APPLIED MATERIALS®

Powering the c-Si Roadmap

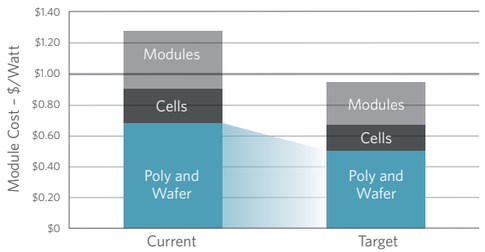
APPLIED HCT WAFERING SYSTEMS

THE CHALLENGE

Driving c-Si to below $1 per watt

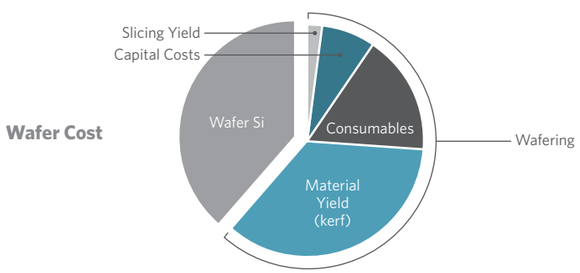
The rapid expansion of solar energy is fueled by a relentless reduction in cost per watt. Because silicon and wafering represent over 50% of total module cost, advances in wafering technology are paramount. Applied HCT, the world leader in wafering technology, is accelerating the c-Si roadmap with process solutions to attack all high leverage areas that reduce wafer cost. From advances in platform architecture that enhance productivity and performance, to accelerating new wire technology, Applied HCT is propelling the industry forward with unique wire saw innovation.

Silicon and wafering are >50% of module cost



Silicon and wafering costs together represent over 50% of module cost. They must be reduced dramatically to meet industry cost reduction objectives.

Wafering influences nearly 2/3 of wafer costs



Wire size has a major impact on silicon cost through kerf loss. Process optimization drives nearly 1/4 of total wafer cost, primarily through slicing yield, wire and slurry consumables and tool fixed costs. Process performance has direct impact on wafer slicing yield. Wafering process optimization is also critical to achieve even thinner wafers.

Wafering cost reduction strategies

Thinner Wire	▲ Increased Material Yield	▼ Reduced Productivity and Slicing Yield
Higher Table Speed	▲ Decreased Fixed and Wire Costs	▼ Reduced Slicing Yield
Lower Wire Speed	▲ Decreased Wire Cost	▼ Reduced Slicing Yield
Recycled Slurry	▲ Decreased Slurry Cost	▼ Reduced Slicing Yield
Thinner Wafer	▲ Decreased Si Wafer Cost	▼ Reduced Productivity and Material Yield

Achieving lowest overall wafering cost requires process optimization among multiple variables. Each reduction strategy has potential trade-offs. An integrated approach to process optimization using platform design flexibility, advanced consumables and process know-how is required for lowest total cost.

DRIVING DOWN WAFERING COST

PROCESS OPTIMIZATION CHALLENGE

Slicing Yield

Yield has tremendous leverage in reducing wafering cost. Yield is affected by wafer surface quality (TTV, TV, saw marks) and wafers lost during the wafering process (wafer and wire breaks). Advances in net throughput, consumables and wire technology must be accomplished without sacrificing yield. Large load size and advanced wire handling, along with tight process control and sophisticated tool automation are key yield enablers.

Net Throughput

Achieving high productivity or MW/Y from the system has a direct impact on fixed costs and return on invested capital. Both higher table speed and higher load size can boost productivity but careful balance with yield is required.

Consumables Cost

Wire and slurry consumption drive consumables cost. Slurry recycling is a powerful way to lower slurry cost if slicing yield is not impacted. Wire breakage severely impacts consumables cost — process optimization is critical in keeping productivity high at the same time as maintaining low wire breakage rates. Advanced wire technologies, such as structured and diamond wire, promise to lower consumables cost per wafer while boosting productivity.

