

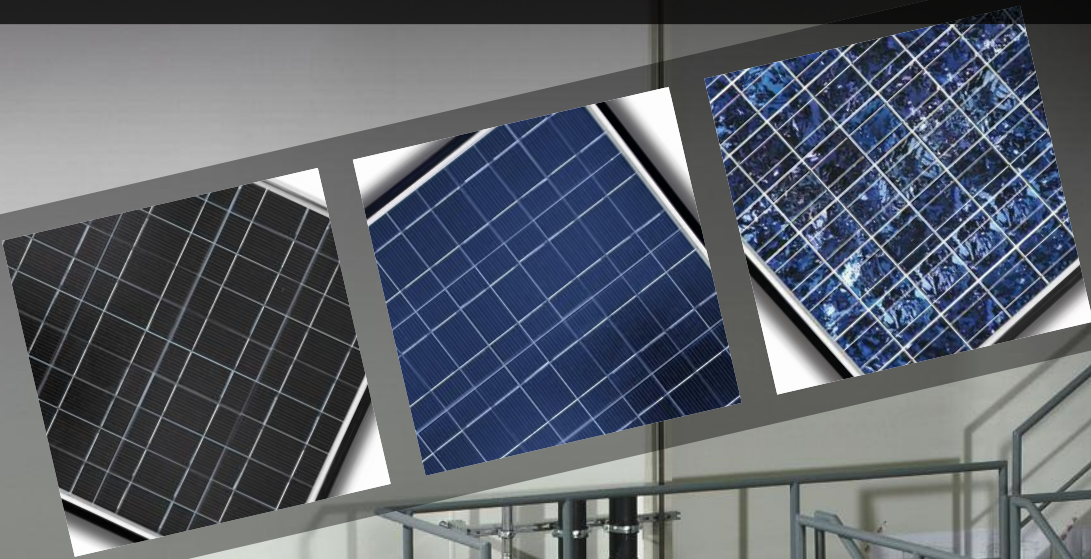


ALD Vacuum Technologies

High Tech is our Business

SCU450 and SCU650

Solar-grade Silicon Crystallization Units for Multi-Crystalline and Mono-Crystalline Ingot Production



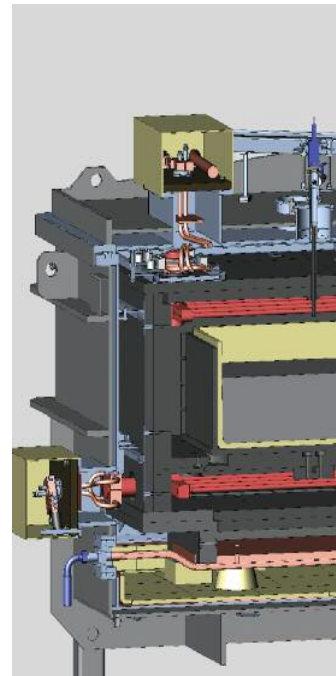
Mono²™
Technology



Uniform heat flux
and flat temperature
profile by using top &
bottom heating

ALD's Family of Silicon Crystallization Units (SCU) for Solar-grade Ingot Production

ALD's crystallization units are stand-alone furnaces for melting and crystallizing of solar-grade silicon into an ingot for subsequent processing into wafers for solar cells. They are based on top and bottom heating and produce one high quality square multi-crystalline or mono-crystalline ingot per cycle.



Unique Crucible Size Range: Gen5 and Gen6

The **SCU450** series furnace is available for use of **Gen5** crucible generation with a capacity range of 400-500 kg per cycle, corresponding to an annual solar power output of approximately 9 MWp/y.

The **SCU650** series furnace is available for use of **Gen5 or Gen6** crucible generation with a capacity range of 500-800 kg per cycle, corresponding to an annual solar power output of approximately 9-12 MWp/y.

Optional Mono^{2TM} Process

for production of mono-crystalline Gen5 or Gen6 ingots.

