

Crystalmax

Mono-like technology developed by ECM

01/10/2015
January 28th, 2015

Company introduction



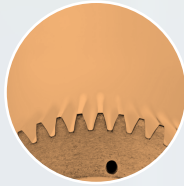
ECM Greentech is the photovoltaic division of the mother company ECM Technologies.

Located in Grenoble, by the French Alps, **ECM Technologies** designs, manufactures, and sells **heat treatment industrial installations**.

Our expertise resides in the following industries:



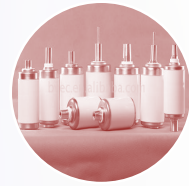
PHOTOVOLTAIC



AUTOMOTIVE



AERONAUTIC



ELECTRONIC
& NUCLEAR



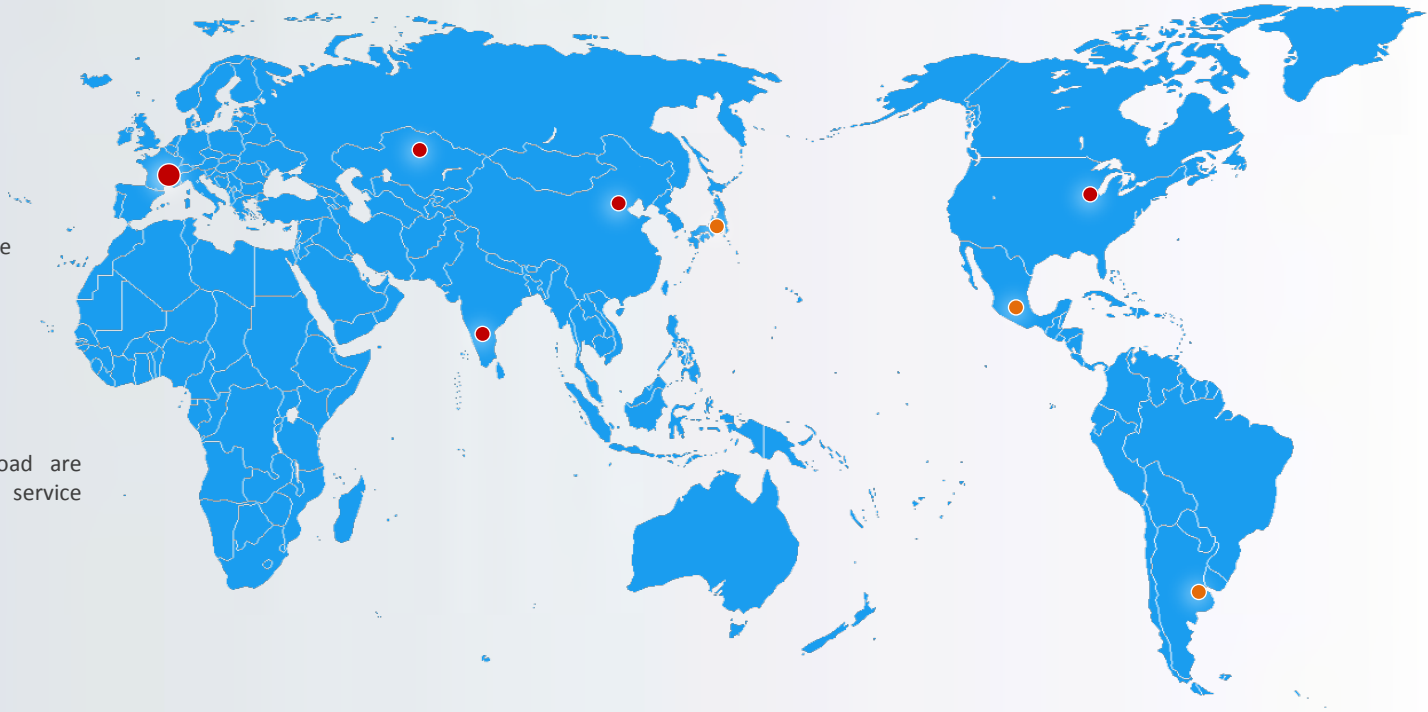
A global presence



- Main office
- Sales and service office
- Service center

International offices:

Our 4 subsidiaries abroad are sales office, after sales service and spare parts stock