Reduced Silicon Usage

Silicon is still the largest single cost component of wafer cost. Ultra-thin wire capability is required to reduce kerf loss but it can come at the expense of productivity to keep slicing yield high. Balance of the trade-off depends largely on raw silicon market price which can fluctuate and so can optimal wire size. Thinner wafers lower the cost of Si per wafer but challenge kerf loss, yield and productivity. Careful process optimization is required to achieve the potential gain.

LOWEST TOTAL COST PER WAFER

THE APPLIED HCT B5

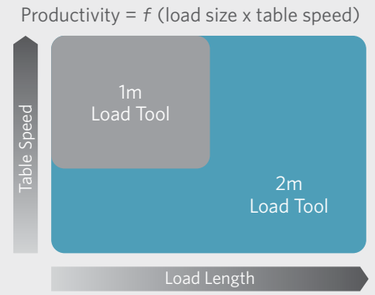
BEST IN CLASS YIELD
INDUSTRY'S HIGHEST PRODUCTIVITY
LOWEST TOTAL COST

- **The benchmark in process performance**
- **Industry leading throughput and lowest total cost**
- **Designed for high availability in volume manufacturing**
- **Proven thin wire capability down to 120µm and below**
- **Robust platform extendable to advanced wire technologies**

THE FUNDAMENTAL ADVANTAGE OF LARGER LOAD SIZE

A wider process window delivers yield with higher productivity

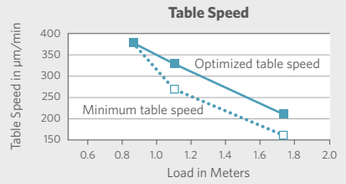
With **2x the load potential** of conventional competing systems, the B5 gives users a wider process window to tune load size and table speed for highest yield and productivity and as a result lowest wafer cost.

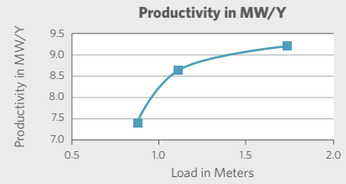


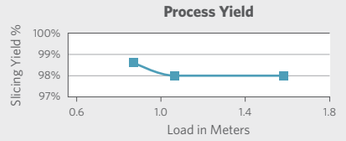
B5 uniquely optimizes load and table speed for lowest total cost

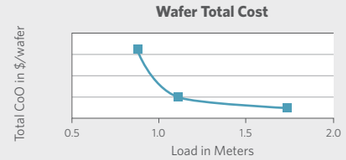
As load size increases above 1m, table speed is reduced to optimize performance and yield. However, the larger load size more than compensates, delivering higher overall productivity. At work here is the unique relationship linking productivity to table speed and load, P = f (load size x table speed) and higher tool uptime with less frequent swaps of larger loads. By tuning load and table speed, users can maintain **yield** and **rapidly increase productivity**, for the lowest total cost.

Reference data collected by Applied HCT on a B5 with 120µm wire, 180µm wafer, 80% recycled slurry, with load size 0.85m, 1.1m and 1.73m.



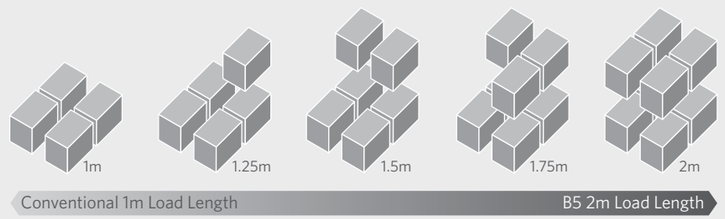






Flexible loading up to 2m

The unique **4 position architecture** has the capacity for up to 2m in total load, easily configurable to provide a high degree of flexibility to meet industry roadmaps at high yield with major advances in productivity.

