Challenging aspects in the development of next-generation modules

SOPHIA Workshop of April 2023

Hanwha Q Cells

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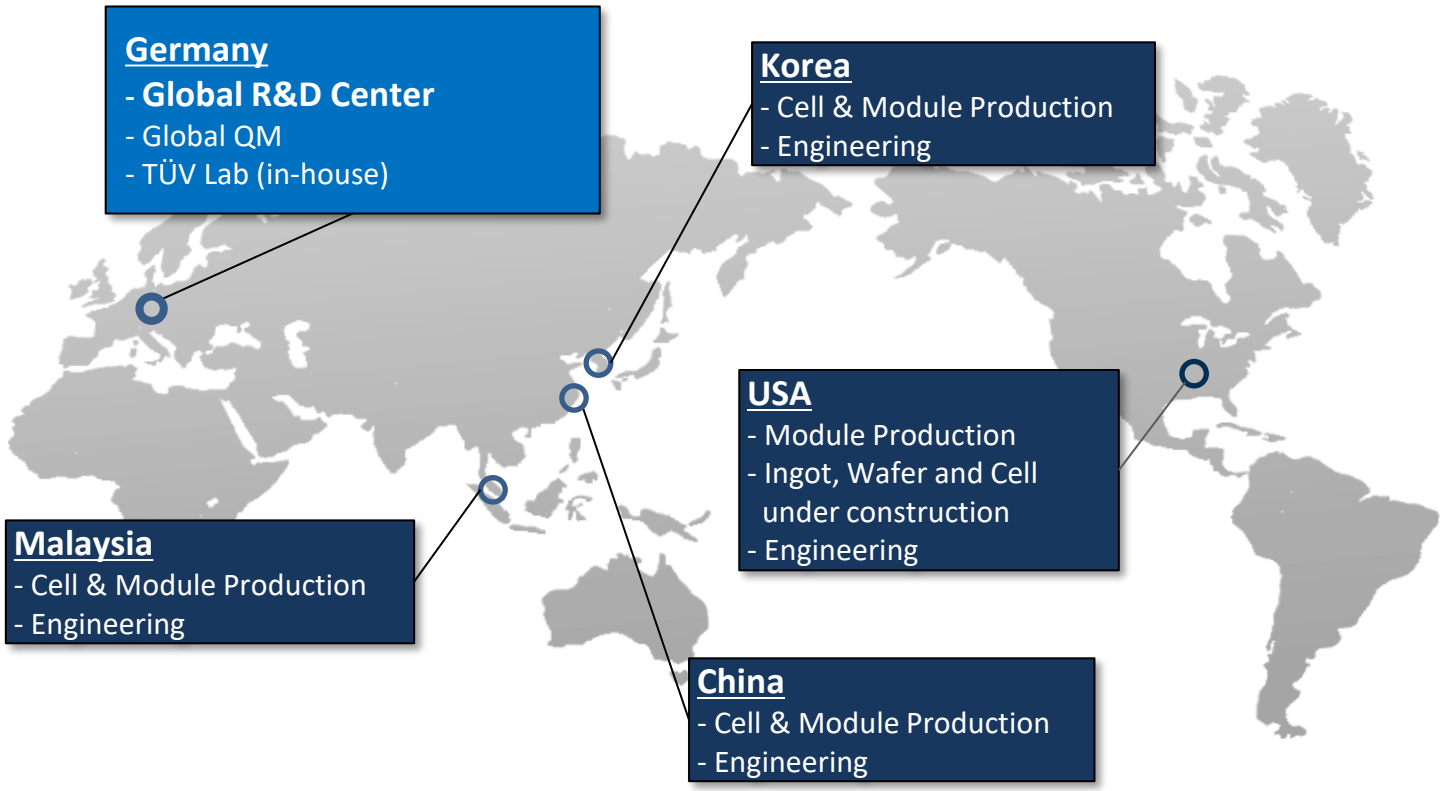
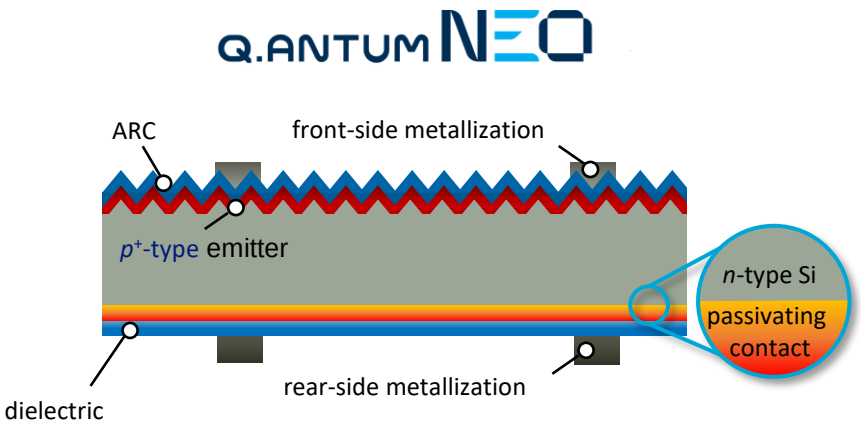
Hanwha Qcells – Global operation for R&D and production



