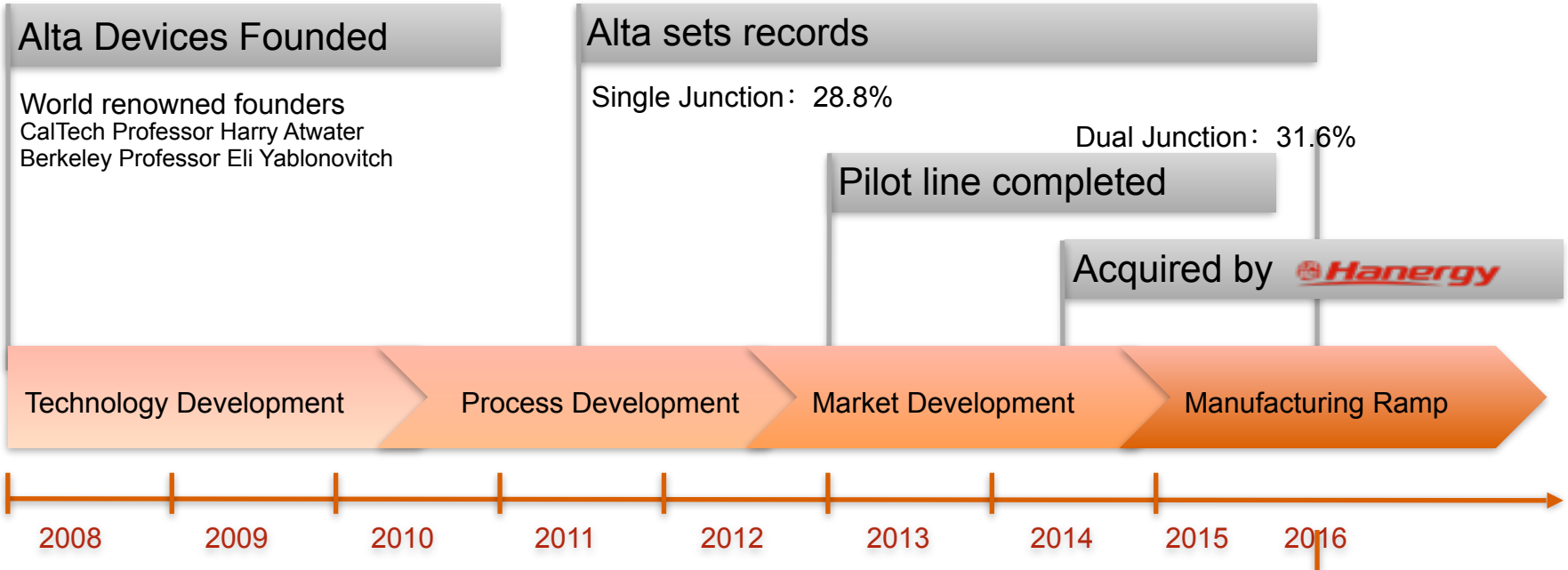




Lightweight, High-Efficiency Solar Cells

Aarohi Vijn

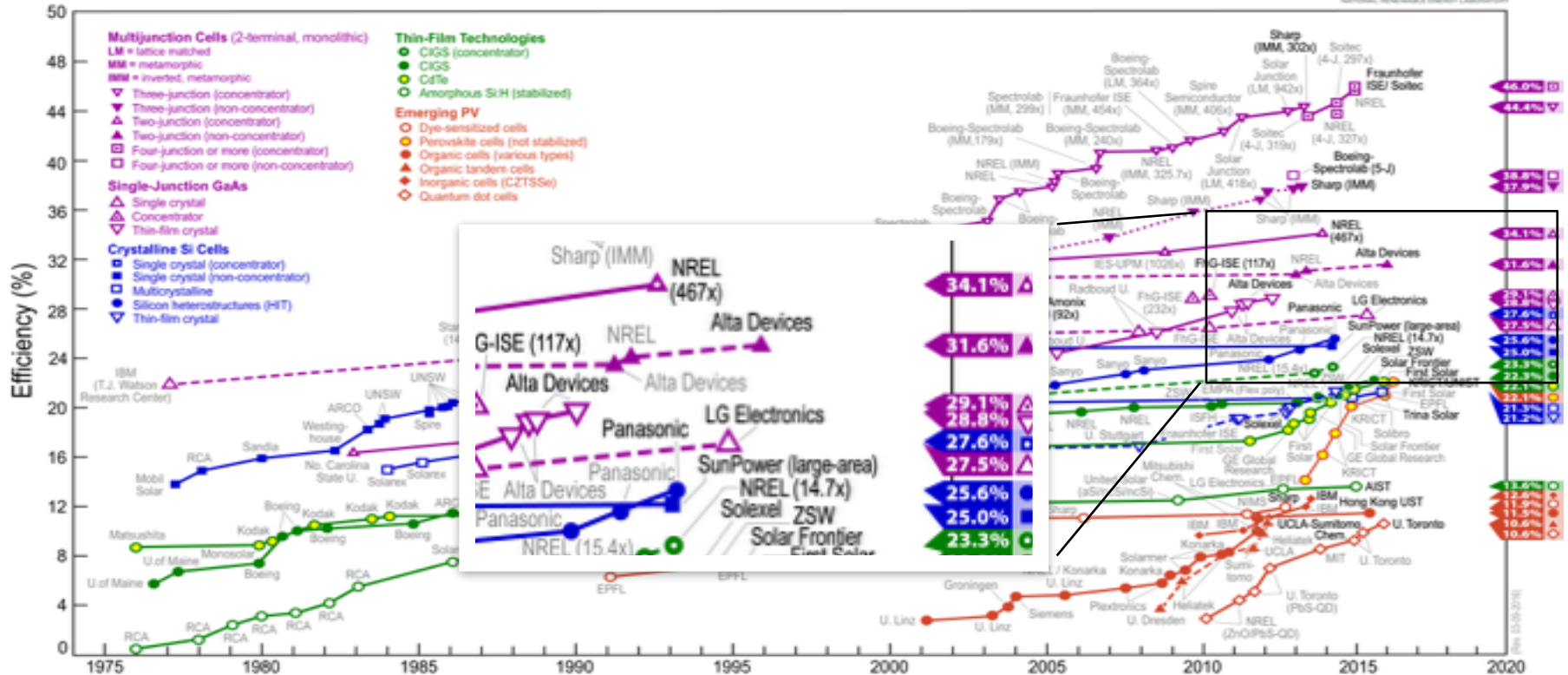
Company History



Mission is to bring highest efficiency solar to broad markets

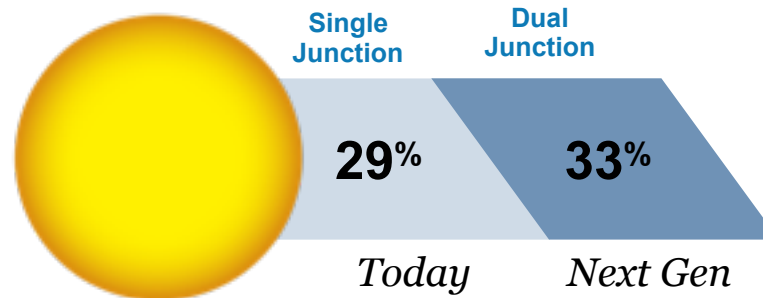