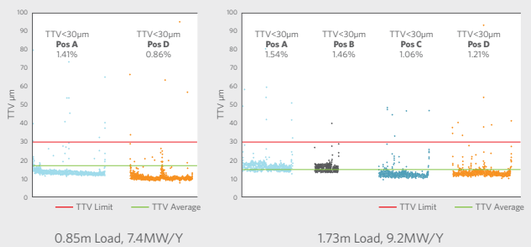


BEST IN CLASS YIELD

98% yield with >15% more productivity

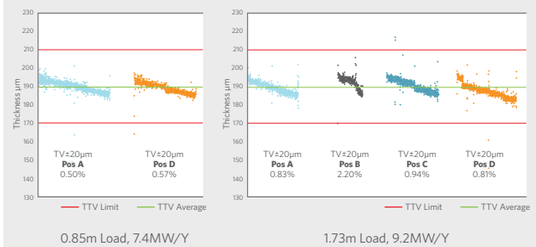
Data collected at Applied HCT Cheseaux R&D Center: 120µm Wire, 180µm Wafer and 80% Recycled Slurry

TTV LOAD SIZE COMPARISON



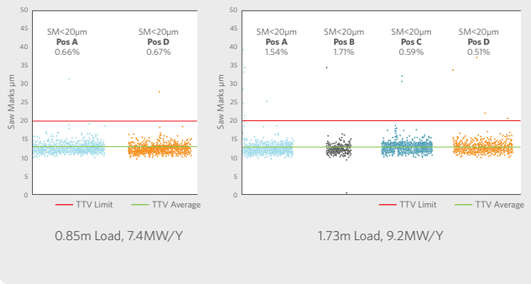
Both load sizes demonstrate best in class performance TTV yield >98% at <30µm limit, with a 15µm average.

TV LOAD SIZE COMPARISON



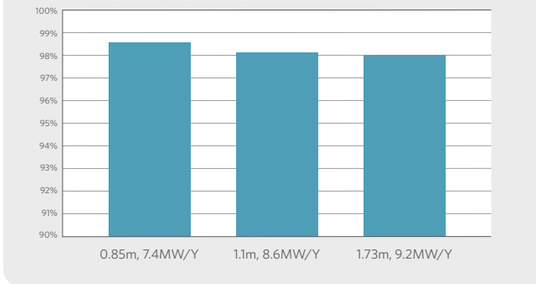
Both load sizes demonstrate best in class performance TV yield >98% at <20µm limit.

SAW MARKS LOAD SIZE COMPARISON



Both load sizes demonstrate best in class performance saw marks yield >98% at <20µm limit, with a 13µm average.

YIELD LOAD SIZE COMPARISON

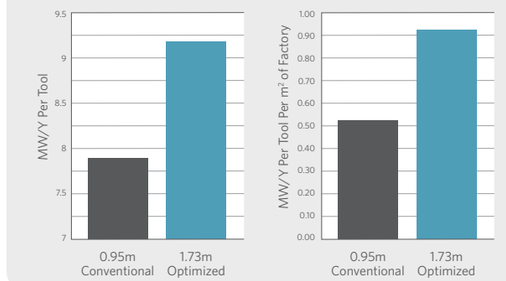


A wider B5 process window enables high yield with greater productivity. Comparison of process data for runs at 0.85m, 1.1m and 1.73m loads shows virtually identical process yields >98% at industry leading 30µm TTV, 20µm TV and 20µm saw marks limit while productivity increases by nearly 25%.

INDUSTRY'S HIGHEST NET THROUGHPUT AND LOWEST TOTAL COST

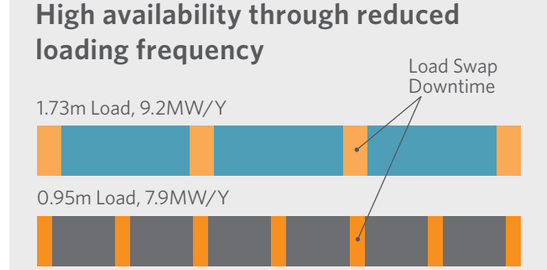
Productivity is driven by larger load size

>15% MORE MW/Y PER TOOL



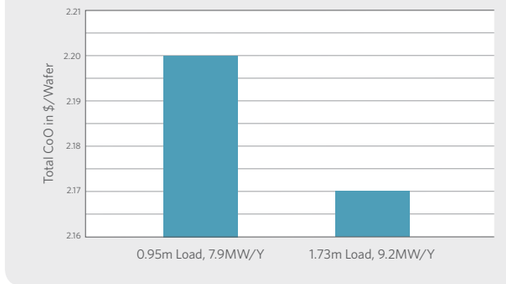
At industry leading 120µm wire size and 180µm wafer thickness, the B5 load advantage delivers >15% higher productivity per system when compared with conventional 1m load tools. When combined with the B5 25% footprint advantage over these same tools, the productivity advantage for a given factory size approaches 50% more wafers per year.