- **Qcells current module capacities > 12 GW/a**
- Expansion of **ingot, wafer, cell and module** production in US on-going
- Module capacity in US until 2024: **8.4 GW/a**
- **Low carbon polysilicon** manufacturing in US by REC Polysilicon (Hanwha holds 33.3% share)

Qcells Q.ANTUM NEO technology



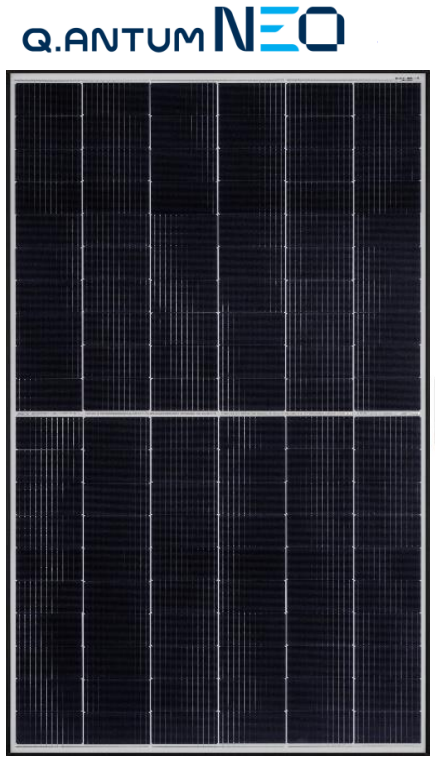
- texture
- diffusion
- edge isolation
- passivating contact
- clean
- dielectrics + ARC
- metallization

Q.ANTUM NEO[1] technology (TOPCon based)

- *n*-type Cz silicon substrate
- Passivated rear-side contact
- Lean & cost-effective process
  (ARC module optimized, 12BB, screen print, mass-production processes …)
- 2 additional steps vs. Q.ANTUM (PERC based)
- Possible to retrofit existing Q.ANTUM lines
- Same module technology as Q.ANTUM

[1] J.W. Müller (2021). Q Cells' Way to Solar Cell Efficiencies Exceeding 24 % in Mass Production. Silicon PV 2021.