PV turnkey line



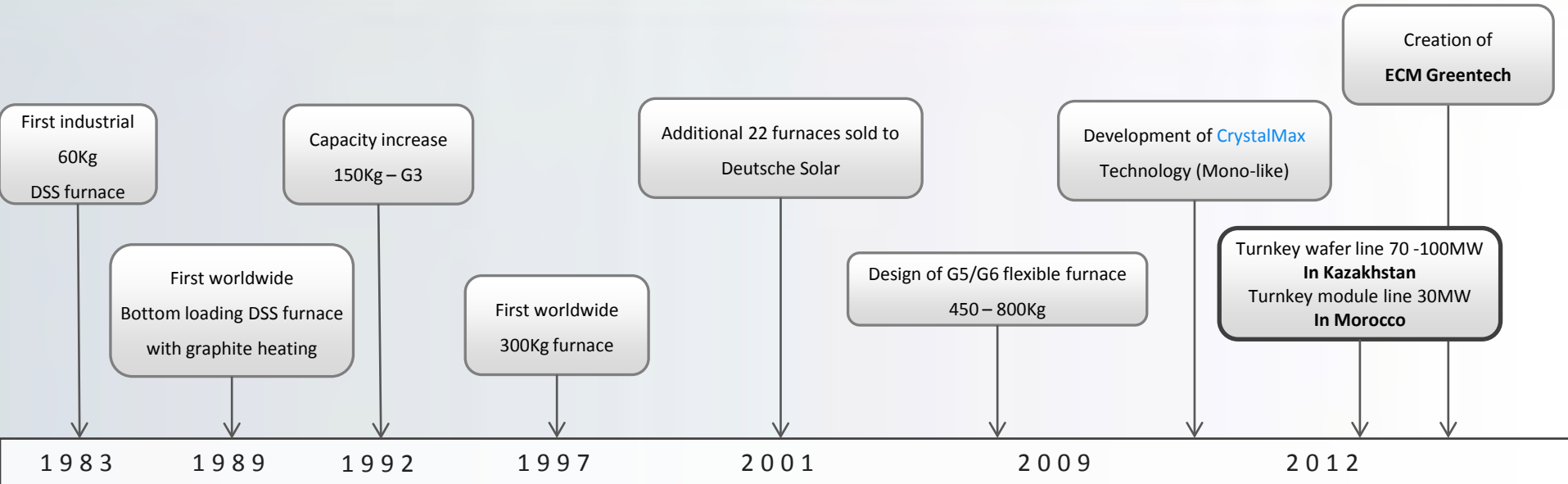
A superior technology with continuous improvement



French Atomic and
Alternative Energy
Center
(15 000 employees)

ECM has strong tie up with the CEA for R&D and process evolution. This enables us to provide our customer with cutting edge technology, always up to date.

Experience in PV



Reference in PV turnkey line



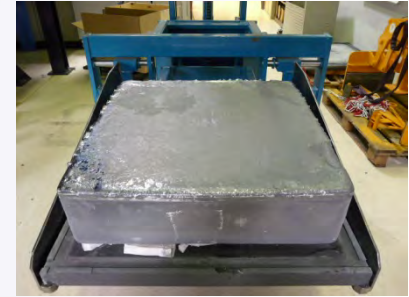
ECM has delivered an ingot and wafer manufacturing line in Kazakhstan

Technology: **Multicrystalline**

Capacity: **60MW**, extendable to 100MW

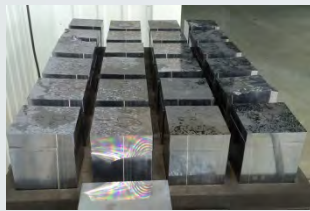
Location: **Ust-Kamenogorsk, Kazakhstan**

Contract type: **Turnkey**



Reference in turnkey line

ECM is the only equipment supplier whom has delivered such I&W line.



NB: Photos dates from
September 2013

Reference in turnkey line

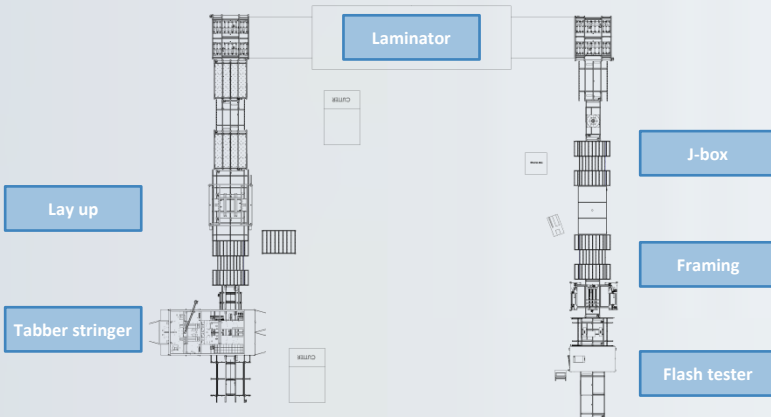
ECM has delivered a module manufacturing line in Morocco

Technology: **60/72 cells module** (bifacial ready)

Capacity: **30MW semi-automatic**

Location: **Rabat, Morocco**

Contract type: **Turnkey**



Expert in silicon crystallization



Directional Solidification System (DSS):

ECM pioneered the silicon crystallization since the early 1980's
We deliver high end furnaces suitable for the following processes:

- Multicrystalline
- HP multicrystalline
- *CrystalMax*® (Mono-like)