30% LOWER SYSTEM DOWNTIME



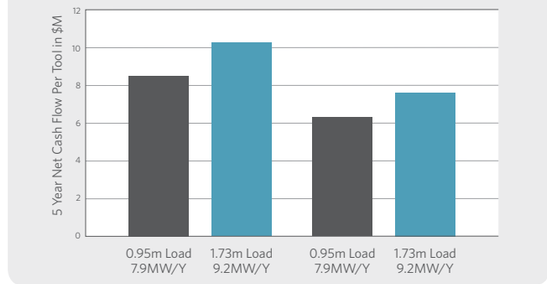
As part of the 20% productivity advantage of larger load, lies a lower system downtime advantage due to less frequent swaps of larger loads.

3¢ LOWER COST/WAFER



Total wafer cost modeling comparison at 120µm wire size and 180µm wafer size shows as much as a 3¢/wafer total CoO advantage between a 7.9MW/Y 0.95m load conventional tool and a 9.2MW/Y 1.73m load B5.

20% GREATER CASH FLOW/TOOL



Total wafer cost savings combined with higher productivity results in a powerful cash flow generation per tool advantage for wafer manufacturers. The B5 advantage results in a 20% higher net cash flow generation.

DESIGNED FOR HIGH AVAILABILITY IN VOLUME MANUFACTURING

Flexible load size

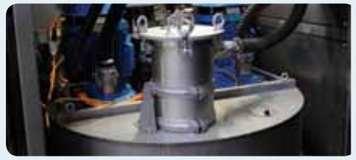
Flexible 2m maximum load size, in 0.25m increments, lets factories adjust capacity and achieve the highest yield and productivity.

Reduced footprint

With 25% smaller footprint than competing tools, the B5 produces 50% more MW annually for a given factory size.

Minimal downtime for wire change

The B5's unique conical take-up spool and expandable shaft feeding spool enable fast wire change in a production environment.



Reduced downtime for slurry change

The B5 design provides for simple, rapid change of slurry canisters, with the option for automatic slurry refill.

Minimal wire breakage

Advanced wire management continuously controls acceleration, tension and alignment angle for low breakage and consistent cut.

Minimal downtime for breakage

Early-warning wire wear detection alerts operators before wire failure, minimizing yield loss and downtime.

Greater process reproducibility

Interface to Applied's E3 process automation software enables real-time data logging, fault detection and function control.

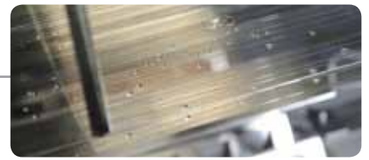
PROVEN THIN WIRE CAPABILITY DOWN TO 120µm AND BELOW

Thin wire capability is essential to reduce kerf loss. With Applied HCT's system engineering approach, the proven B5 system has been designed for optimum performance with thin wire technology, providing high yield with industry leading productivity. With over 500 systems in production with thin wire capability, the B5 is the clear leader in bringing thin wire to volume manufacturing.

Existing installed B5 tools can be easily upgraded to thin wire capability with a thin wire retrofit kit. Local process application consultation can assist customers to achieve optimal process performance and productivity with the B5 platform.

The experience from more than 1000 systems in volume production.

B5 design optimized for thin wire performance



Continuously adjustable wire tracking

Continuous wire position tracking at the feeding spool ensures optimum alignment during unwinding, avoiding unwanted tension and wire breakage risk.

