Solar Technology; Crystalline Silicon PV Solar Cells

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Agenda

- Applied Materials
- c-Si Manufacturing Process Flow

  Poly → Ingot → Wafer → Cell →Module
- Cost Reduction and Technology Roadmap

Applied Materials

Applied Materials Business Segments

SILICON SYSTEMS GROUP

Pursuing growth in emerging logic, emerging memory and packaging technologies

DISPLAY

Lowering cost and improving performance of displays

ENERGY & ENVIRONMENTAL SOLUTIONS

Lowering the cost of electricity

APPLIED GLOBAL SERVICES

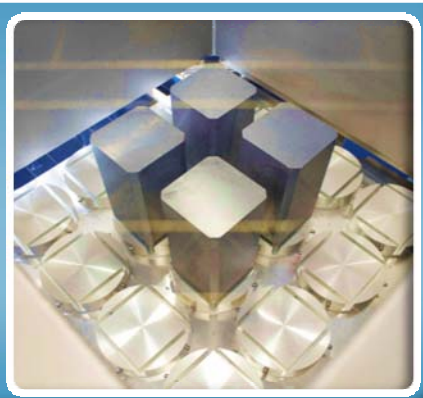
Optimizing output and efficiency through service, equipment and automation software

PV Manufacturing Solutions Leadership

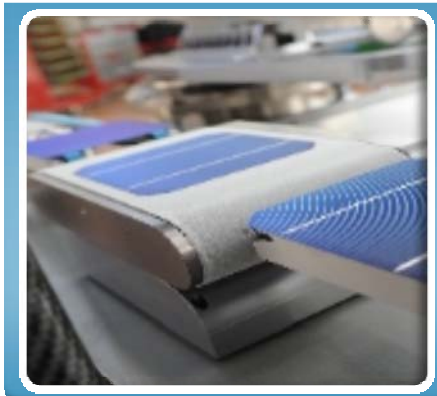
SILICON → INGOT → WAFER → CELL → MODULE

APPLIED HCT WAFERING SYSTEMS

- Higher productivity
- Thinner wafers
- Consumables reduction



APPLIED BACCINI CELL SYSTEMS



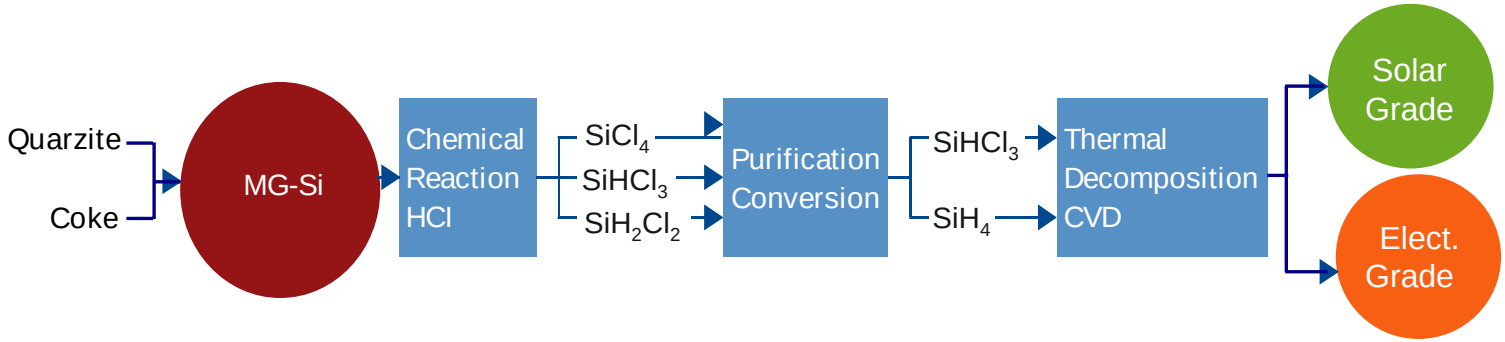
- Increased cell efficiencies
- Higher productivity
- Advanced automation