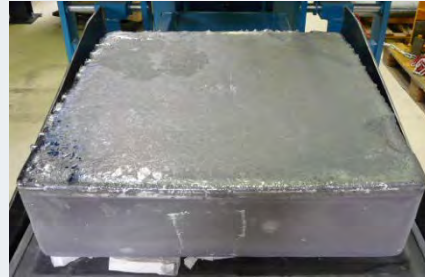


Photo of a G5 multicrystalline ingot



100% of bricks mono

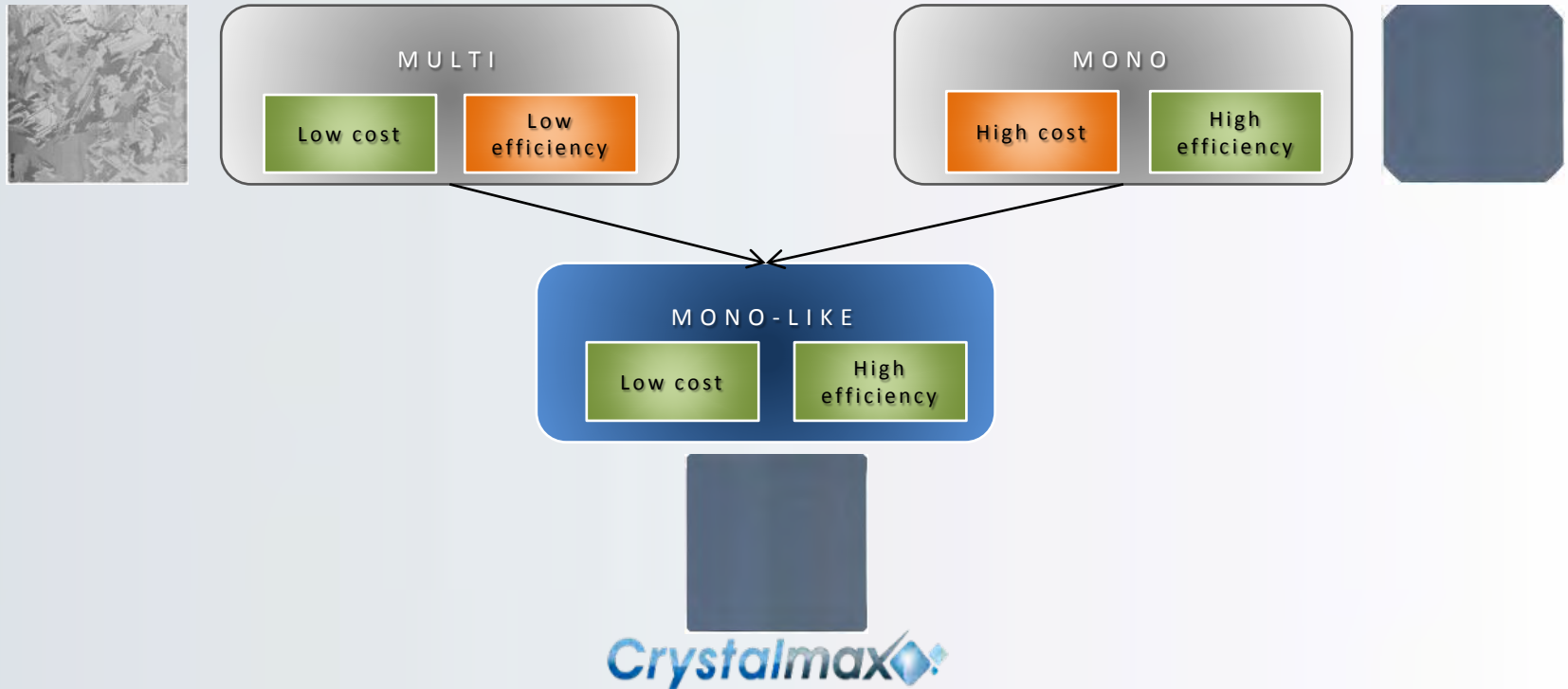
Photo of a G5 mono-like ingot



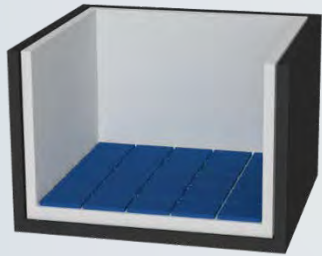
Photo of a G6 HP multicrystalline ingot

The best of both worlds

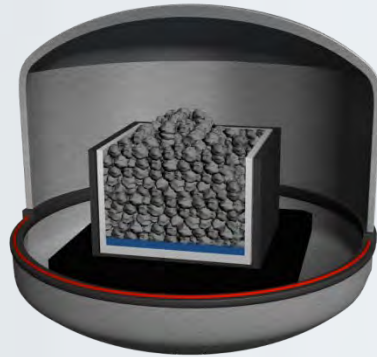
Our technology enables the growth of high quality material with a low manufacturing cost



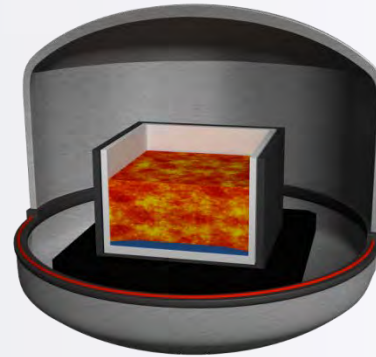
Crystalmax



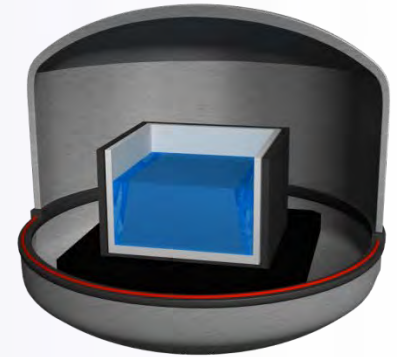
1. Seeding



2. Loading



3. Melting



4. Crystallization

Part of the success of mono-like ingot resides in the preparation of the seeds:

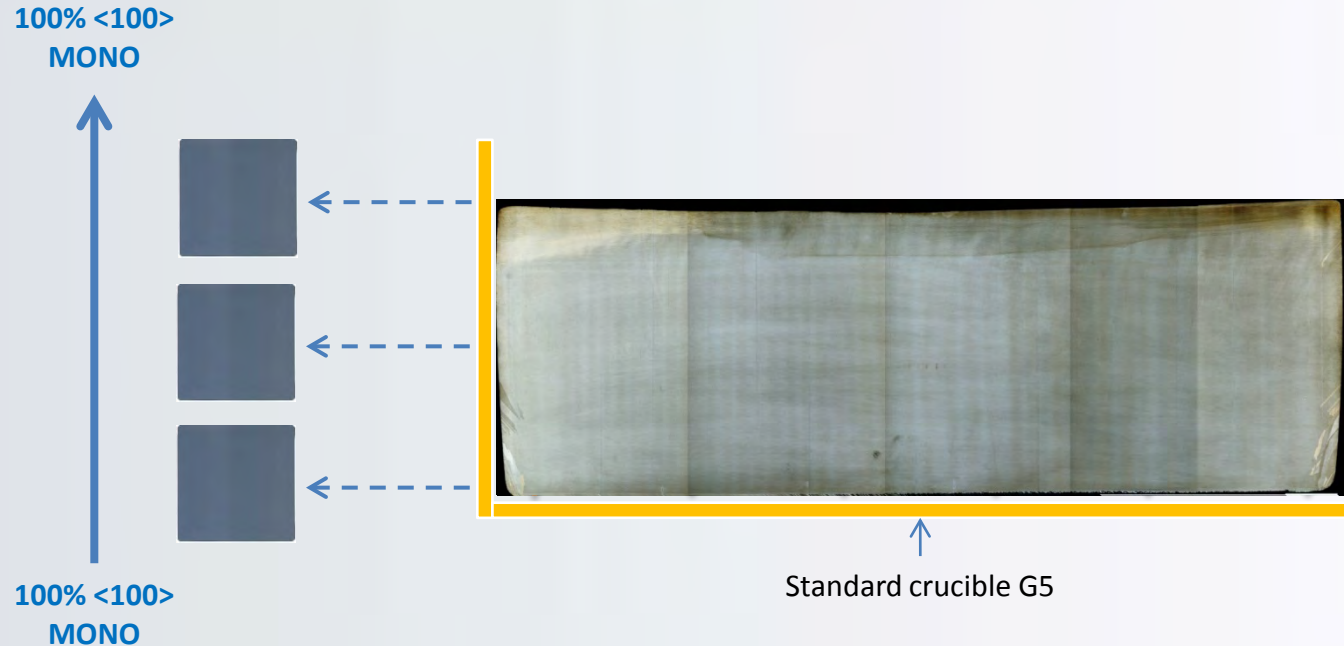
- Shaping the seeds from a CZ ingot
- Specific arrangement in the crucible for avoiding dislocation and parasite multicristalline structure

2 international patents filed for this seed preparation technology!



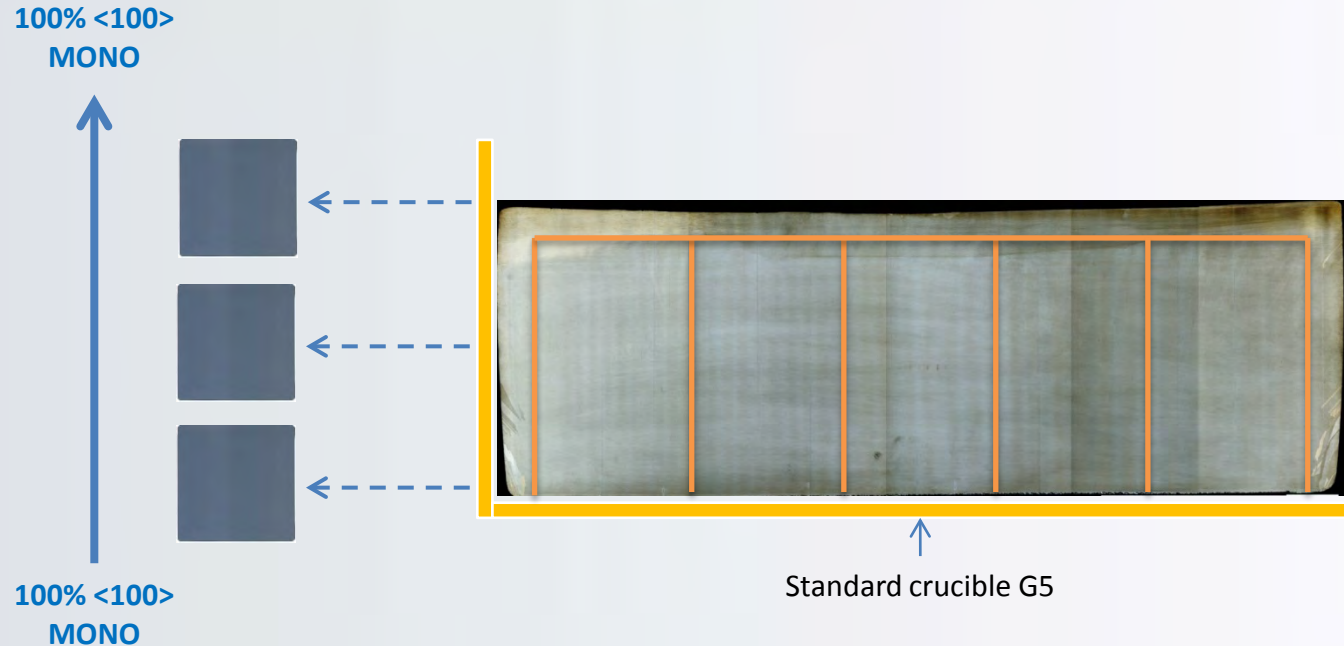
Crystallization: crystalline orientation

- Crystalline orientation $\langle 100 \rangle$ on all bricks \rightarrow 100% “mono”