Controlled acceleration and deceleration algorithms

The B5 system's control software continuously manages wire acceleration/deceleration to reduce the potential for wire breakage.

Low inertia wire management

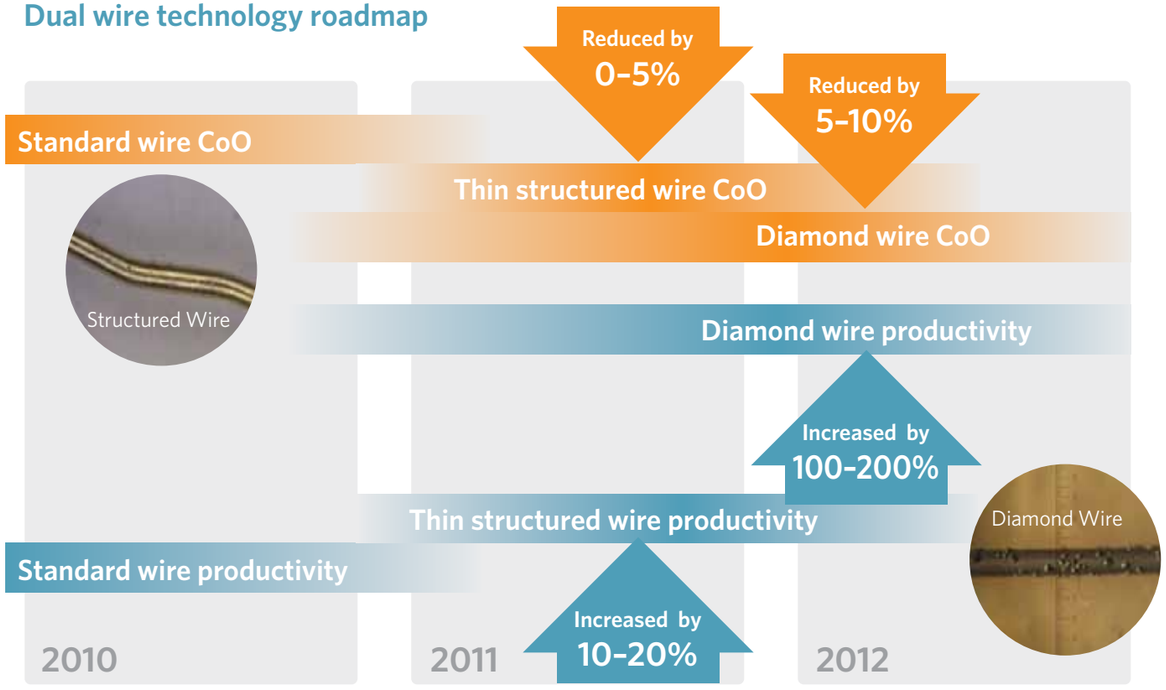
A proprietary low-inertia design carefully controls wire vibration and strain at the wafer level and reduces tension in transition periods.