- New: solar cells processed from Mono^{2TM} ingots feature full square shape and uniform deep black surface appearance

Active Heat Sink

for constant crystallization rate throughout entire ingot from bottom to top improving ingot quality.

Easy Top-loading

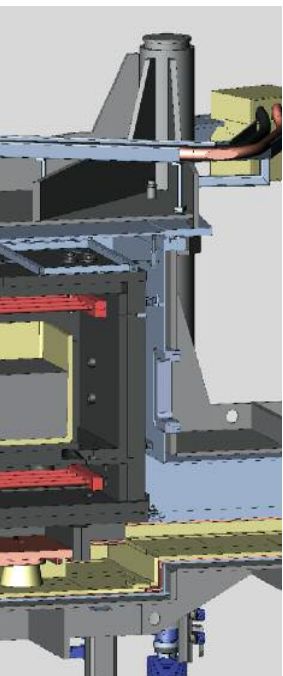
allowing faster and easier loading/unloading and minimum down time during maintenance.

- **Top & bottom heating** arrangement for vertically oriented uniform heat flux and flat temperature profile allowing

- faster melt cycles
- larger ingots
- tight control of crucible bottom temperature distribution
- lower crystallization cost
- perfect fit with Mono^{2TM} process upgrade

- **Optional features** are available such as triple heat gate, side heaters and other custom designed options





MULTI- AND MONO-CRYSTALLINE INGOT PRODUCTION

from the Technology Leader

- First to introduce Gen5 furnace (SCU450)
- First to introduce Gen6 furnace (SCU650)
- First to introduce Mono²TM process (patented technology)



- **Modular hot zone** for a minimum down time during maintenance and for future update to Gen6 when additional productivity is required

- **Dual-layer spill** protection shield with double layer of copper and refractory tiles, PLC-safety interlocks, permanent bottom heater monitoring and high cross-section chamber pressure relief device

- **Mono²TM upgrade** only available from ALD using its patented seeded growth plates, process instrumentation and software

- **Central**, remote, redundant server-based **control centre** for maximum operator safety and comfort, flexible process recipe administration and safe process data storage, based on worldclass **SIEMENS** hard- and software

- Open **recipe editor** for customization of process recipes

- **Dry-pump vacuum system** for minimum maintenance cost, elimination of hydro-carbons in the process chamber and facilitation of Ar-recovery system retrofit

- **Completely assembled** and hot-tested in German factory prior to shipment, for minimal on-site installation and commissioning period



Left: Gen5 ingot with 450 kg
Middle: Multi-furnace installation with extension modules platform
Right: SCU450/SCU650 for multi-crystalline ingot production



Typical Mono^{2TM} seed plate, which initiates uniform crystal growth of mono-crystalline ingots



ALD

- The only company with patented Mono^{2TM} know-how

Mono^{2TM} Highlights

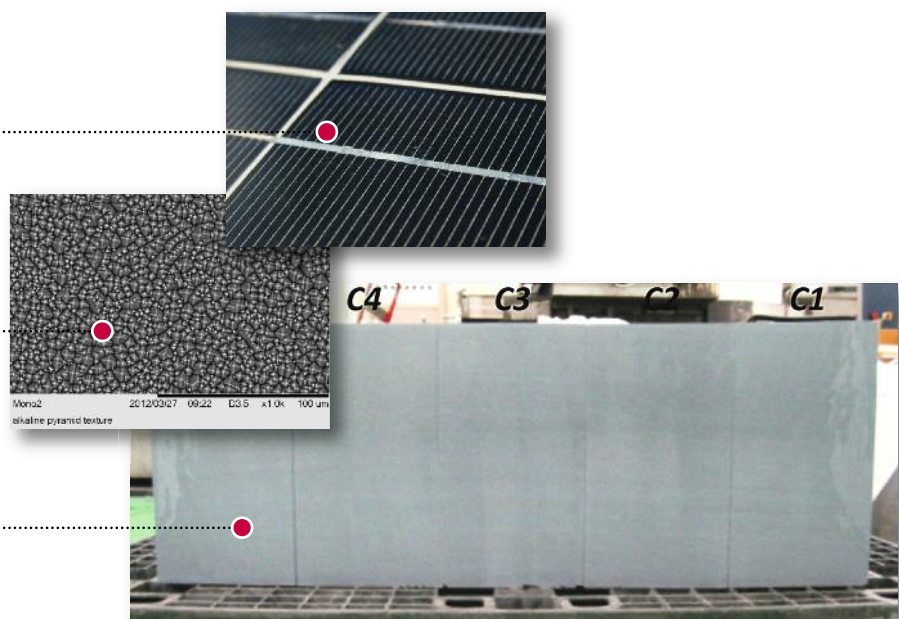
- Higher cell efficiencies than large grain DS
- Lower manufacturing cost than mono-CZ
- Decreased light-induced degradation (LID) effect due to lower oxygen content
- Compatible with existing CZ-cell process, including alkaline [100] pyramid etching (uniform deep black surface appearance)
- Full-square cells
- Retrofit process/equipment upgrade and license available for ALD SCU450/SCU650