Qcells Q.TRON module technology



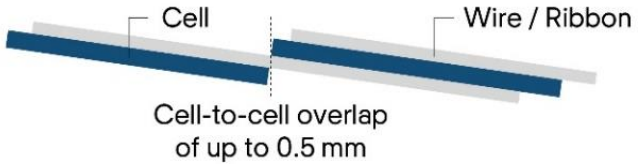
25 YR Warranty Product & Performance

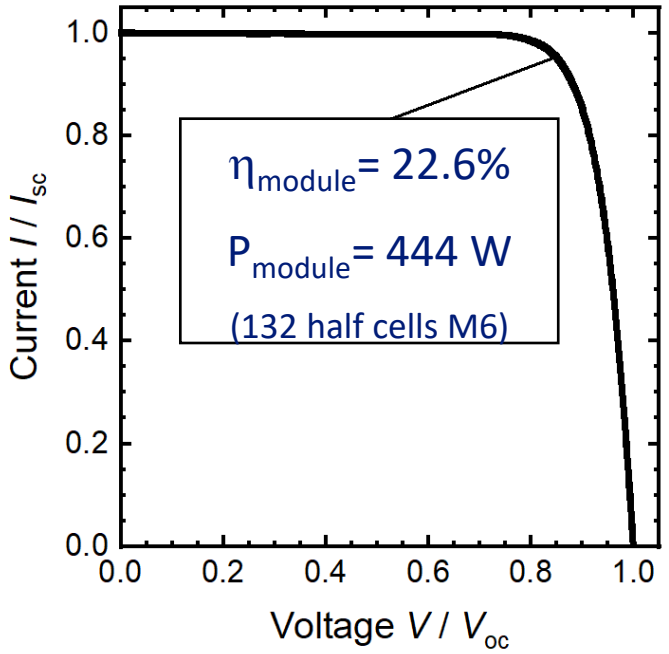
Q CELLS Advanced Yield Security

Quality Controlled PV TÜVRheinland CERTIFIED www.tuv.com ID 1111232615

ZERO-GAP TECHNOLOGY

- No spacing between cells in string
- Compact module design with improved module efficiency





Current status module development

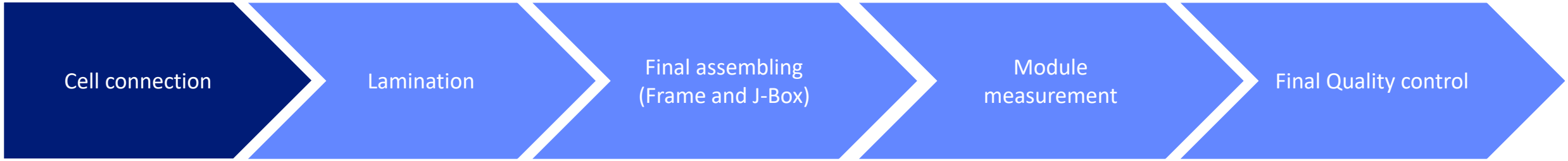
- State-of-the art module interconnection technology can be applied (half-cells, multi-wire, standard encapsulants, zero-gap)
- **22.6% full-area module efficiency (444 W)** achieved (full module size, 132 HC M6 layout)

Current module manufacturing process

Main Module-Process-Flow

Current module manufacturing process

Cell connection



- Fully automatic tabber units
- Temperature peaks up to 220°C
- Process time < 1min / String

Internal wire/ribbon-to-cell stress:

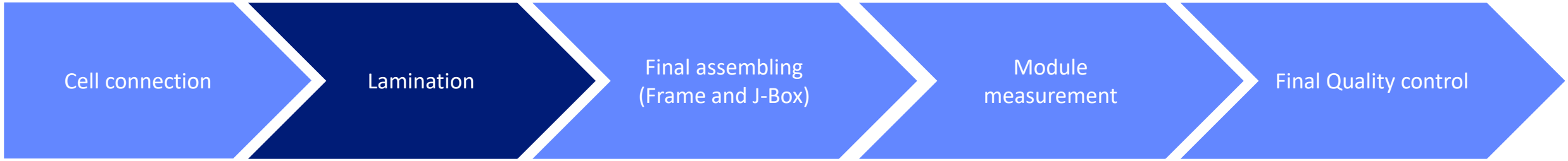
- **proven** and **demonstrated reliability**
  (climate chamber test like TC600+ as well as outdoor)

High temperature

Mechanical stress

Current module manufacturing process

Lamination



- Fully automatic tabber units
- Temperature peaks up to 220°C
- Process time < 1min / String

- Membrane Laminator
- Lamination temperature up to 155°C
- Lamination pressure up to 1bar
- Process time up to 15min