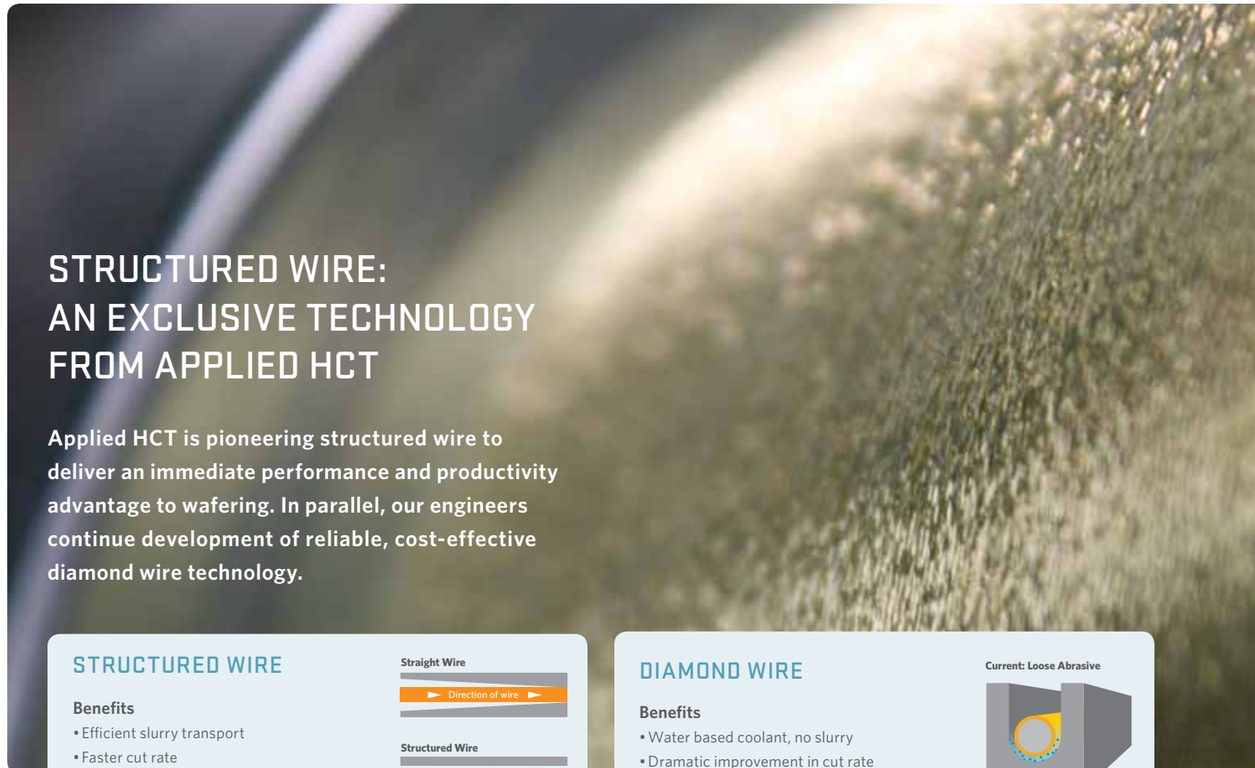
ROBUST PLATFORM EXTENDABLE TO ADVANCED WIRE TECHNOLOGIES

Proven B5 platform reduces risk

Advanced wire technology promises to improve cut performance, increase productivity and substantially reduce slurry costs. However, implementation is a significant challenge: hardware, consumables and process must be fully optimized for yield, high productivity and low cost. Applied Materials has an aggressive roadmap to deliver the new wire technologies as they become proven robust for manufacturing with lower overall cost. As part of this commitment to excellence, Applied has ongoing development partnerships with both wire and slurry manufacturers to optimize performance, reduce cost and ensure multiple sources of supply. Collaborations with leading customers are helping to accelerate learning in volume manufacturing.

Dual wire technology roadmap





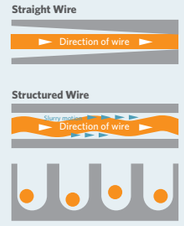
STRUCTURED WIRE: AN EXCLUSIVE TECHNOLOGY FROM APPLIED HCT

Applied HCT is pioneering structured wire to deliver an immediate performance and productivity advantage to wafering. In parallel, our engineers continue development of reliable, cost-effective diamond wire technology.

STRUCTURED WIRE

Benefits
- Efficient slurry transport
- Faster cut rate
- Cooler slicing process
- Expected better surface quality and TTV

Challenges
- ~1% increase in kerf loss
- Lower wire breaking load
- Some wire price increase



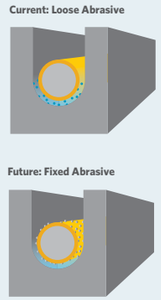
EVOLUTIONARY

Structured wire is the industry-proven solution for squaring, which can be rapidly implemented as a low-risk approach on current or new B5 wafering systems. The enhanced cut rate and efficient slurry utilization enhances productivity.

