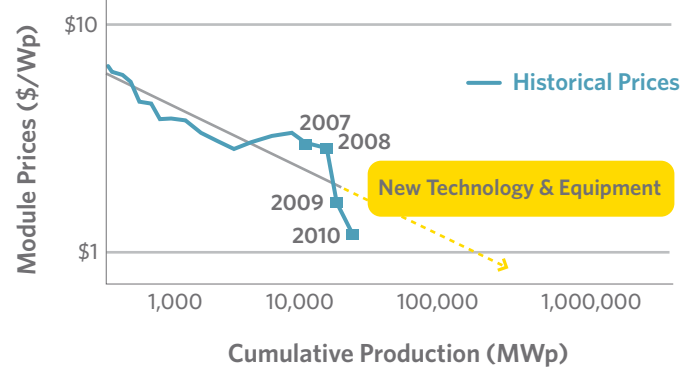




Powering the c-Si Roadmap

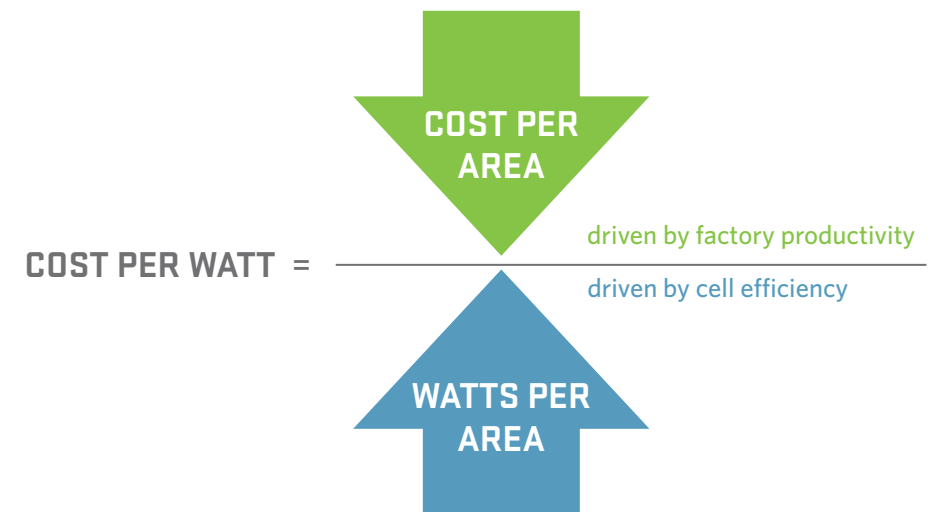
APPLIED BACCINI[®] CELL SYSTEMS

DRIVING C-Si TO ONE DOLLAR PER WATT



To remain competitive in a global market and to enable wider applications of solar energy, it's critical to drive down the c-Si cost per watt.

IT'S ALL ABOUT COST PER WATT



1

Increasing Efficiency

A key lever in reducing cost per watt is increasing cell efficiency. It's all about technology, cell design, metallization processes, materials, and metrology.

Higher efficiency increases factory MW output for a given capital investment, reducing module cost per watt by about \$0.10 for every point of increase. Higher efficiency also reduces the panel area required to generate a given solar energy output, reducing balance of system cost, and further lowering the levelized cost of electricity.

Advances in efficiency require new process integrations, which represent time, cost, and risk. Applied Materials is in a unique position to provide integrated technology solutions to accelerate these advancements for the industry.

2

Reducing Material Cost

Even at current historic low prices, silicon wafers account for a large portion of the crystalline solar cell manufacturing cost. When silicon prices rise again, manufacturers who have already made the move to ultra-thin wafers will find themselves with a built-in cost advantage. Thinner substrates save silicon but increase the risk of wafer breakage in handling and processing, which reduces yield. They require a major change in manufacturing, as all process equipment must handle them reliably.

Baccini Cell System's advances in soft wafer handling dramatically reduce wafer breakage at high manufacturing throughputs. Collaborations with paste and screen suppliers are attacking other key material costs by reducing paste usage and extending screen life.