Single and Dual Junction Records

Best Research-Cell Efficiencies



World record for non-concentrator 1-J and 2-J cells

Ultra-High Efficiency



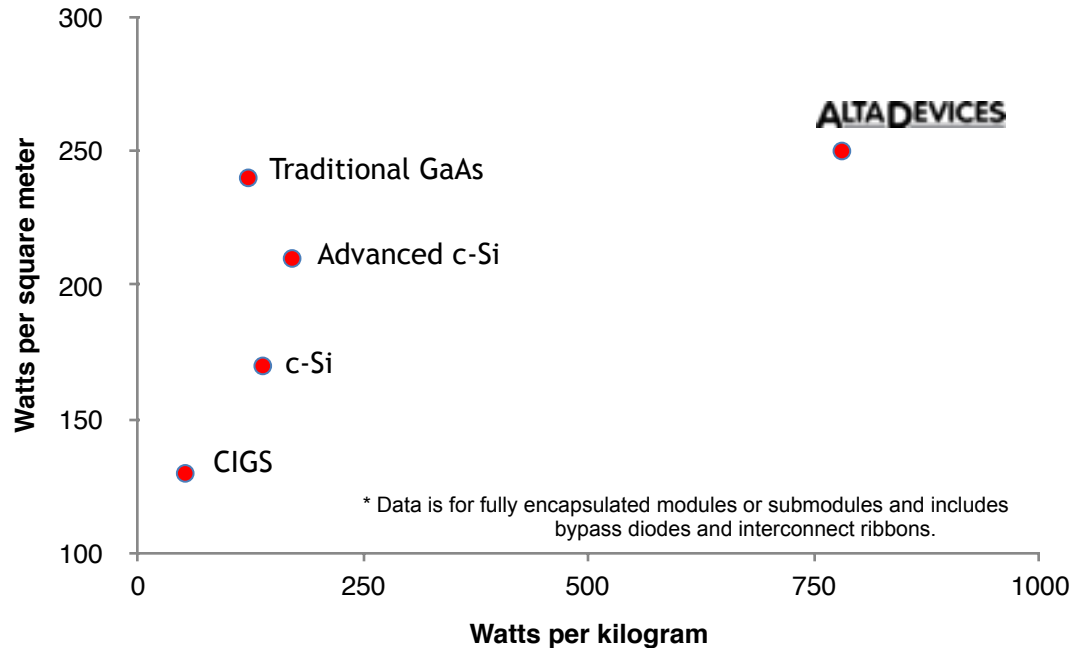
Super-thin solar cell material employing photon recycling enables world record efficiency