Internal cell stress:

- **proven** and **demonstrated reliability** (climate chamber test as well as outdoor)

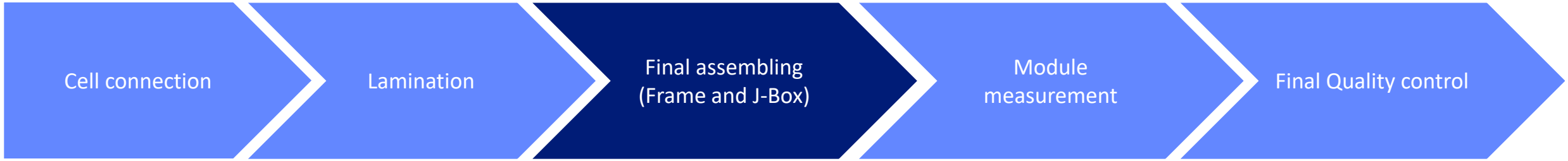
Used materials:

- **proven** and **demonstrated reliability** by **extended climatic stress protocols beyond IEC**

High temperature | Mechanical stress | Atmospheric agents | Polar chemicals

Current module manufacturing process

Final assembling



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- Membrane Laminator
- Lamination temperature up to 155°C
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- Process time up to 15min

- Fully automatic silicone application
- Fully automatic framing
- Fully automatic J-Box application

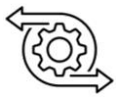
Module stress:

- **proven** and **demonstrated reliability**

Frame- and J-Box – sealing materials:

- **proven** and **demonstrated reliability**

(climate chamber test like DH3000 as well as out-door).

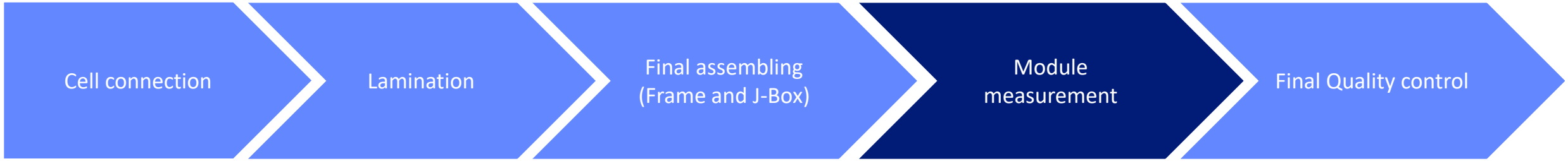


Mechanical stress

Atmospheric agents

Current module manufacturing process

Power measurement



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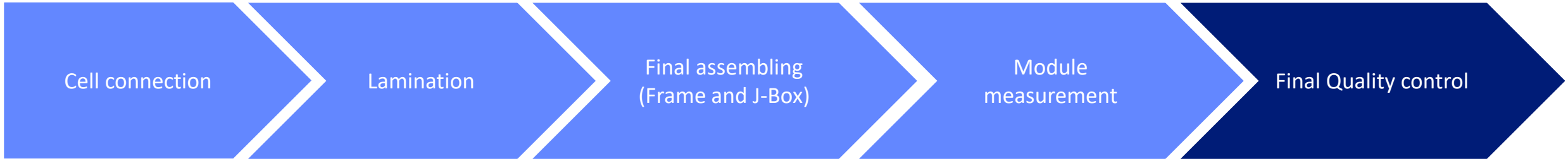
- Fully automatic silicone application
- Fully automatic framing
- Fully automatic J-Box application

- Fully automatic Module-Measurement (like Power, EL, …)
- with cycle time less 15 sec

- **Global Calibration-standards** across production
- **External certified** Golden Module for first level calibration
- Silver Module for **daily** second level calibration

Current module manufacturing process

Final Quality control



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- Fully automatic silicone application
- Fully automatic framing
- Fully automatic J-Box application