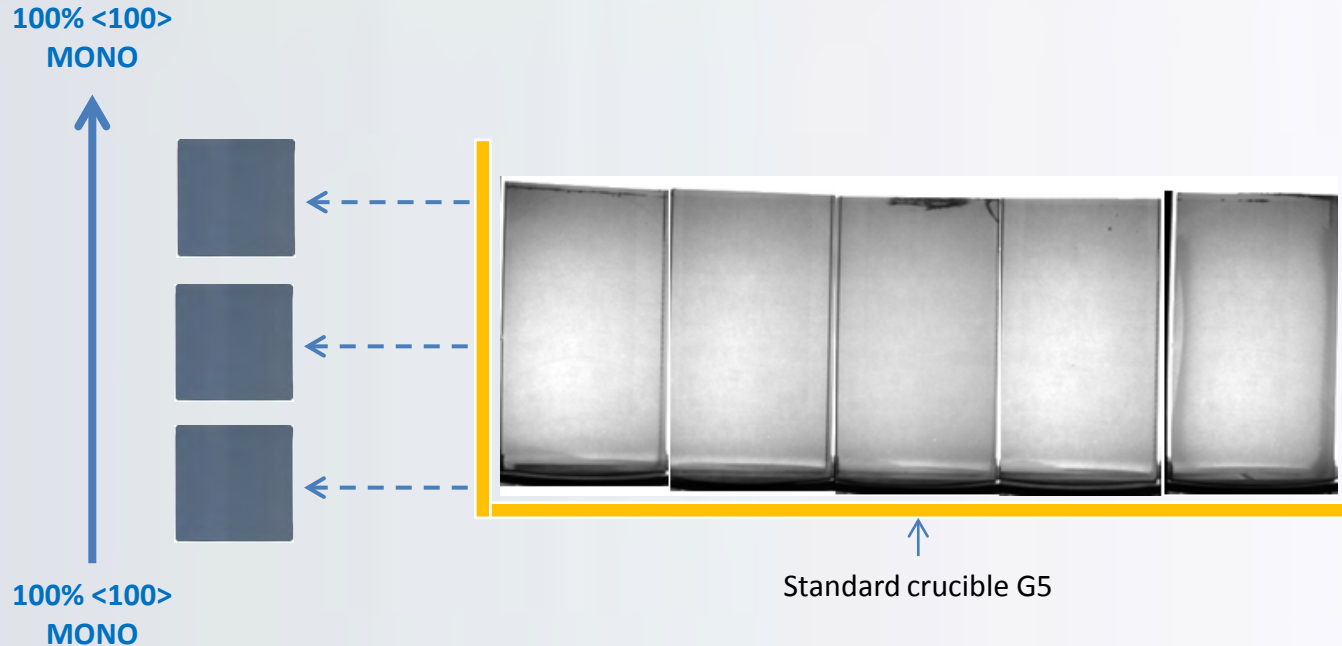


Crystallization: crystalline orientation

- Crystalline orientation $\langle 100 \rangle$ on all bricks \rightarrow 100% “mono”

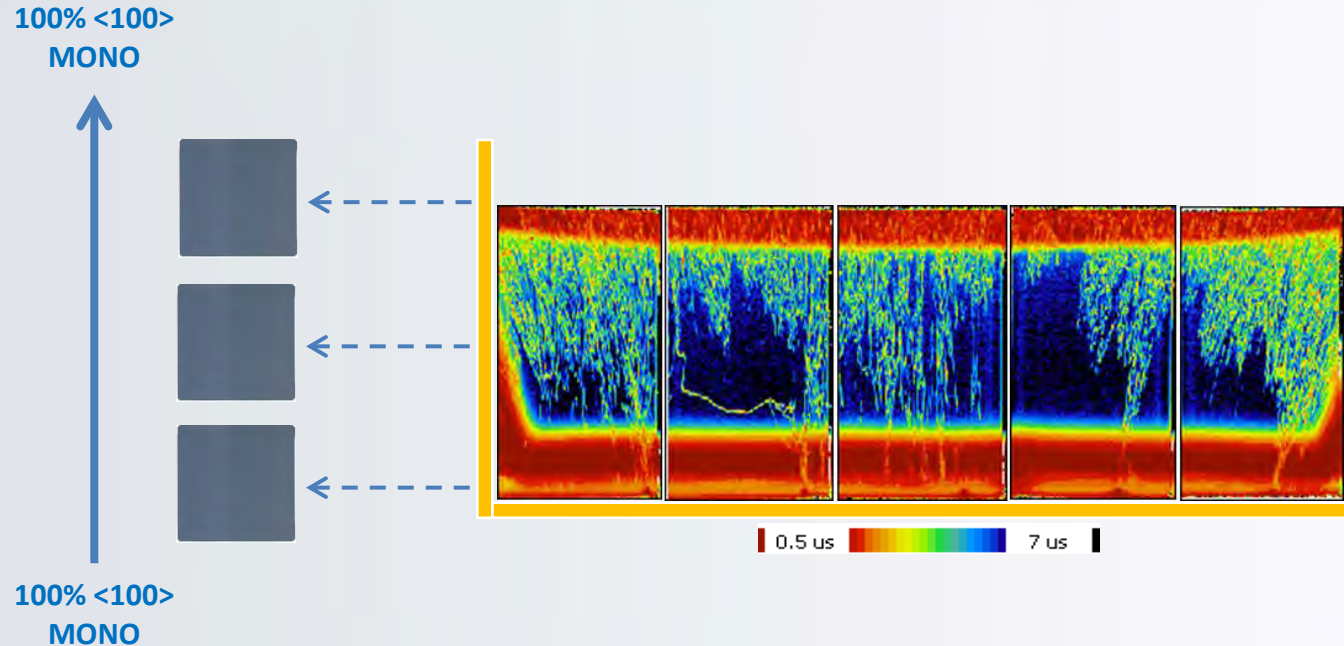


- Transparent bricks → Absence of inclusions (SiC , Si_3N_4 , ...)