3

Scaling Throughput

The biggest driver in reducing cost per watt is increasing manufacturing scale. Panel producers are moving to greater factory output to reduce cost, with new factories routinely producing over 200MW per year. These factories can be enhanced through integration and greater automation to deliver higher throughput and reduce overall floor space.

High system reliability and availability is essential to maximizing total MW output from an installed capacity investment. Applied Materials' Baccini systems set the benchmark for manufacturing availability, for both standard cell processes and advanced cells on ultra-thin wafers.

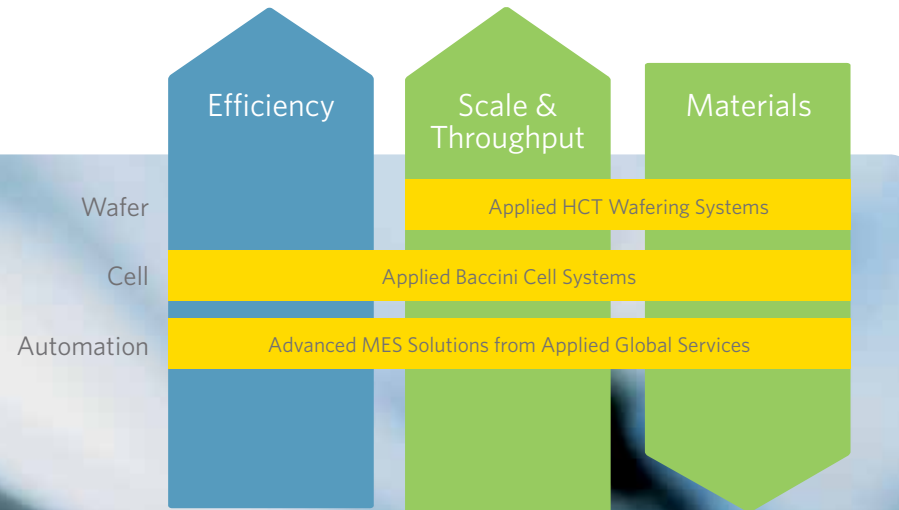
POWERING INDUSTRY ROADMAPS

Important as the performance of existing manufacturing technologies is, our customers need to go further. To win in PV manufacturing, our customers must drive their costs down and their efficiencies up. That means process improvements and breakthrough cell designs. It means they need complete solution providers who will be their partners, providing not just the equipment hardware and software, but also the process expertise and consumable know-how to collaborate and advance their efficiency roadmap. Applied Materials is the only

company that is taking such a holistic, multi-dimensional solutions approach to addressing customers' needs. Our HCT wire saws cut thinner wafers at high throughput with low consumable cost; and Baccini screen printing solutions bring robust, high throughput printing and wafer handling to ultra-thin wafers and advanced cell designs.

To enhance yield and factory efficiency, Applied Materials is utilizing proven automation software products like E3 to provide effective process monitoring and

diagnostics at the equipment level, while SmartFactory MES software enables factory level material management, production sequencing, and APC capability. And Applied Global Services deploy the industry's largest customer service force to deliver unmatched support, anywhere in the world.