#1 Equipment Provider

Source: Ranked by VLSI

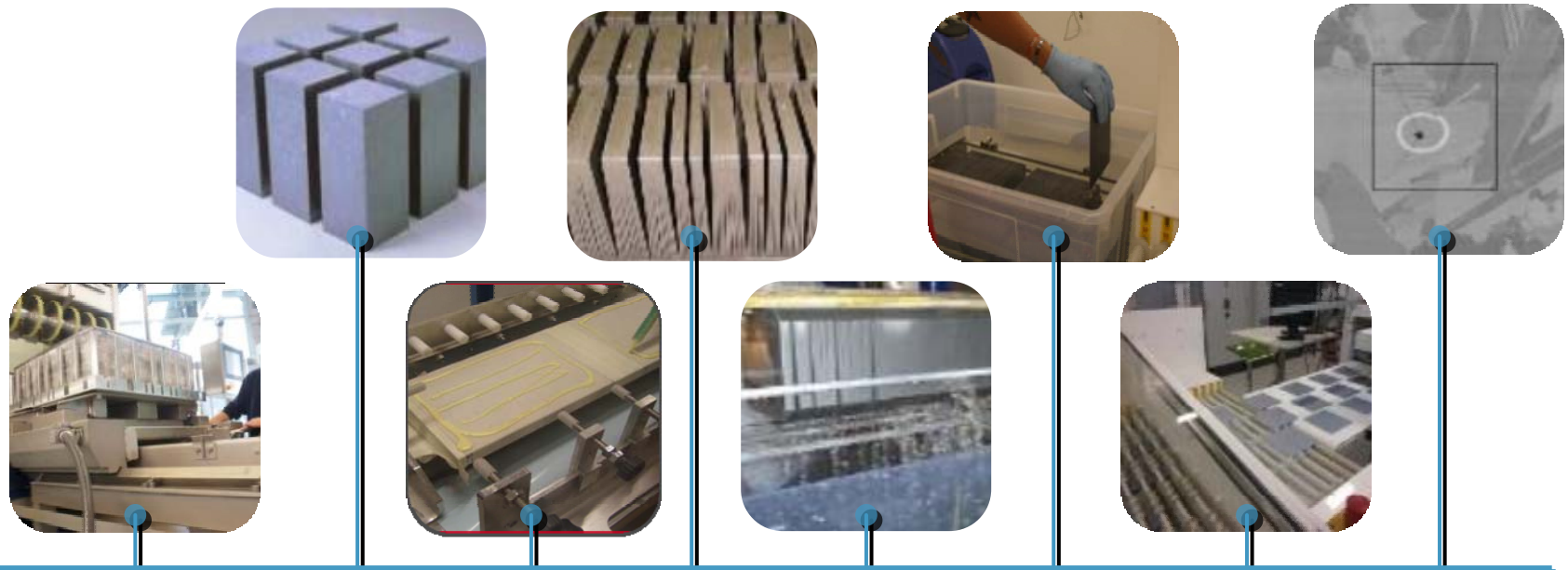
c-Si Manufacturing Process Flow

Silicon – Poly – Ingot Manufacturing



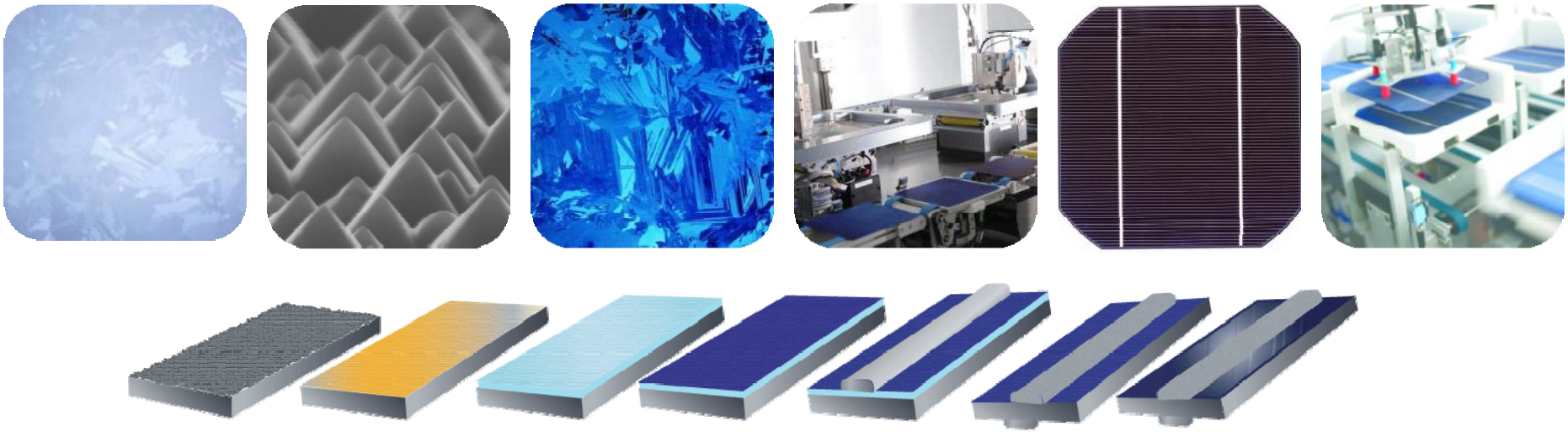
Step	Sand	Purification (99%)	MG Si + HCl = TCS	High Purity Si	Multi c-Si: Casting	Mono c-Si: Ingot Drawing
Technology	Silica Extraction	Arc Furnace	CVD Reactor	Break up rods	Casting crucible with directional re-crystallization	Czochralski Growth
Challenges	Multi: material quality, defectively. Mono: Cost, Rs variation					
Trends	Polysilicon reactor size, Casting size 650kg → 850kg, Cast Mono					