Industry Standard Alkaline Etch Wafer and Cell Processing

Less reflectance loss for higher module power and attractive black module appearance

SEM image of a pyramid-etch Mono^{2TM} wafer

Typical Mono^{2TM} ingot which can be cut into 5x5 Mono^{2TM} bricks



MONO²™ CRYSTALLIZATION

Unique, patented process technology
for mono-crystalline ingot production

Mono²™ Technology Transfer includes:

- Process for ingots grown from seed plates
- Technology for seed manufacturing and replication methods
- Instrumentation for controlled start of crystallization
- License to use instrumentation and software for constant crystallization rate ingot growth

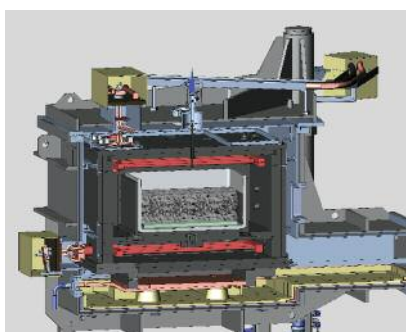
Patents:

- 8,030,633 US
- 7,758,696 US
- 8,048,221 US
- additional patents pending

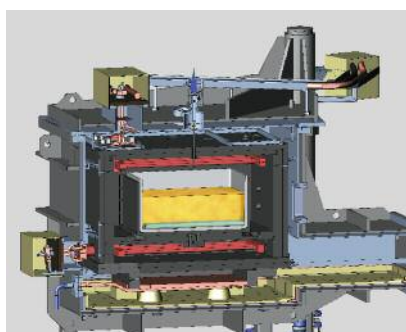


**Mono²™ ingot with
monocrystalline
brick structure**

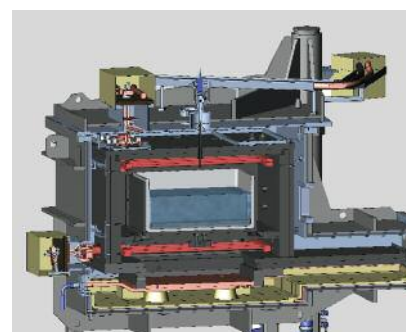
Mono²™ Process Principle



- Load mono-crystalline seed-plate at crucible bottom
- Load polysilicon chunks on top



- Melt down the feedstock
- Keep mono-crystalline seed-plate partially solid
- Initiate uniform crystal growth on seed-plate enabled by uniform and flat temperature profile

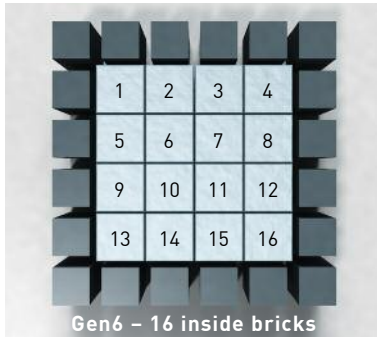


- Grow mono-crystalline ingot
- Cut edges with band saw
- Recover seed-plate for re-use