Ultra-Light Weight



We are targeting low weight designs to increase our power-to-weight performance, by using advanced materials.

Mass and Area Ratios



>1000 W/kg unencapsulated

>750 W/kg with encapsulation on one side

Ranked in World's 50 Disruptive Companies

Listed 3 consecutive years

MIT Technology Review 50 DISRUPTIVE COMPANIES

Alcatel-Lucent COMPUTING	Alta Devices MED	Apple COMPUTING	Applied Materials MATERIALS
Complete Genomics BIOMEDICINE	Dreamworks Animation COMPUTING	Dropbox WEB	EADS MATERIALS
HealthSpan Services BIOMEDICINE	IBM COMPUTING	IBM COMPUTING	Integrated Device Technology BIOMEDICINE
Palantir Technologies COMPUTING	Pfizer/Allergan BIOMEDICINE	Qualcomm COMPUTING	Roche BIOMEDICINE
Skyline Imaging COMPUTING	SpaceX TRANSPORT	SpaceX TRANSPORT	Spotify WEB
Wildcat Discovery MATERIALS	WITriality TRANSPORT	Zynga WEB	

2012

MIT Technology Review 50 DISRUPTIVE COMPANIES 2013

Introduction
The 50 Companies
Apple's Next Innovation

Q+A Steve Balmer
Ambr's Better Battery
Q+A Ursula Burns

BGI's Genome Machine
Nest's Smarter Home
Q+A Ben Silbermann



MIT Technology Review 50 SMARTEST COMPANIES 2014

Introduction
The 50 Companies
FAQ

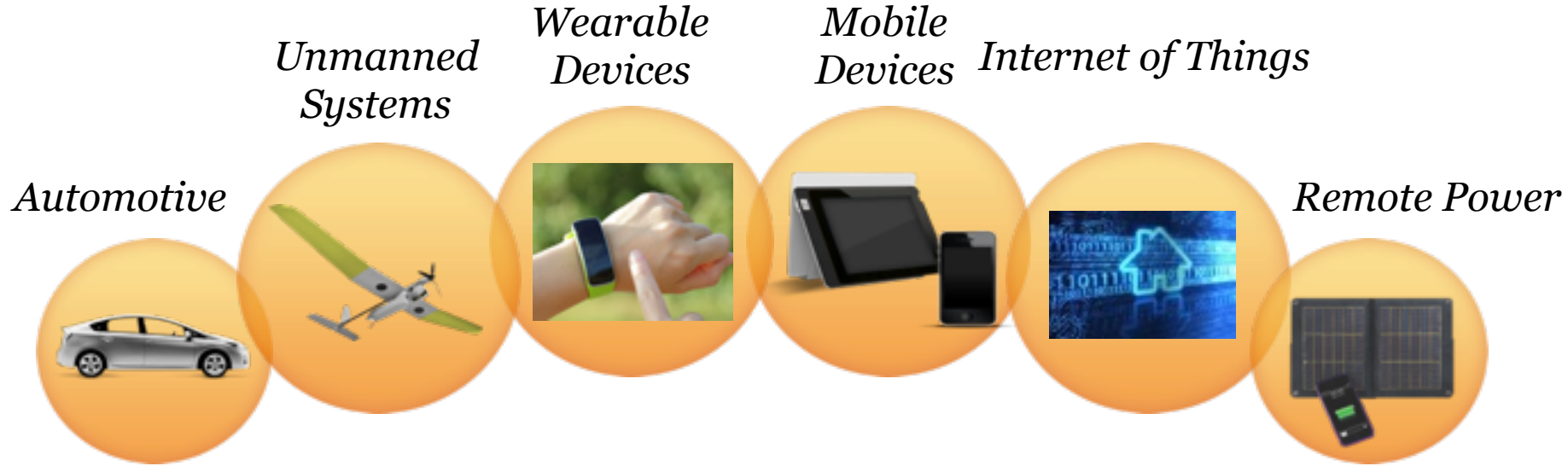
Bumina on Top
Tesla's Tech Advantage
Google's Next Act
Third Rock is Biotech's Top VC
Cree: Reinventing the Lightbulb