Ingot – Wafer Manufacturing



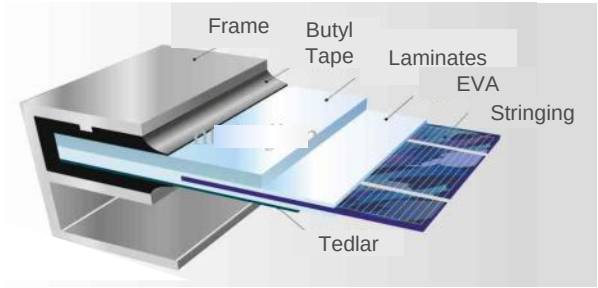
Step	Cropping and Squaring	Brick Finish	Mount Brick	Wafer Slicing	Pre-clean and De-gluing	Singulation	Final Clean and Dry	Wafer Inspection
Technology	Wiresaw	Grind, chamfer	Manual	Wiresaw	Wet clean	Manual, automatic	Wet clean	Optical, electrical
Challenges	Reducing kerf loss, yield and productivity							
Trends	Thinner wafers, wafering productivity (structured/diamond wire)							
Applied Position	B5 Cropper, B5 Squarer		Shower BEAM™	B5 Wiresaw				

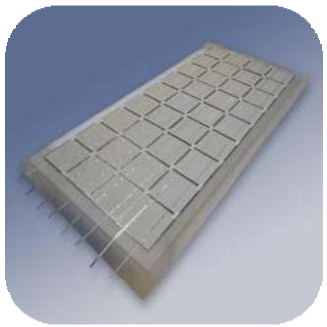
Cell Manufacturing



Step	SDE, Texture Etch & Clean	$POCl_3$ Diffusion	PSG Etch	ARC, Passivation	Front Busbar And Grid	Back Busbar	Back Metal	Co-Fire	Test & Sort
Technology	Wet Etch	Furnace	Wet Etch	PECVD SiN	Ag Screen Print, Oven	Ag/Al Screen Print, Oven	Al Screen Print, Oven	Furnace	IV test
Challenges	Yield, uniformity, rising Ag cost, efficiency at cost								
Trends	Factory productivity, efficiency improvement								
Applied Position					Screen Print, Dryer	Screen Print, Dryer	Screen Print, Dryer		Test & Sort

Module

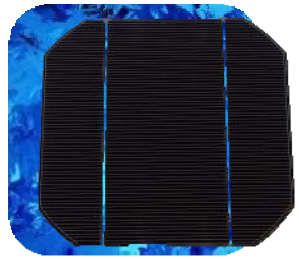



Step	Stringing	Circuit Assembly	Layup	Laminate	Edge Trim and Butyl Tape	Frame	Junction Box	Test
Technology	Automatic, Manual	Soldering leads	EVA, Tedlar™	Vacuum, cross-links the EVA	Flush against glass	Anodized Al, pressed or screwed	Spot welded	Flasher IV Test
Challenges	Stress from stringing operation, manual operations, material cost							
Trends	Monolithic Module Assembly, alternative encapsulants							
Applied Position								