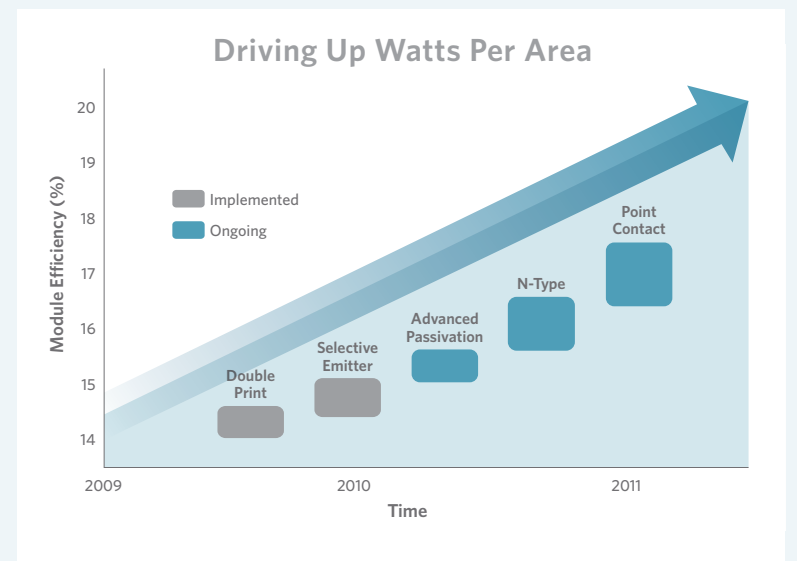
PLATFORM LEADERSHIP DRIVES THE PRODUCTIVITY ROADMAP

Applied Materials has a development path to address each of the primary drivers of reduced manufacturing cost. Wire saws from HCT lead the way in ultra-thin wafering, while Baccini platforms set the standard for thin wafer handling. Advances in automation, metrology and process control software enable higher manufacturing throughput with enhanced yield and greater overall availability.



ENABLING TECHNOLOGY DRIVES THE EFFICIENCY ROADMAP

Applied Baccini Esatto Technology™ is providing enabling capability for advances in cell metallization and selective emitter structures which have the potential to increase cell efficiency.



PRODUCTION-PROVEN PLATFORMS

A HISTORY OF RELIABLE PERFORMANCE

Screen printing has been the proven manufacturing method of choice for solar cell contact deposition. It is reliable and cost-effective, with low scrap and high throughput. Baccini's screen printing process lines are well-established as the solar industry's benchmark platforms. The lines are fully automated and completely integrated. They comprise screen printers, dryers, optical inspection systems, laser systems for edge isolation, testers, and high speed sorters.

Applied Baccini Rotary Line

Proven production platform with the highest capital productivity.

- Market leader with more than 400 systems installed
- Throughput greater than 1,400 cells per hour or over 40MW per year
- <0.5% wafer breakage for full line
- Uptime greater than 90%

>160µm Cell Production



TECHNOLOGY LEADERSHIP



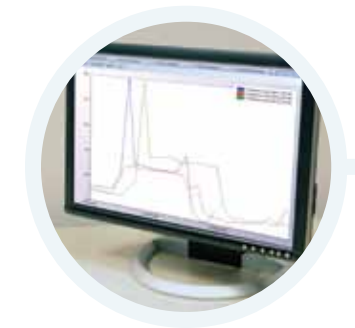
Printing Reliability

- Automatic inspection (rejection/recovery capabilities)
- Automatic paste refilling and screen cleaning device
- Automatic paper roll refresh and easily replaceable print nest cartridges



Soft Handling

- Highly controlled wafer handling and transportation
- Use of paper on print nest
- Print head adjustment and positioning for set-up eliminates the need for pick and place re-location of the wafer



E3 Diagnostics Software

- Monitors equipment
- Detects and classifies faults
- Tracks performance
- Controls process run to run
- Analyzes data and reports statistics

Applied Baccini Soft Line

Advanced platform with lowest CoO and extendibility to ultra-thin wafer.

- Provides greatest flexibility and extendibility
- Greater than 1,440 cells per hour or over 45MW per year
- <0.2% breakage rate for full line
- Uptime greater than 92%

>100µm Cell Production



ESATTO INTEGRATED PROCESS SOLUTIONS

REDUCING TIME, COST, AND RISK

Through Esatto Technology, Baccini systems enable cell manufacturers to conveniently and quickly enhance the efficiency of their c-Si solar cells, produced on existing or future lines.

Esatto Is a Complete Solution

A combination of hardware, software, qualified consumables, production proven processes, and customer specific applications.

Esatto Is Enabling

Enables screen printing of overlapped patterns of similar or different materials on c-Si wafers with high precision and repeatability in a manufacturing environment.