1366: Solar Survivor
Xiaomi's Smartphone Success
Cheap Gas from Siluria
Upworthy: Going Viral
Ripple Labs: New Money

1 Bumina	2 Tesla Motors	3 Google	4 Samsung	5 Salesforce.com	6 Dropbox	7 EMW	8 Third Rock Ventures	9 Square	10 Amazon
11 Tencent	12 Snapchat	13 Cree	14 Box	15 BrightSource Energy	16 Wal-Mart Stores	17 General Electric	18 Qualcomm	19 Kaggle	20 Second Sight
21 SpaceX	22 Kickstarter	23 Hanergy Holding Group	24 Siemens	25 1366 Technologies	26 Uber	27 Evernote	28 Baidu	29 GitHub	30 Xiaomi
31 Oculus VR	32 Qihoo 360 Technology	33 Monocanto	34 Aqualan Energy	35 IBM	36 Jawbone	37 Medtronic	38 Valve	39 Genomics England	40 Q-Wave Systems
41 Siluria Technologies	42 Kulima Bio-Agritech	43 Defwind	44 Freescale Semiconductor	45 Upworthy	46 LG	47 Expect Labs	48 AngeLab	49 Arcadia Biosciences	50 Ripple Labs

World's most influential technology awards:
MIT Technology Review

Mobile Power Applications



*Alta Devices provides power where it simply doesn't exist today:
anything that moves, can be carried, or worn*