Making a Crystalline Si Cell



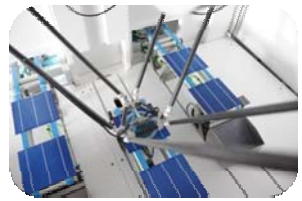



Poly Silicon Growth → Ingot → Wafering → Cell Processing → Module → Installation

SQUARER | CROPPER | WAFERING | PRINTER | DRYER | TEST&SORT

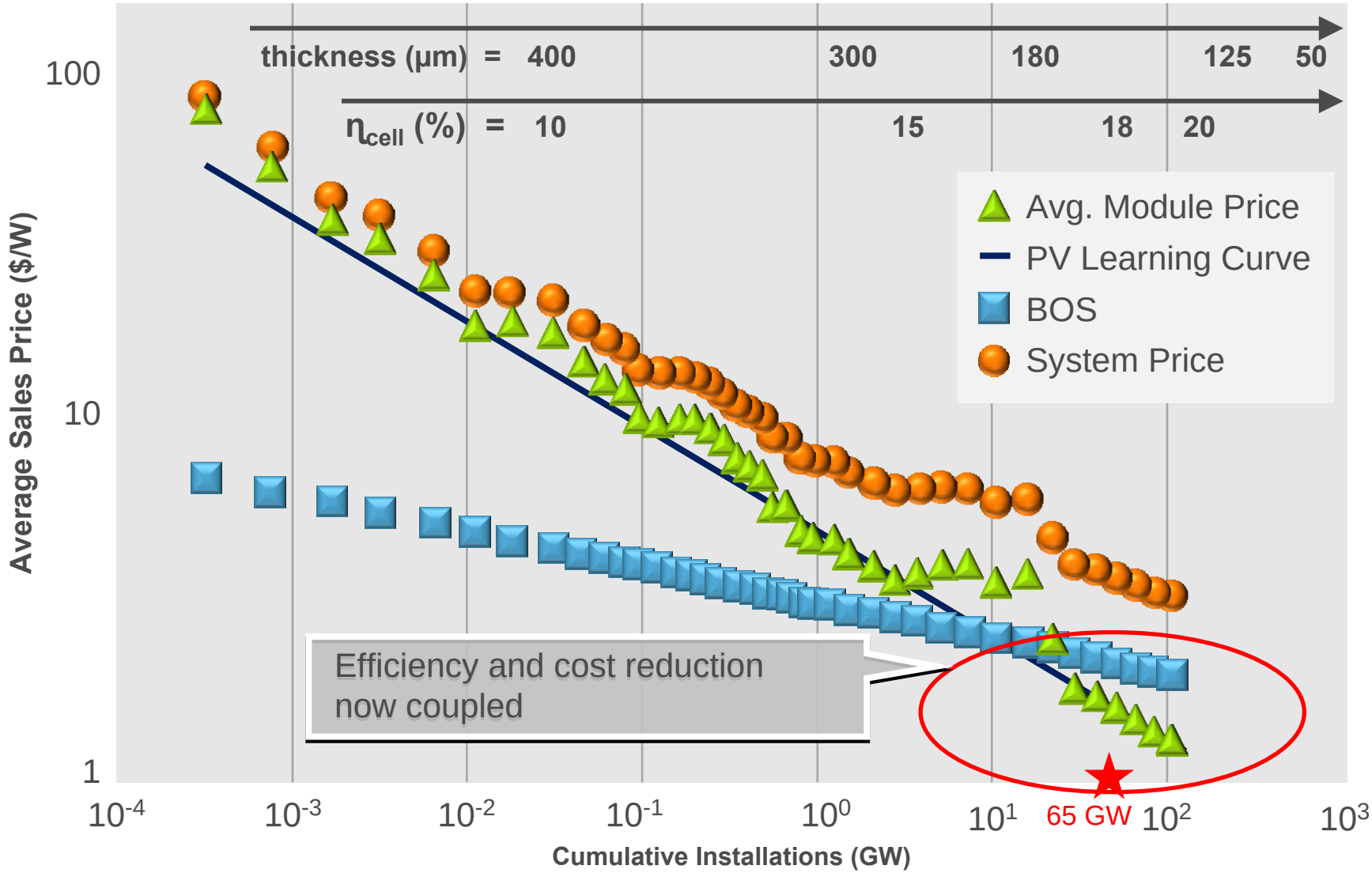