Crystallization: lifetime 1st trial

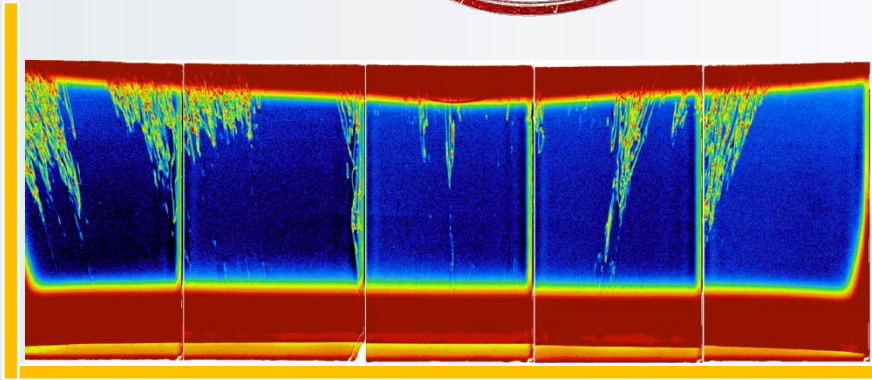
- Limited lifetime due to high density of dislocations during the first trial



Crystallization: lifetime optimized

- Development of an optimized process and enhancement of the solidification front → Reduction of dislocation density

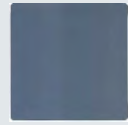
100% $\langle 100 \rangle$
MONO



100% $\langle 100 \rangle$
MONO

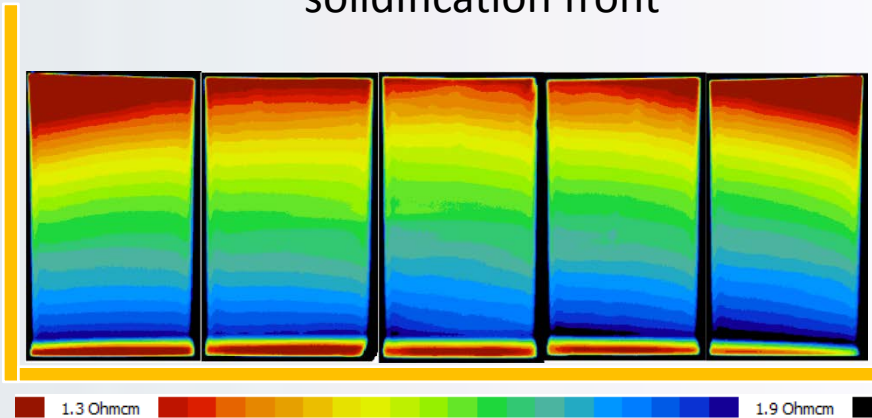
- Optimal control of impurities segregation → Homogenous resistivity

100% <100>
MONO



100% <100>
MONO

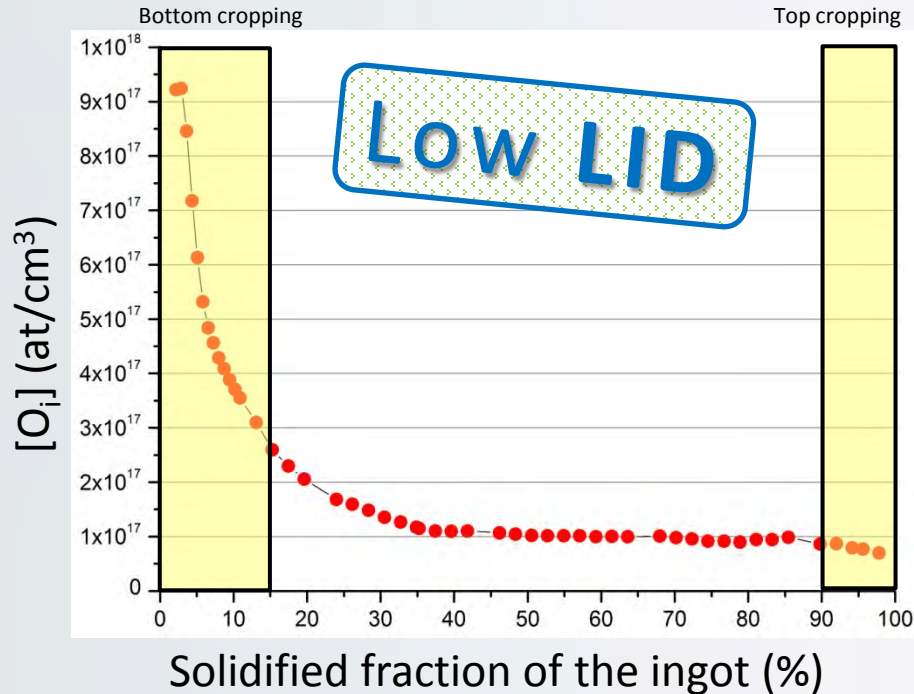
Isoresistivity map, representative of the
solidification front