UAV Example





Technology Overview

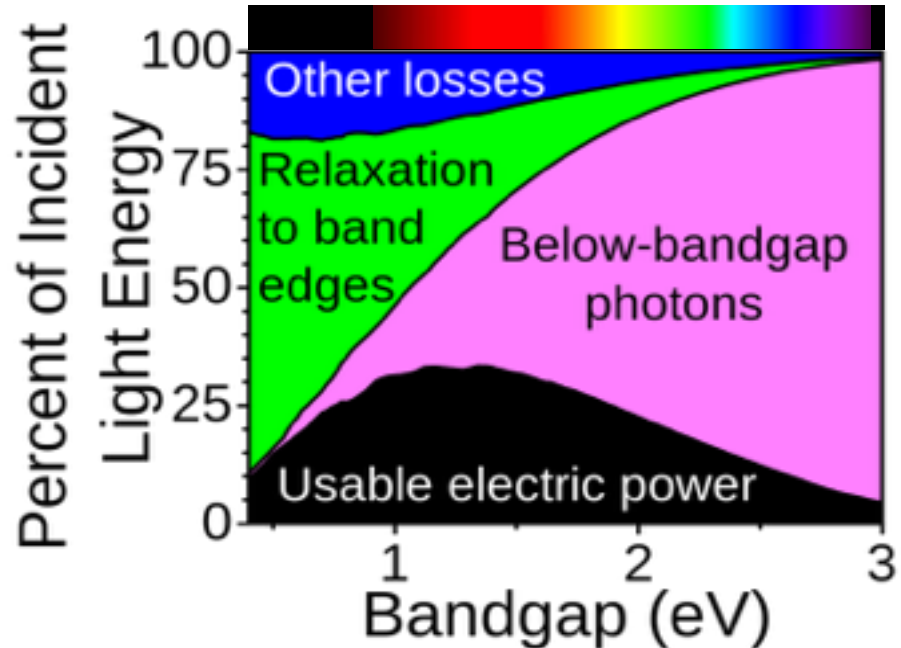
Key Enablers

Mission is to bring highest efficiency solar to broad markets

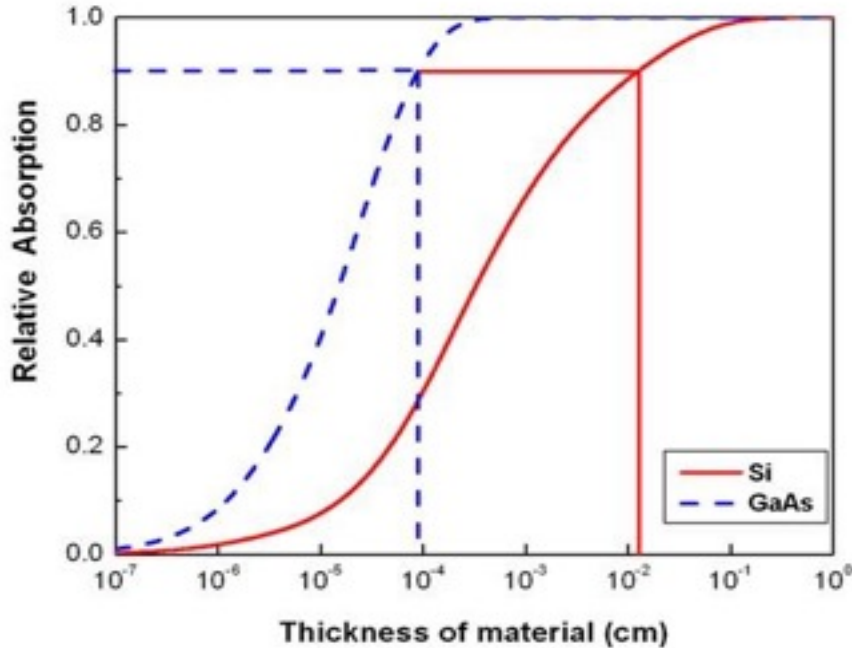
1. Single crystal GaAs
2. Thin film/epitaxial growth and lift off
3. Photon recycling

Optimal Bandgap Cells

- ▶ GaAs is close to the ideal bandgap for single junction cells (1.4 eV)
- ▶ Lower bandgap wastes energy of “blue” photons
- ▶ Higher bandgap cannot absorb “red” photons

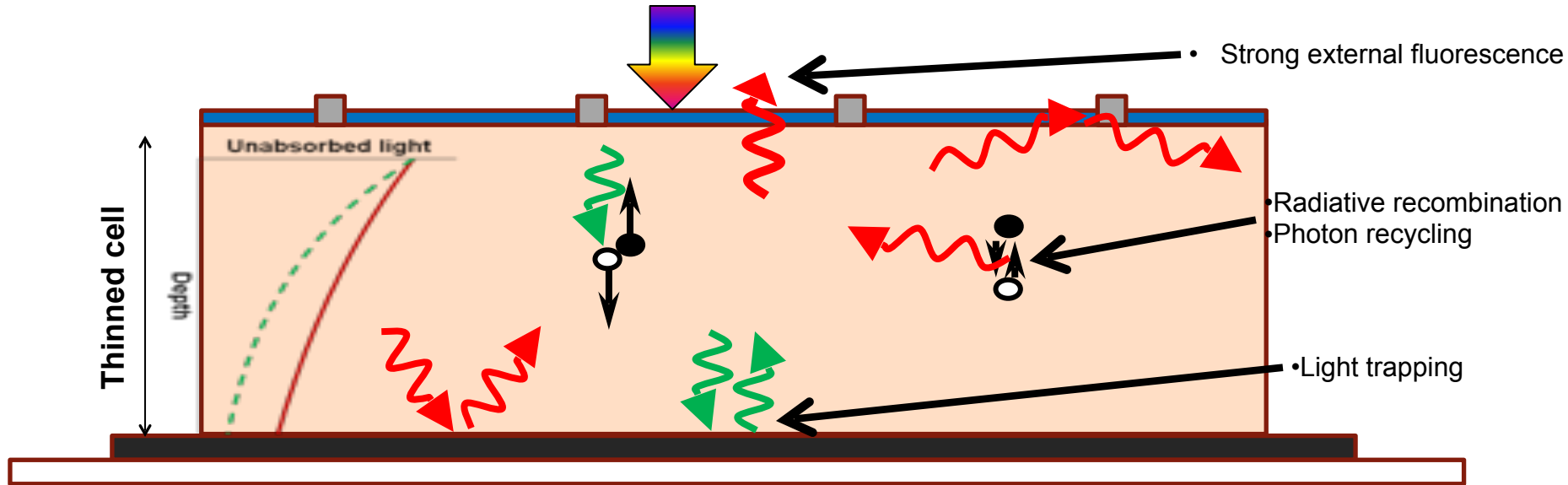


Comparing GaAs vs. Silicon



- ▶ Over 100 microns (0.004") of silicon are needed to absorb 90% of photons
- ▶ For GaAs, this number is about 1 micron (0.00004") of material.
- ▶ Silicon layer will need to be a hundred times thicker than GaAs for same absorption
- ▶ Because GaAs is a direct bandgap material

Design of Thin-Film, Single-Crystal Cell



- Single-crystal thin films provide new solar cell design opportunities
- Minimizing optical, as well as electrical, losses key to high performance