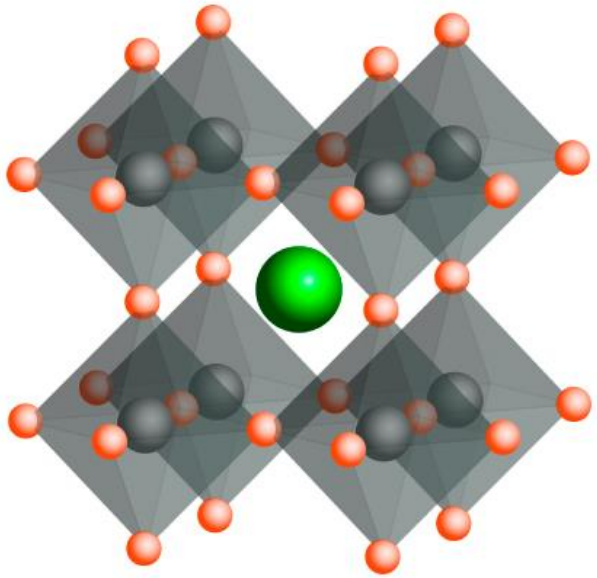
- Fully automatic Module-Measurement (like Power, EL, …)
- With take time less 20 sec

- 100% visually inspection
- manual module release based on all IPQC information

Excellent integrated Quality system established in the full production chain.

- **IQC for all materials**
- **In-line process control systems**
- **Final module quality release**

Challenging module manufacturing process



Perovskit Tandem Cells/Modules

High temperature

Mechanical stress

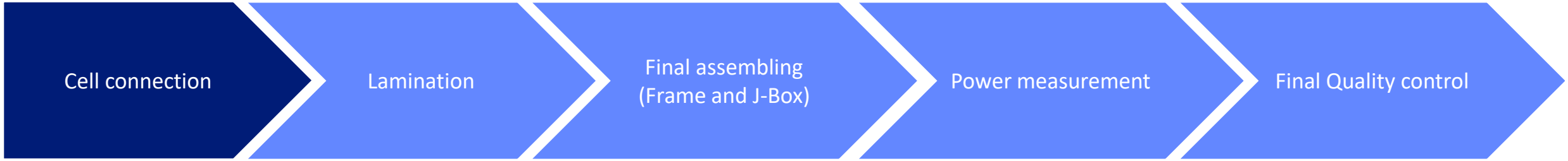
Atmospheric agents

Polar chemicals

Manufacturing cost

Challenging module manufacturing process

Cell connection



- Fully automatic tabber units
- Temperature peaks up to 220°C
- Process time < 1min / String

Question?

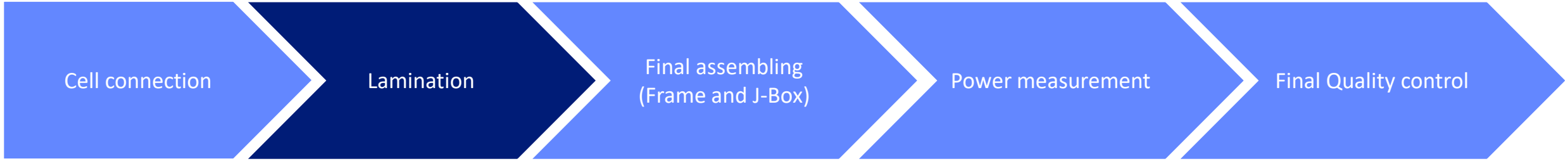
- Current soldering process can work?
- New interconnection concepts needed?

High temperature

Mechanical stress

Challenging module manufacturing process

Lamination



- Membrane Laminator
- Lamination temperature up to 155°C
- Lamination pressure up to 1bar
- Process time up to 15min

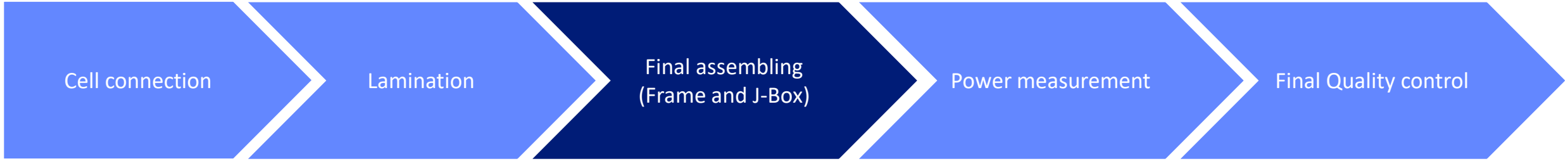
Question?