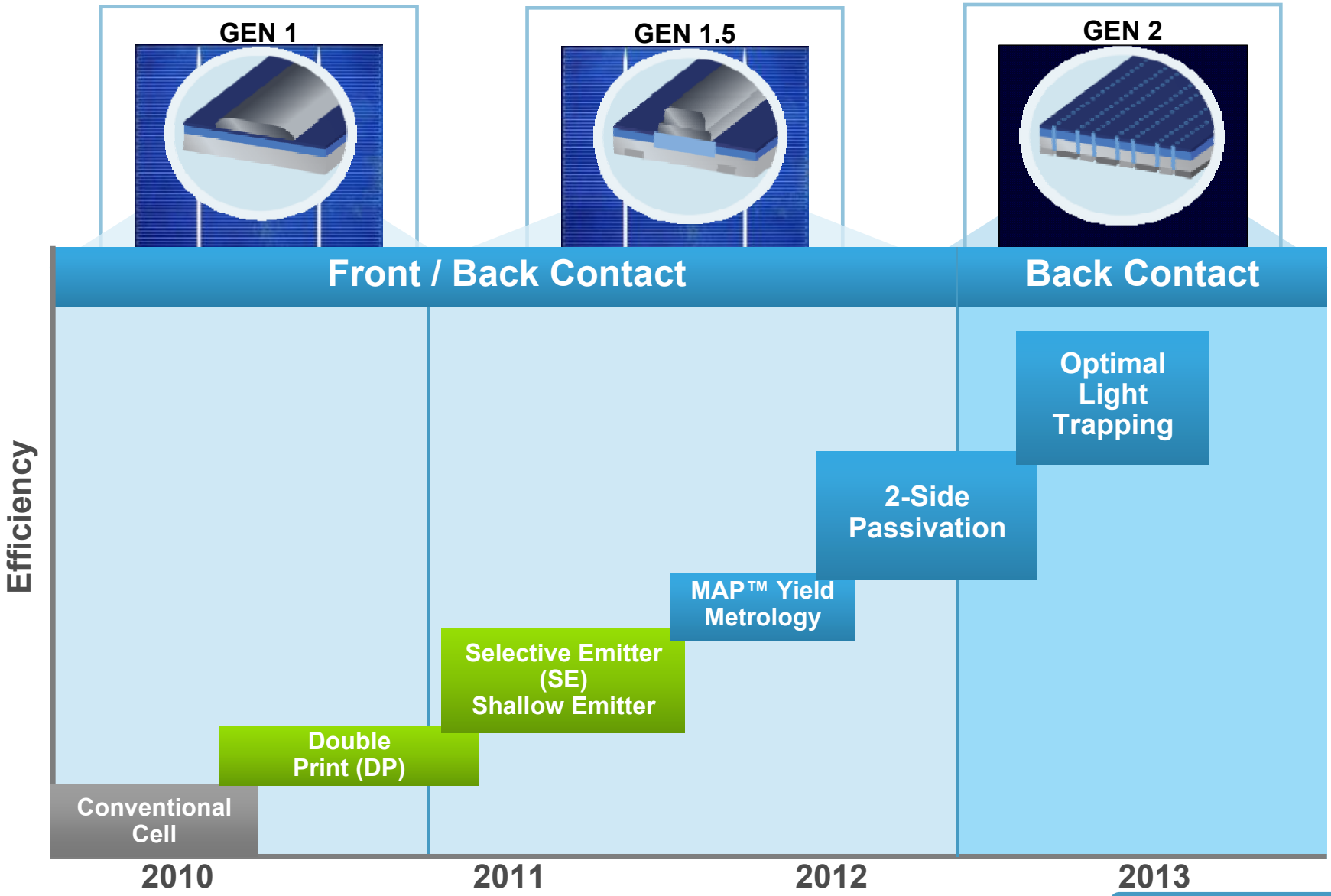
C-Si Technology Roadmap

The Predictable Cost Reduction of PV



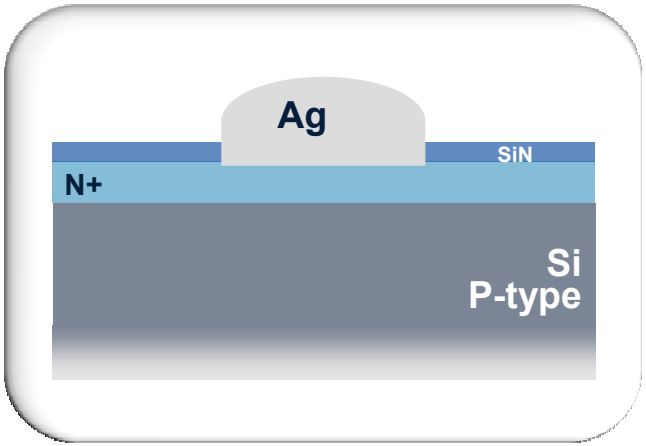
Source: Navigant Consulting, NREL, Solarbuzz, pvXchange, Morgan Stanley, New Energy Finance