Esatto Is Extendible

Esatto is available as an upgrade to both Rotary and Soft Line installations by adding additional printers with the high precision kit and additional dryers. This upgrade provides a low cost, low risk path to higher cell efficiency.

Customer Specific Applications

Esatto is all about enabling a customer's efficiency roadmap. We work with the customer to either implement a standard process or jointly develop a new process for creation of advanced cell structures that will increase efficiency.

Proven Processes

In our advanced research lab, we have the capability to do complete cell process flows, for both mono- and polycrystalline cells, to validate advanced process solutions and accelerate customer time to market.

Precision Alignment

The Esatto precision alignment system enables high levels of repeatability in critical volume production conditions and offers great flexibility to match individual process needs. The system includes high-resolution cameras and illumination, a high precision rotary table, sophisticated alignment algorithms, and other supporting components.

Advanced Process Control

Esatto's advanced post print vision system for process control provides high system accuracy, within $10\mu\text{m}$ ($\pm 3\sigma$), improves overall process repeatability, and ensures higher uptime and better process yield management.

Enhanced Pastes

Working closely with suppliers, we have optimized pastes for low series resistance and fine-line performance, including thickness, height, spreading, and paste utilization — qualifying them for Esatto applications.

Optimized Screens

Working with screen suppliers, screens have been optimized for interaction with the new pastes to deliver fine-line image definition and control, with stable lifetime performance and extended screen life.