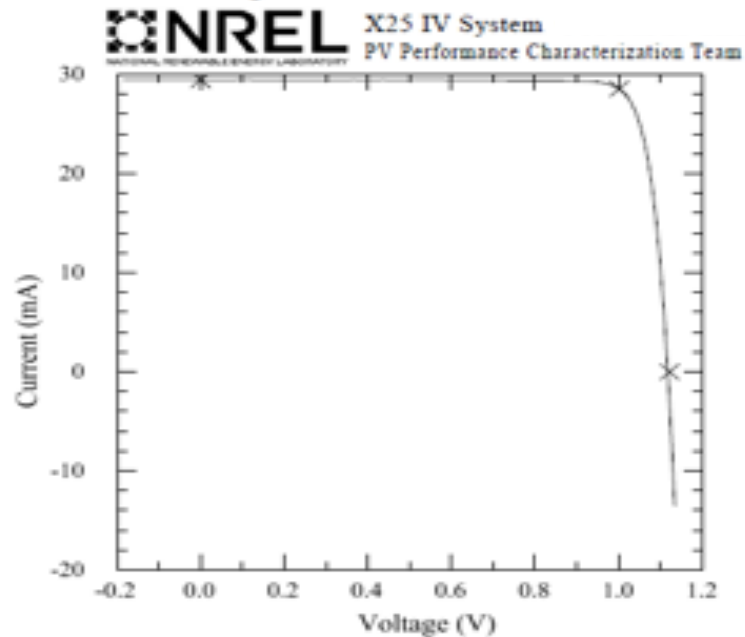
Alta Devices' World-Record Cell

Mar 06, 2012 10:57

Device Area: 0.9927 cm²

Spectrum: ASTM G173 global

Irradiance: 1000.0 W/m²



$V_{oc} = 1.1220$ V

$I_{max} = 28.557$ mA

$I_{sc} = 29.461$ mA

$V_{max} = 1.0013$ V

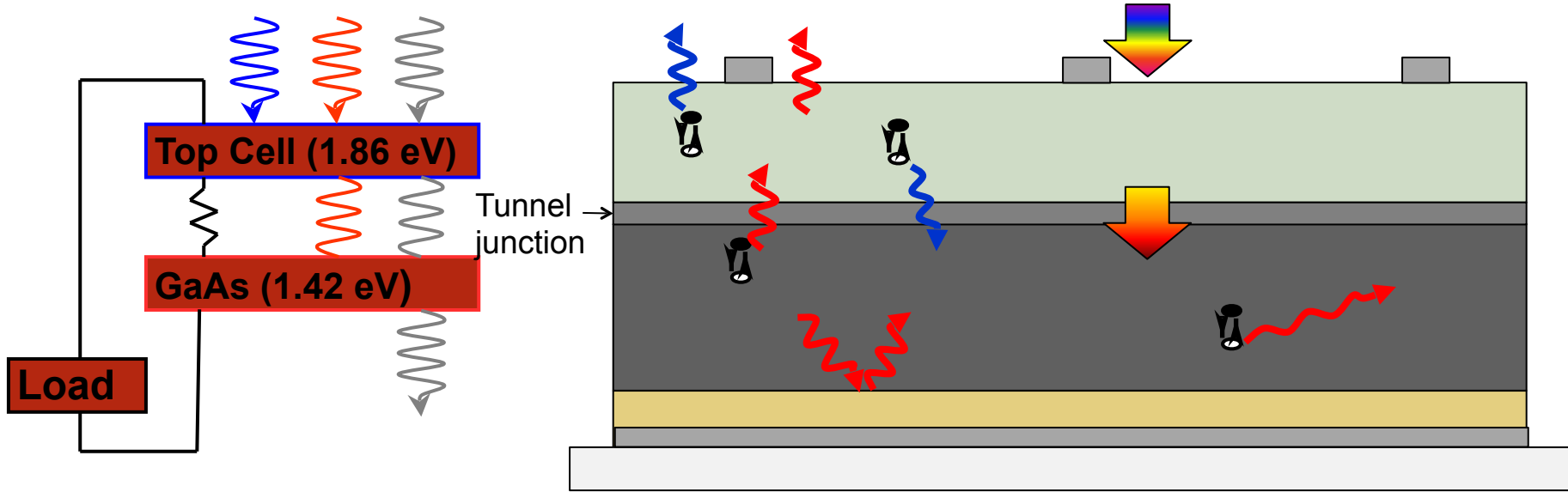
$J_{sc} = 29.677$ mA/cm²

$P_{max} = 28.593$ mW

Fill Factor = 86.50 %

Efficiency = 28.80 %

Dual Junction Solar Cells



Voltage adds in series

Both junctions designed to have the same current

Efficiency increases because top cell better utilizes high-energy photons

NREL-Certified 31.6% Cell Efficiency

Alta Devices

GaInP/GaAs Tandem Cell

Device ID: AD33551-I-3

Device temperature: 25.0 ± 1.0 °C

5:14 PM 1/5/2016

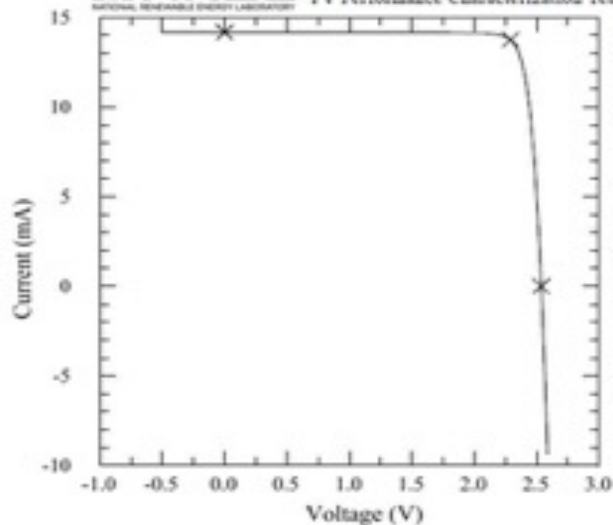
Device area: 0.999 cm²

Spectrum: ASTM G173 global

Irradiance: 1000.0 W/m²



OSMSS IV System Confidential
PV Performance Characterization Team



$V_{oc} = 2.5381$ V