SCU650 GEN6 INGOTS

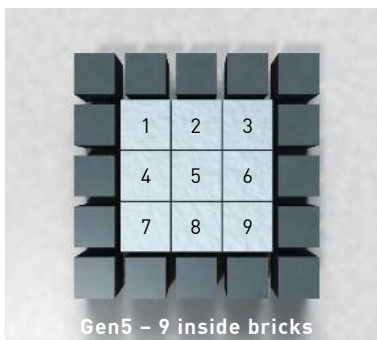
Higher quality and lower conversion cost

- Quality – more inside bricks with no contact to crucible wall
- Yield – higher quality inside bricks with Gen6 crucibles
- Throughput – faster than any other silicon crystallization furnace manufactured today
- Uptime – easy to remove and modular hot zone for a minimum down time during maintenance



Advantages of Gen6 Ingots

- More inside bricks ($16/36 = 44\%$ versus $9/25 = 36\%$) with no contact to crucible wall and coating
- Higher mass ingot yield
- Better surface area to mass ratio



SCU650 series for Gen6 multi-crystalline ingot production with 650 kg charge weight producing 16 inside bricks per ingot





ISO
9001



HIGH VALUE

Engineering & manufacturing from the quality leader

- Many years of experience in design and manufacture of vacuum melting furnaces in the solar, aerospace and specialty material industries
- Worldwide sales and service network
- More than 4 GWp installed base in the world's leading solar industry companies
- In-house crystallization, Mono^{2TM} pilot line and testing at tech-centers in Germany and USA

■ ALD Vacuum Technologies GmbH ("ALD") is the Engineering Systems Division of AMG Advanced Metallurgical Group N.V.

■ ALD is the world-wide market leader in vacuum metallurgy and the technology leader in vacuum heat treatment

■ The company supplies equipment and turnkey solutions for thermal and thermo-chemical treatment of metallic materials in solid and liquid form

■ Continuing R&D projects and acquisitions of complementing technologies are further strengthening ALD as a supplier of key technologies in traditional and emerging growth markets



Every furnace is completely assembled and has passed comprehensive performance tests prior to delivery ensuring compliance with factory standards.

SCU650



Technical Data

		SCU450	SCU650
Crane hook height	[m]	4.8	4.8
Overhead crane capacity	[t]	2	2
Max. operating temperature	[°C]	1,570	1,570
Ultimate vacuum	[Pa]	5	5
Leak rate	[Pa l/s]	5	5
Inert gas		Ar, He (max. 900 mbar)	Ar, He (max. 900 mbar)
Cycle time	[hours]	approx. 48-55	approx. 58-65
Connected power	[kVA]	210	220
Power consumption per cycle	[kWh]	3,600	4,800
Ar-consumption per cycle	[Nm³]	approx. 60	approx. 70
Cooling water consumption	[l/min]	approx. 170	approx. 190
Batch capacity in		400-500	
Gen5 configuration	[kg]		
Gen6 configuration	[kg]		500-800
Ingot crystal structure		multicrystalline	multicrystalline
Annual production capacity* (cell power)	[MW _p]	approx. 7-9	approx. 9-12

* Depending on actual crucible dimensions, ingot mass, feedstock quality, wafer thickness, downstream wafering and cell processing.

Technical Data

	MONO ² ™
Ingot crystal structure	> 80 % monocrystalline
Brick crystal structure	Monocrystalline
Cell surface texture/etching	Suitable for [100] pyramid texture/alkaline
Cell appearance	Full-square, deep black
Cell efficiency gain	Plus 1-2 % points (depending on cell process)
Cycle time	50-58 hours (Gen5)
Seed plate type	Monocrystalline [100] texture, recoverable
Seed plate recovery process	Included in technology transfer with license

ALD provides assistance in factory layout and basic engineering for multiple furnace layouts.

All technical data subject to change ©ALD 2012

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