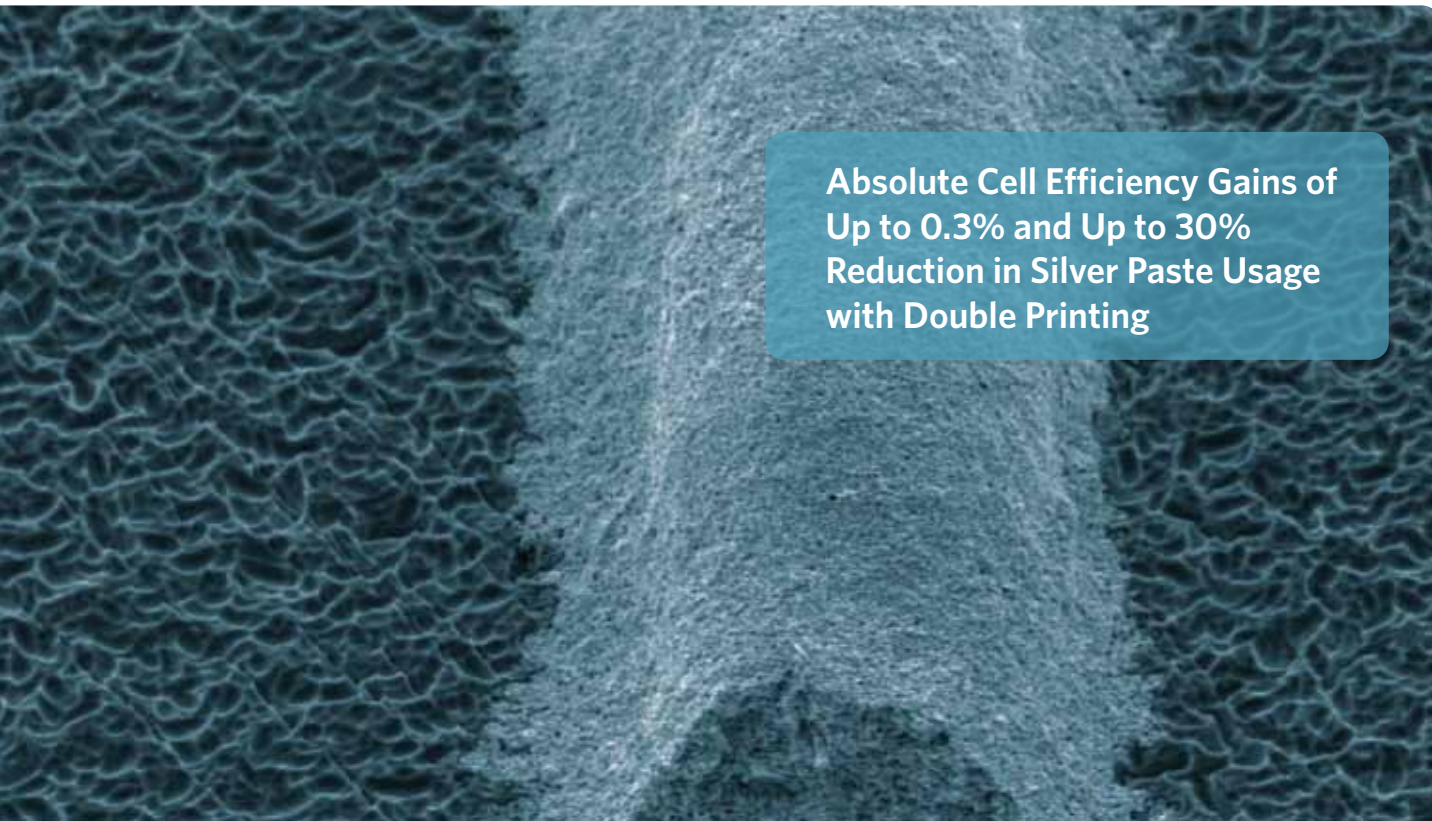
DOUBLE PRINTING

To maximize efficiency, cell designs need to minimize shadowing of the active surface while also reducing resistive losses. An advanced printing technique, double printing, places a second, narrow layer of silver paste on top of a conventional contact line, achieving a narrow profile that reduces line resistance without increasing width. Double printing drives down cost/watt by increasing efficiency of the cells as well as a reducing paste consumption by optimizing bus bar formation.

Double printing is one of the first cell enhancements to benefit from Esatto

Technology. Esatto Technology uniquely delivers this capability through a combination of hardware and software which ensure alignment accuracy — a critical factor for double printing and other multi-printing applications. In addition, an integrated approach to optimize paste, screen, and process ensures repeatable results in manufacturing. Double printing, using the Applied Baccini Esatto solution with optimized printers, paste, and screens, yields an absolute efficiency gain of up to 0.3% and up to 30% reduction in front silver paste usage.

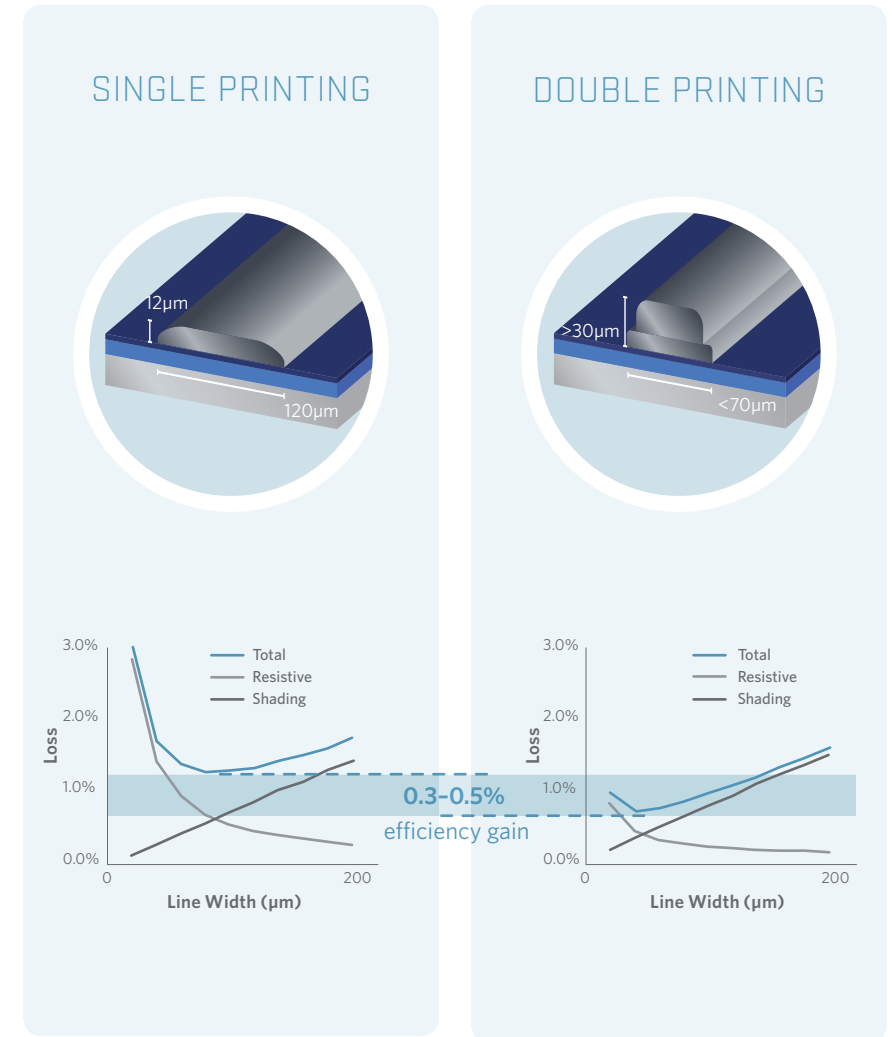
Double printing using Esatto Technology is in mass volume production at a number of leading customer locations — and is generating several additional MW with only one extra printer and drying oven.