- Current lamination conditions can works?
- Current used materials provides sufficient protection?
- Negative affect of by-products or degradation products?

High temperature **Mechanical stress** **Atmospheric agents** **Polar chemicals**

Challenging module manufacturing process

Final assembling



- Fully automatic silicone application
- Fully automatic framing
- Fully automatic J-Box application

Question?

- Current Frame- and J-Box sealing concepts and materials can work?
- Currently sealing materials/concepts provide sufficient protection?

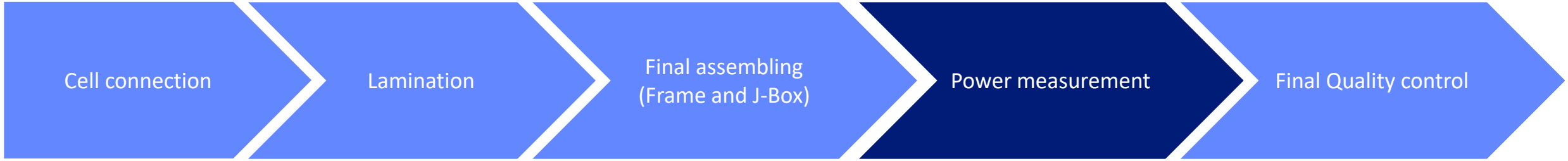

Mechanical stress


Atmospheric agents


Polar chemicals

Challenging module manufacturing process

Power measurement



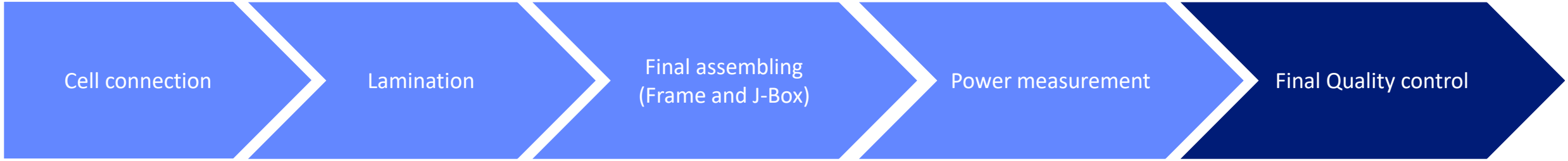
- Fully automatic Module-Measurement (like Power, EL, …)
- with take time less 15 sec

Question?

- How we can measure Tandem Modules in a correct way in the short times needed in mass production?

Challenging module manufacturing process

Final Quality control



- 100% visually inspection
- manual module release based on all IPQC information

Question?

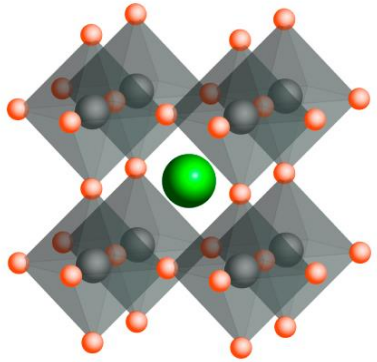
- Established IEC Norm sufficient for Tandem modules?

Summary / Out-look

There are a lot of open questions across the hole module production chain, which have to be solved and understood before starting a Perovskit-Tandem mass production.

Therefor a detailed understanding of the degradation mechanism of Perovskit-Tandem cells during module production is needed.

Behind the module production, if the current IEC Norms capable to ensure Perovskit-Tandem-Module reliability regarding out-door requirements for the given life time.



High temperature

Mechanical stress

Atmospheric agents

Polar chemicals

qcells

THANK YOU

Module R&D l Marcel Kühne

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