80.2	7.66
No Buffer	0.72	22.3	81.9	9.6

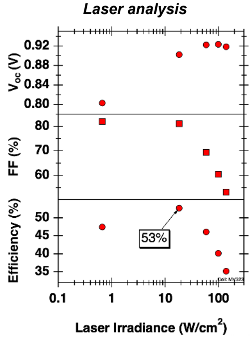
Laser Performance

JV Curves



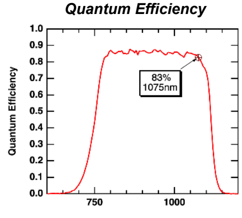
- Goal: design cell for laser irradiance of 1-10 suns
- Cell area = .01 cm²
- Used real laser
- As laser irradiance increases…
  - J_{sc} & V_{oc} increase
  - Fill factor decreases
  - Resistance losses dominate
- ARC increased QE to 83% at 1075nm

Laser analysis



- $\eta = \frac{P_{cell}}{E_{tot}} = \frac{V_{mpp} * J_{mpp}}{J_{sc} / QE(\lambda) * hc / q\lambda}$
- Adding an ARC increased LPC efficiency to 53% at 18 $\frac{W}{cm^2}$

Quantum Efficiency

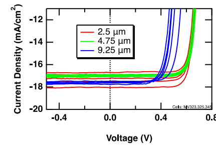


Triple Junction Analysis

Buffer Thickness Experiment

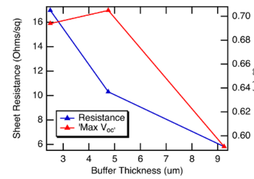
- GaInP graded buffer changes lattice constant to grow GaInAs on GaAs substrate
- In 1J, optimized buffer reduces threading dislocation density
  - Decreases non-radiative recombination
  - Increases V_{oc}
- In 3J, buffer serves also as a **lateral transport** to intermediate contact
  - Sheet resistance is key
- Results show increasing buffer thickness decreases sheet resistance
- If buffer is too thick, cell quality decreases
- Optimal thickness around 5μm

JV curves



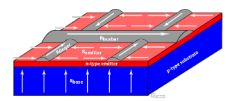
Thickness (µm)	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)
2.5	0.689	17.2	81.3
4.75	0.694	16.9	81.9
9.25	0.534	17.6	74.9

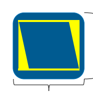
Sheet resistance vs. buffer thickness



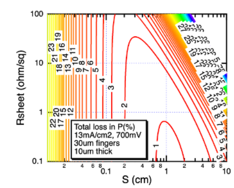
Resistance Modeling

- Goal: Determine power loss given cell size
- Resistance values of interest
  - Sheet, contact, grid finger, base
- More grid fingers -> lower resistance loss -> more shadowing
- Optimal buffer thickness has sheet resistance of ~10 ohms
- Fabrication requires fingers only on cell perimeter





Power loss (%) for R_{sheet} and grid finger spacing (S)



Summary

- 53% laser conversion efficiency achieved on lattice mismatched GaAs cell at 1075nm
- Buffer thickness optimized for cell quality in both 1J and 3J
  - Reduce threading dislocation in PN junction for 1J and 3J
  - Reduce sheet resistance for 3J
- Optimal grid finger spacing for cell is 0.2-1cm

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