DIAMOND WIRE

Benefits
- Water based coolant, no slurry
- Dramatic improvement in cut rate
- Reduced energy consumption
- Expected lower sub-surface damage

Challenges
- Quality of diamond wire
- Wire price and consumption
- Wire damage/breakage risk
- Coolant formulation, distribution and price
- Mono vs. multi dependence



REVOLUTIONARY

Diamond wire is currently being optimized in both cropping and squaring applications to ensure robust release for wafering applications, expected in 2012. This staged approach reduces risks associated with implementation of diamond wire technology.

COMPLETE SOLUTION

Meeting customers' cost and productivity challenges requires high-output wafering hardware, process control software, plus advanced wire technology and slurry management. Applied Materials' has the engineering depth, financial strength and industry experience to meet these technology challenges and deliver innovation at all levels.

A FULL RANGE OF SOLUTIONS FOR CRITICAL WAFERING STEPS

Ingot production → Squaring → Cropping → Wafering → Grinding & Chamfer → Clean → Metrology

SQUARER

The Applied HCT Squarer is capable of squaring both mono and multi-crystalline silicon ingots with productivity of up to 80MW per year and low kerf loss (0.30–0.35µm wire). The system is upgradable to both diamond and thick structured wire.

CROPPER

The Applied HCT Cropper cuts the tops and tails from crystalline silicon ingots at a high load capacity. It offers the same low kerf loss, high throughput and high reliability as the Applied HCT Squarers.

B5

The Applied HCT B5 wafering system cuts both monocrystalline and multi-crystalline silicon stock into ultra-thin wafers. The system provides best in class process yield with the industry's highest productivity, and is a proven platform for advanced wire technologies.

AUTOMATION SOFTWARE

E3 AUTOMATION

The Applied Materials E3 equipment diagnostics platform connects to any solar tool, providing pre-integrated MES connectivity specifically designed for c-Si manufacturing. For example, the E3 SPC component automatically detects product quality variations, providing control charts, automatic notification and a corrective action plan to factory operators.

SMARTFACTORY

SmartFactory is a scalable, affordable factory automation solution that improves tool utilization and increases throughput. By tracking work-in-progress (WIP) within a factory, SmartFactory assures high factory productivity.

APPLIED GLOBAL SERVICES

Applied Global Services has the solar industry's largest team of highly trained support experts and provides spare parts, parts refurbishment and system upgrades, all designed to help you get the most out of your tools.

R&D LEADERSHIP

STATE OF THE ART R&D TECHNOLOGY CAPABILITY

REDUCING THE TIME, COST AND RISK FOR CUSTOMERS

- Advanced wafering equipment development
- Process research and optimization
- Wire technology development and performance validation
- Wafer 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

Wafering Center of Excellence Cheseaux, Switzerland

New product and process development
Development and demonstration of advanced wire sawing processes
Customer demos and training

Engineering fast turn design for manufacturability

R&D Lab for performance validation

Manufacturing proximity to engineering for fast cycles of learning

SWISS DESIGN, ACCELERATED LEARNING

APPLIED MATERIALS + HCT

MARKET AND TECHNOLOGY LEADERSHIP

Born of Swiss precision engineering combined with Applied Materials volume production experience.

Over 2000 systems in volume manufacturing worldwide.

Market leader for wafering systems.

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 25 YEARS

OF LEADERSHIP IN WIRE SAW TECHNOLOGY

First wire saw produced in 1984

First wire saw for 300mm wafers

First to develop wire saw for ingot squaring

First to use wire saws for ingot cropping

First to use wire saws for cutting multiple ingots

First to offer 2m load potential

First to cut 120µm thin wafers in volume production

First to cut Jumbo (Gen 5) ingot in less than three hours

First to introduce structured wire technology

Applied Materials
3050 Bowers Avenue
P.O. Box 58039
Santa Clara, CA 95054-3299
U.S.A.
Tel: +1-408-727-5555

Applied Materials
Route de Genève 42
1033 Cheseaux
Switzerland
Tel: 41 21 731 9100
Fax: 41 21 731 9101

solar_sales@amat.com

www.appliedmaterials.com/technologies/solar