 $I_{sc} = 14.164$ mA
 $J_{sc} = 14.184$ mA/cm²
Fill Factor = 87.7 %

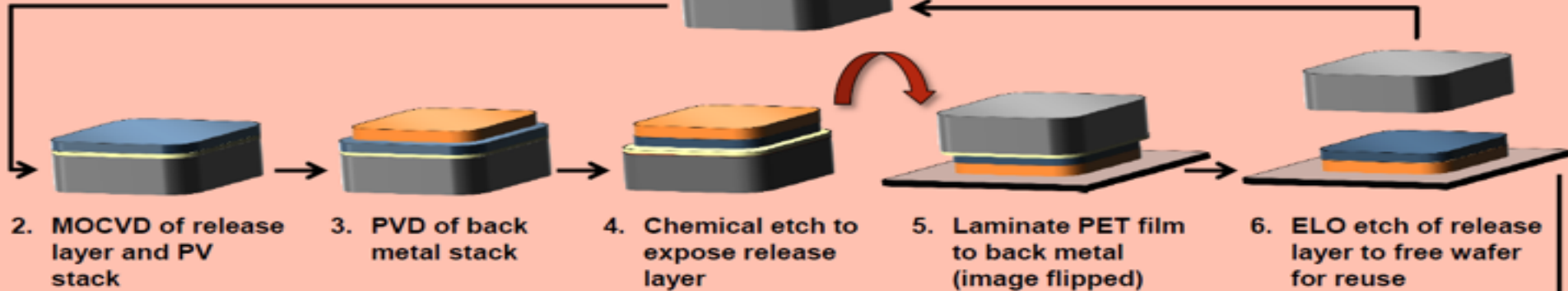
$I_{max} = 13.754$ mA
 $V_{max} = 2.2906$ V
 $P_{max} = 31.505$ mW
Efficiency = 31.55 %

Process Overview

Summary of Alta's Process Flow

Front End of Line

1. Prepare wafer surface for MOCVD



Back End of Line



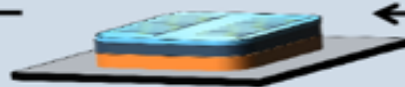
10. PVD of anti-reflective coating (ARC)



9. Chemical etch to isolate cells



8. Electroplate front metal contacts



7. Screen print front metal pattern



11. Complete laser separation of cells



12. Matrix assembly

The top half of the slide features a dark orange background with several thin, parallel, wavy lines in a lighter shade of orange that create a sense of motion and depth.

ALTA DEVICES

Application

Performance of Production Cells

Alta Devices produces the highest performance single junction solar cells available on the market.