- Compatible
p or n type

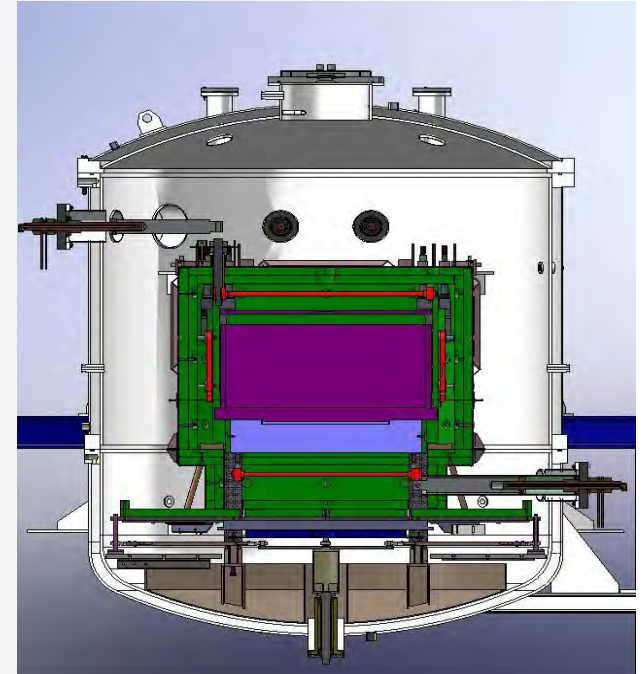
Crystallization: oxygen & carbon

- Very low concentration in oxygen: $[O_i] < 3 \times 10^{17} \text{ cm}^{-3} \rightarrow$ reduction of LID effect

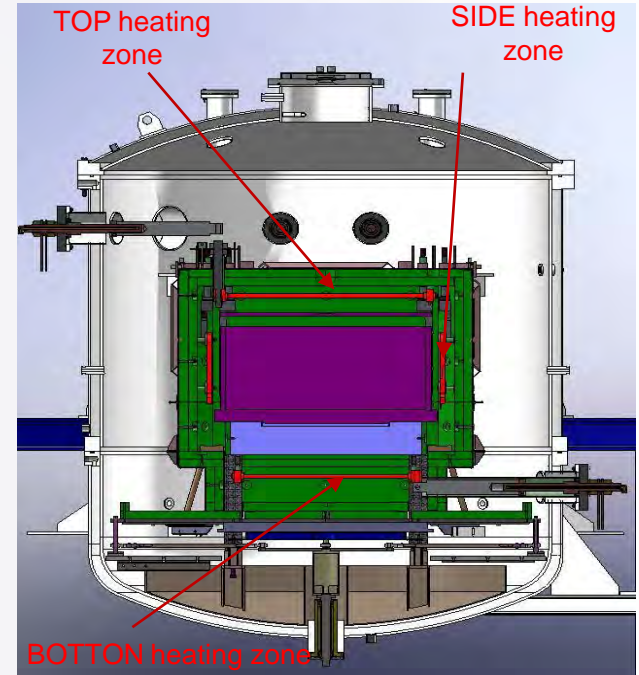


ECM PV600 : Furnace configuration

- DSS furnace ECM PV600

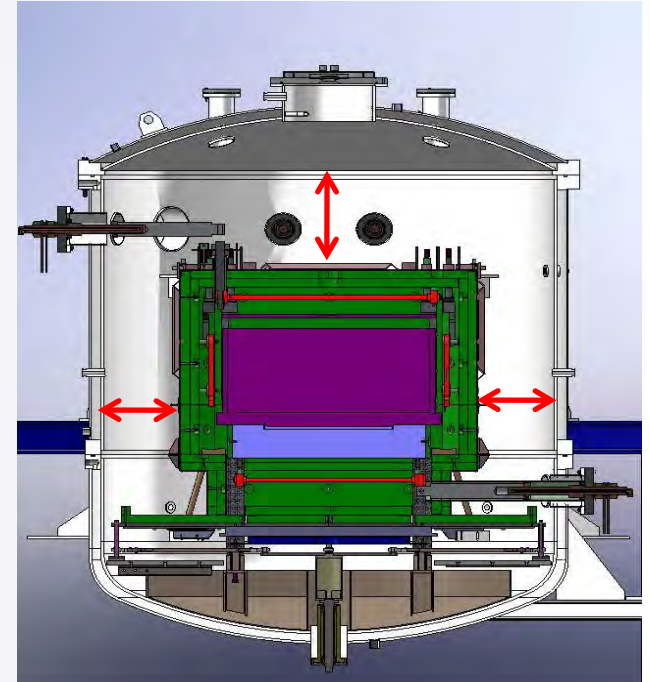
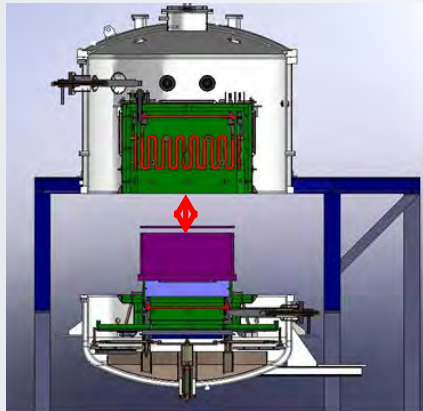


- **3 independent heating zones for an acute control over the process parameters:**
 - Optimized cycle time
 - Thermal gradient optimization
 - Thermal balance reducing stress
 - Optimization of electrical consumption



ECM PV600 : furnace configuration

- **3 independent heating zones**
- **Flexible furnace design**
 - Compatible for both Gen5 and Gen6
 - Maximum load of 800Kg in Gen6



ECM PV600 : safety features



Several levels of silicon spill protection



A large safety valve opens as soon as the pressure inside the vessel goes over the room pressure.