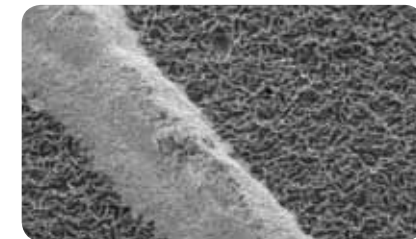
Narrower and Taller Lines Reduce Shadow and Resistive Loss

Esatto Technology enables precision double printing of narrower, taller lines which reduce shadowing and resistive loss. Precision alignment and optimized pastes and screens are required to achieve high yield in volume manufacturing.

Thinner metallization lines reduce loss due to shadowing, but also increase resistive loss. Precise double printing enables the full benefit of reduced shadowing by enhancing conductivity.



The combination of Esatto precision alignment, optimized pastes and screens, and proven process recipes provide repeatable profiles and aspect ratio for double patterned lines of 70µm and below.



70µm double printed metal line using Esatto Technology exhibits precise alignment of the second layer and tight control of line edge, profile, and aspect ratio.

SELECTIVE EMITTER

Selective Emitters (SE) on high performance cells increase efficiency by improving panel voltage and current (Voc and Isc) values and minimizing recombination and resistive losses. It is extremely critical to align the metal lines precisely on top of the selective emitters, so that the highly doped regions lie directly below the contact fingers. If the metal lines are not printed precisely the cell can fail due to a shunt. Correct and robust alignment also enlarges all downstream and upstream process windows.

Using an Integrated Solutions approach, Applied Materials is developing equipment, materials and technology, together with key partners, to enable selective emitter technology.

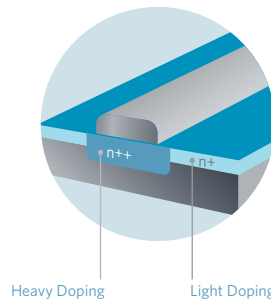
Esatto Technology metallization solutions offer the ideal solution independent of wafer type

and SE formation methods with upgradable high-precision kits.

Esatto's high precision camera kits, illumination systems and advanced software enable precise alignment of metal critical for SE structure formation.

Esatto Technology supports all aspects of the selective emitter process, including selection and printing of the high-dose doping paste, etching paste and contact paste.

Double printing over selective emitter structures using Esatto Technology further boosts cell efficiency and also reduces consumption of metal paste.