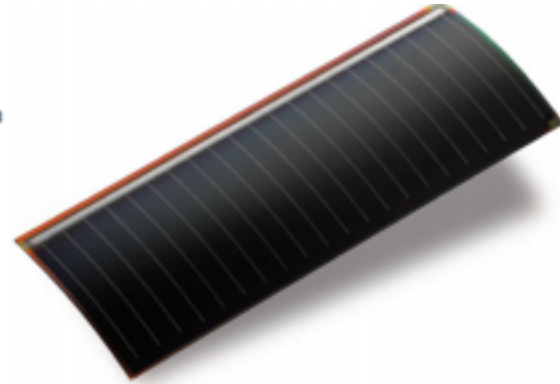
- The gallium arsenide based cells are thin, flexible, and lightweight, enabling a broad range of mobile power applications
- World-record cell and module efficiencies
- Low temperature coefficients and high sensitivity to low light generate unsurpassed real world performance

Mechanical Data and Design

Format	[mm]	50 x 19.6 ± 0.5
Thickness	[µm]	110 ± 10
Weight	[mg]	180
Front	[-]	1.0 mm bus bar, AR coating
Back	[+]	Polymer carrier film, vias for electrical contact

Electrical Performance

- ▶ ~214 mW (AM1.5)
- ▶ ~1 volt per cell
- ▶ Temperature coefficient -0.1%/C over a wide temperature range



Temperature Coefficients

Voltage	[%/ °C]	-0.187
Current	[%/ °C]	+0.084
Power	[%/ °C]	-0.095

Series/Parallel Connections



Example ~3U Layout

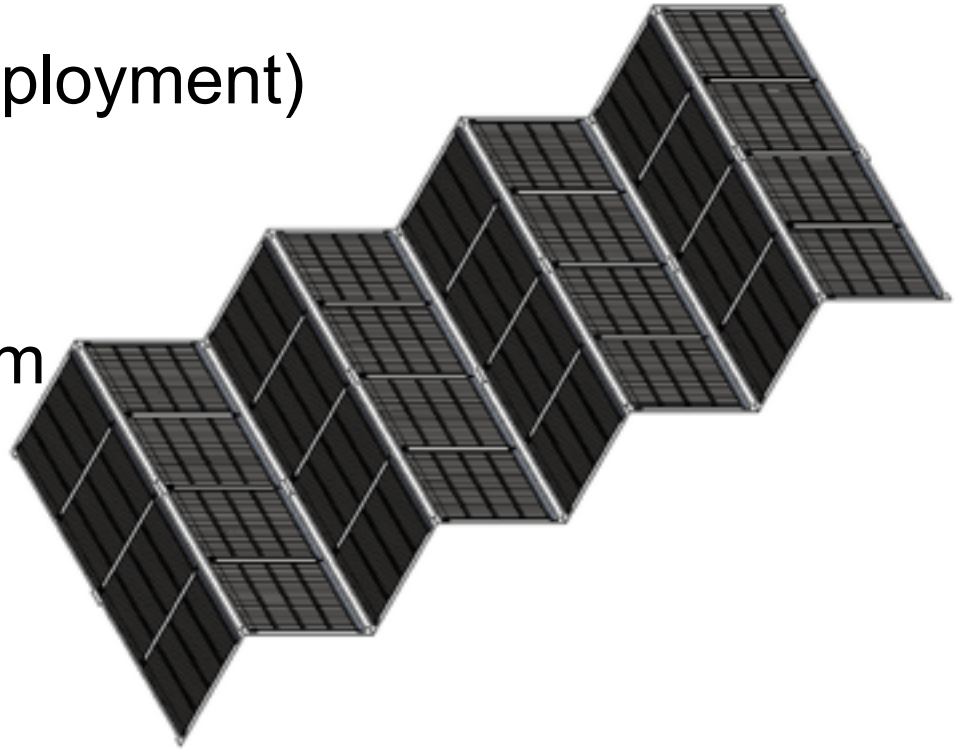
- ▶ 6 watts
- ▶ 10 grams of added weight including diodes, adhesives and encapsulation



- ▶ Cells are thin ($\sim 0.1\text{mm}$) and can be overlapped for high packing factors

Example ~2U folding subarray

- ▶ 29W
- ▶ Weight 60 grams (plus deployment) including encapsulation
- ▶ 310x700mm
- ▶ Thickness per fold <math><0.5\text{mm}</math>
- ▶ Can also be rolled



Is weight important?

- ▶ Initial launch costs per kg are coming down
 - ▶ Weight is still important
 - For higher orbits, moon missions
 - Station keeping and reorientation maneuvers
 - Raising and lowering orbits
- >>> Particularly interesting for electric propulsion

Summary

- ▶ Thin GaAs solar provides high W/kg, W/m² and W/m³
- ▶ Alta Devices (Sunnyvale, CA) is a world leader in this technology
- ▶ Open to working with cubesat teams

- ▶ Contact: aarohiv@altadevices.com

ALTADEVICES

Thank You
www.altadevices.com
aarohiv@altadevices.com