Crystalline Silicon Technology Roadmap



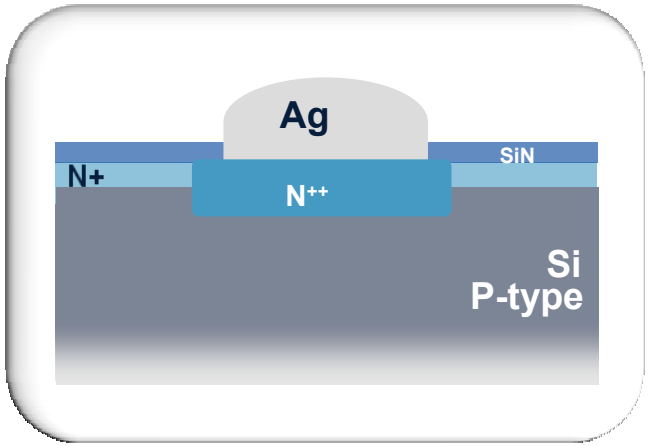
Example 1: Selective Emitter

Standard Cell



- Homogeneous emitter region requires compromise
- Good junction performance
- Low resistance to the front silver grid

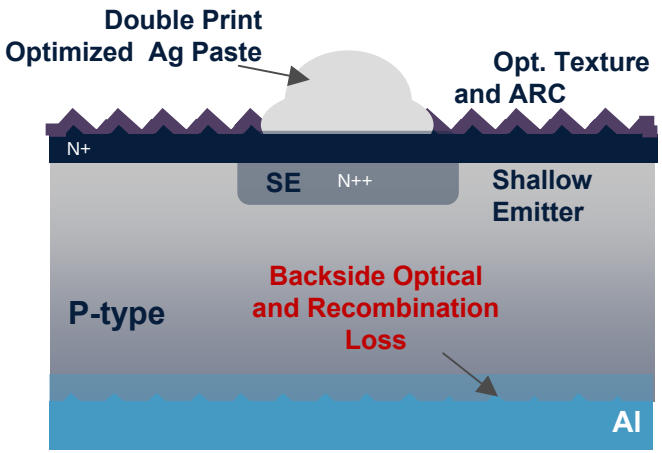
Selective Emitter Cell



- Selective emitter decouples the regions
- Lower dopant concentrations of the field region help reduce recombination
- Higher dopant concentration emitter improves ohmic contact

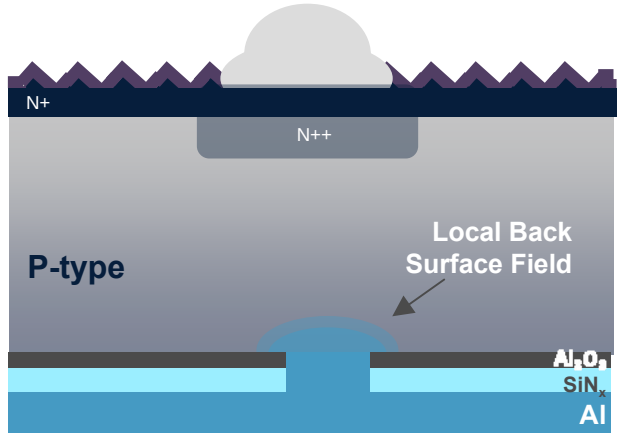
Example 2: Two Side Passivation

Conventional Cell



- Front side gains through reducing shading, optimizing emitter and optics

Backside Passivation



Reduces recombination losses
- Repairs defects and dangling bonds
- Reduces charge effect
- Negative Al_2O_3 film charge repels electrons
- SiN improves barrier properties
- Al_2O_3 low index of refraction reflects light back to bulk

Summary

- Applied Materials is the largest equipment supplier in the PV industry
- We mainly deal in the wafer and cell production technologies
- Module cost reduction has driven the growing market (now at ~30GW/year)
- Now BOS (balance of system) costs and module efficiency are coupled to achieve continued cost improvements.
- Applied Materials is developing cost effective materials, tools and services to increase cell and module efficiency to continue to drive down costs for our customers.

Turning innovations
into industries.™