- Heavily doped region is limited to the emitter contact area
- Metal needs to be aligned on top of emitter for best efficiency
- Reduced width of the heavily doped region limits recombination

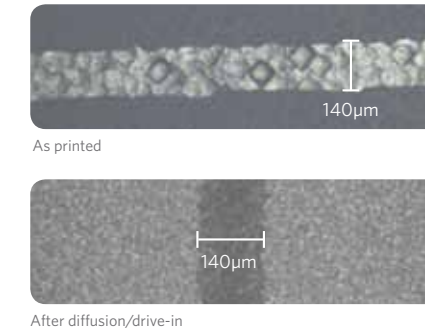
Esatto Selective Emitter Formation Solution

Leveraging the Esatto Technology platform, Applied Materials offers a Selective Emitter formation solution that provides customers with a rapid, low-risk route to fabricate SE structures.

The Esatto Selective Emitter solution is a simple direct dopant process using proven equipment designed for screen printing dopants, qualified consumables and dedicated process support. This solution is easily integrated into the cell manufacturing process immediately before the conventional emitter diffusion and subsequent phosphorous gas (PSG) removal.

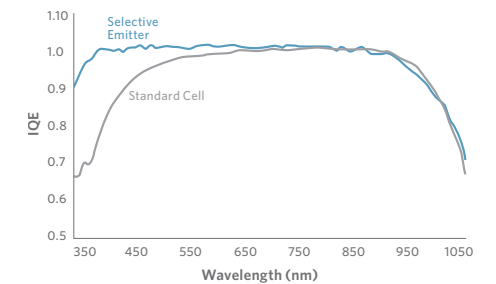
The Applied Materials' Esatto SE Solution has been proven to raise absolute cell efficiency by 0.5%.

Selective Emitter Development Structures



Dopants screen printed utilizing Esatto Technology show excellent placement accuracy and line edge control.

Selective Emitter Efficiency Gains Internal Quantum Efficiency



Short wavelength light response improvement with PDP SE and optimized POCl diffusion.

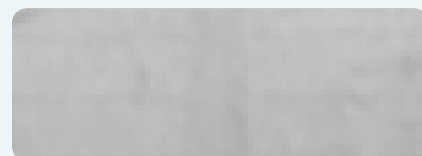
0.5% efficiency enhancement achieved for mono c-Si.

SE Methods - Paths to Selective Emitter

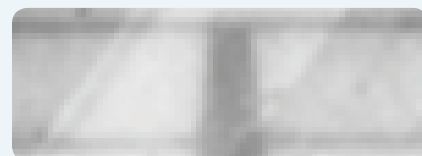
There are several different known SE formation methods. Applied Materials' screen printing platforms and Esatto Technology provide all the elements required for tightly aligning and printing the front metal grid over the SE pattern.

Advanced vision, alignment, and print solutions detect difficult to see SE patterns to accurately print over the SE region.

Esatto Technology Alignment Capability



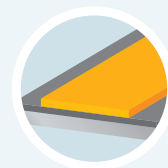
Difficult to "see" SE



Esatto Technology

1 PRINTED DOPANTS

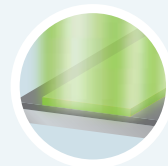
- Single print and dry step
- Easy integration
- Low cost



Dopant Paste / Mono c-Si

2 LASER DOPING

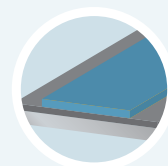
- Additional 1-2 steps
- Sharp junctions
- Cell reliability issues



Laser Doping / Mono c-Si

3 ETCH BACK

- Multiple additional processing steps
- Narrow process window



Etch Back / Multi c-Si

4 ION IMPLANTATION

- Profile control
- Implant followed by high temperature annealing
- High capital cost