The lower vessel is not locked (pulled by vacuum only), it opens up automatically in case of internal overpressure

No explosion has ever been recorded with ECM Furnace. The design of the furnace is **SAFE**

ECM PV600 : productivité et coûts



- Reduced cycle time / high material yield

Taille	t_{cycle} (h)*	η_{material} (%)
G5	< 63	>72%
G6	<75	>73%



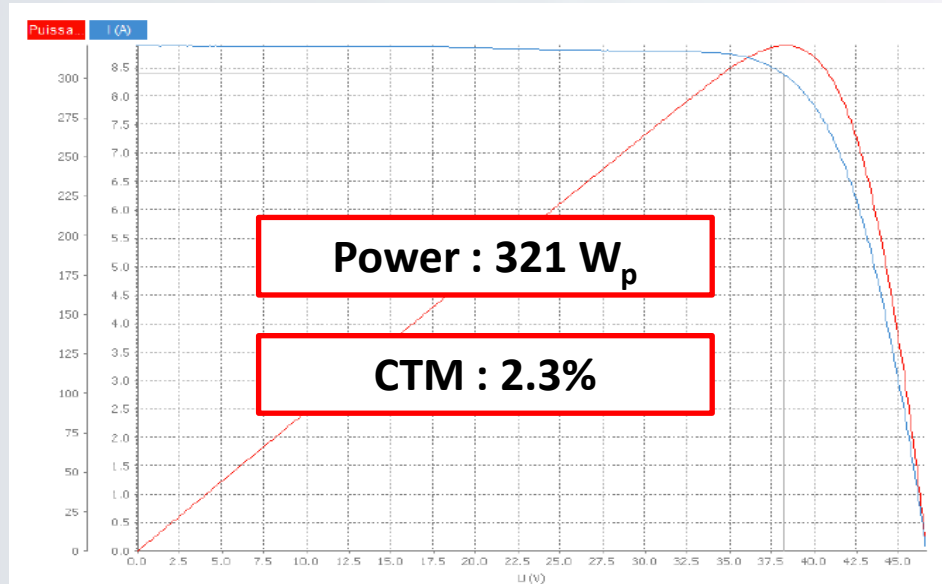
**The cycle time depends on the initial charge as well as the type of crystallization process*

- Evaluation of our monolike material on different cell structures (wafer 156x156mm, Gen 5)
- High lifetime characteristics and <100> crystalline orientation
→ **Compatible with all cell structures**
- High potential on PERT technology → process development ongoing
- Results below are non optimized and should be higher with optimization for monolike material

Architecture	Type	η_{average} ML [%]	η_{max} ML [%]	$\eta_{\text{réf}}$ Cz [%]
Standard Al-BSF	<i>p</i>	18.4	18.5	18.7
Selective emitter Al-BSF	<i>p</i>	18.8	19.2	19.3
PERC	<i>p</i>	19.9	20.2	20.5
PERT	<i>n</i>	19.0	19.9	20.0
HET (G2 - 100cm ² / réf FZ)	<i>n</i>	21.2	21.6	22.2

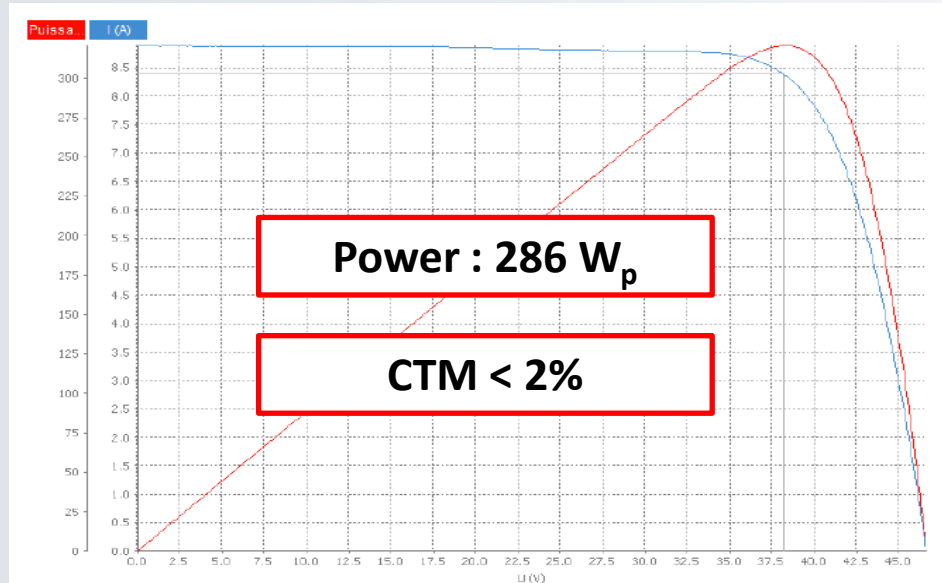
Module ↔ Mono-like cells

- 72 cells module with selective emitter / Al-BSF
- Standard encapsulation glass/EVA/tehdar



Module ↔ Mono-like cells

- 60 cells module with selective emitter / PERC



- **Unique crystallization process, patented**
- **Main advantages:**
 - **Low manufacturing cost** (compared to CZ)
 - High conversion efficiency **>20%**
 - Compatibility **p type / n type**
 - **Low LID** effect in p type (Low $[O_i]$)
 - **Low resistivity range** for n type (compared to CZ)
 - Diamond cutting compatible
 - **Full-square** wafers



Thank you

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