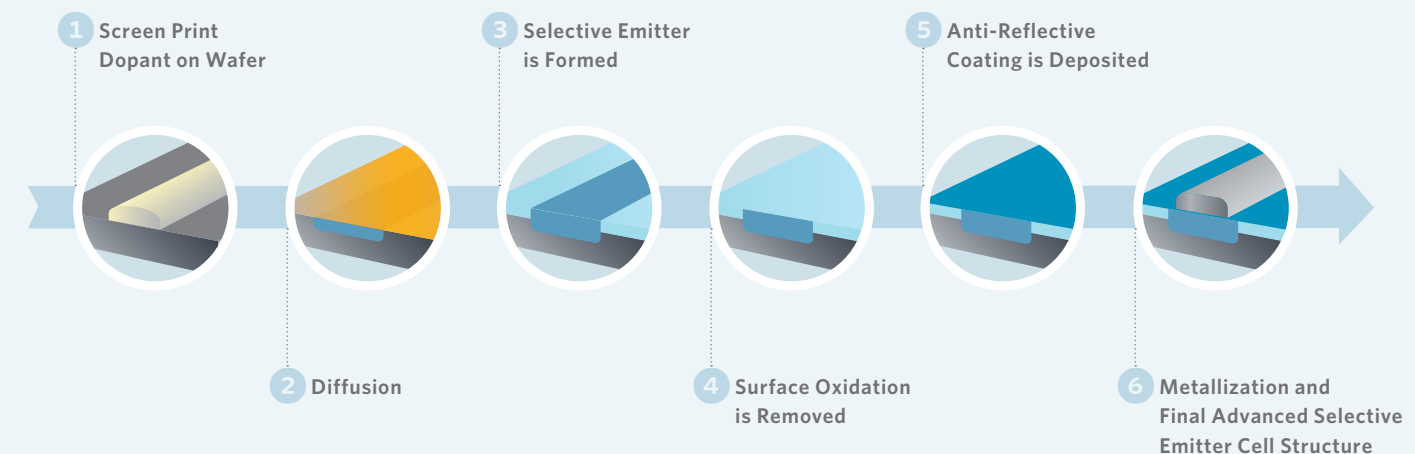


Ion Implant / Mono c-Si

SE Process Flow

Add just one Baccini printer and dryer to your cell manufacturing line. Optimized process recipes and qualified consumables for proven results.

- Simple direct dopant process
- Standard equipment
- Easy integration
- Qualified consumables
- Proven screen printing technology



STATE OF THE ART R&D TECHNOLOGY CAPABILITY

REDUCING THE TIME, COST AND RISK FOR CUSTOMERS

- Advanced cell manufacturing development
- Process research and optimization
- Advanced screen printing technology development and performance validation
- Performance validation on full cell line
- Application development for customer specific solutions



Wafering Apps and Cell Manufacturing Lab Xi'an China

Process validation on wider data sets
Hardware reliability testing
Performance validation on cell line
Customer demos and training



Metallization Center of Excellence Treviso, Italy

New product and process development
Development and demonstration of advanced cell metallization
Customer demos and training

MARKET AND TECHNOLOGY LEADERSHIP



Over **1500** systems installed worldwide at more than **120** customers.

20GW of installed capacity of screen printing tools in the field.

Market **leader** for screen printing and integrated metallization systems.

Technology leader in **advanced** cell manufacturing processes and ultra-thin wafer handling.

Track **record** of system reliability and manufacturing productivity.

Backed by the **global service**, supply chain, process expertise and factory automation capability of Applied Materials.

From the **#1 producer** of solar and semiconductor processing equipment.

OVER 40 YEARS OF TECHNOLOGY LEADERSHIP

Baccini was founded in 1967, in Treviso, Italy, near the historic city of Venice. The company's global reputation for engineering innovation dates from its first screen printing machine for microelectronics in 1972. In the mid-1980s, Baccini introduced the solar industry's first integrated cell metallization line for PV manufacturing — the predecessor to its current market-leading portfolio of systems and fully-automated lines for high volume c-Si cell production. Baccini's acquisition by Applied Materials in 2008 combines state-of-the-art Baccini printing products and technologies with Applied's global infrastructure and 40-year expertise as the world's leading equipment supplier for semiconductor, LCD, and solar — ultimately helping customers around the world accelerate their efficiency and productivity roadmaps with better, faster, more cost-effective manufacturing lines.



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