BRAE 470 Solar Photovoltaic System Engineering

Photovoltaic Energy Conversion

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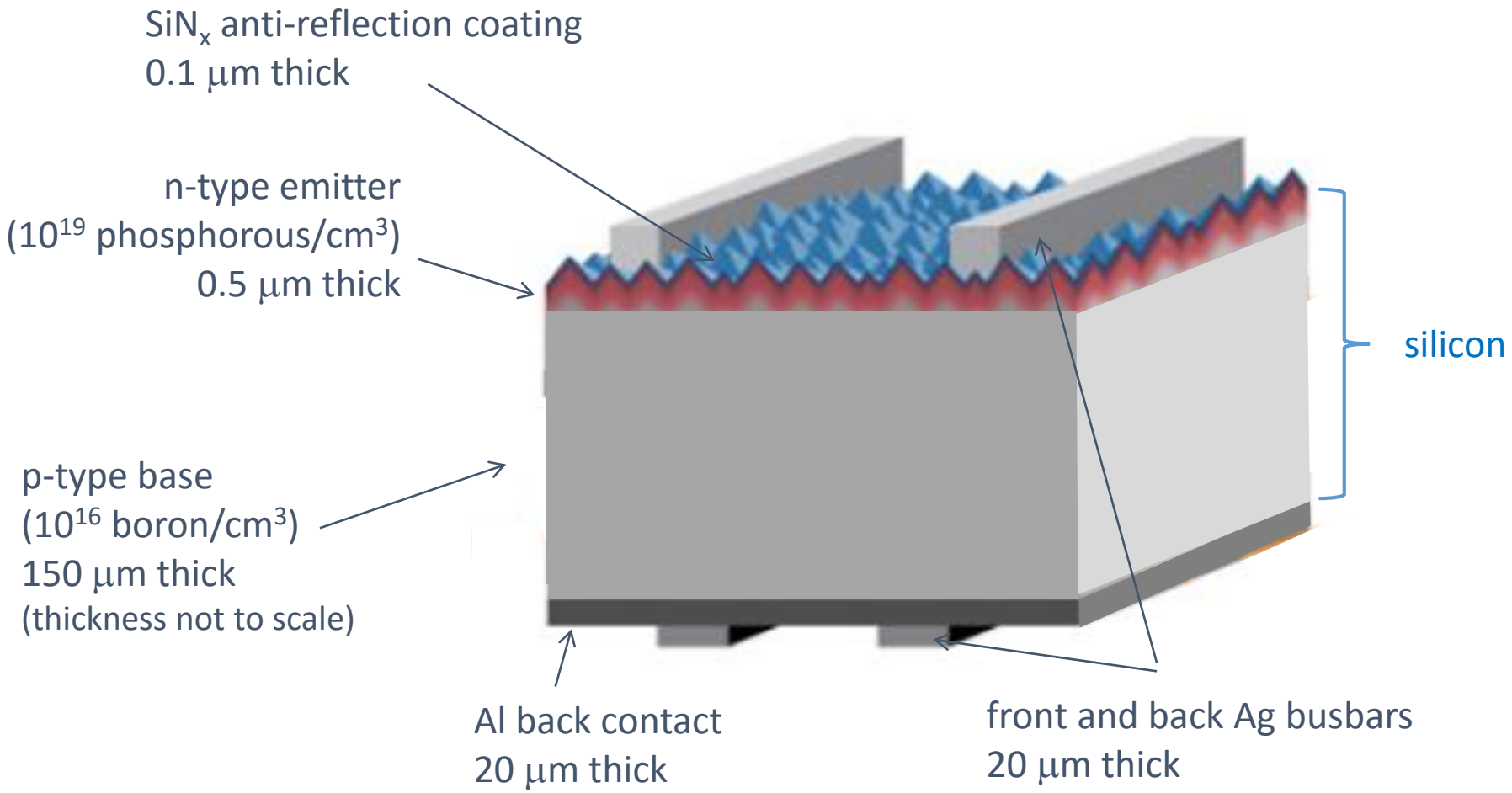
Outline

1. How solar cells are fabricated
2. Why (and how) cells are made into modules

3. How modules are fabricated
4. Types of crystalline photovoltaic modules
5. Module Specs

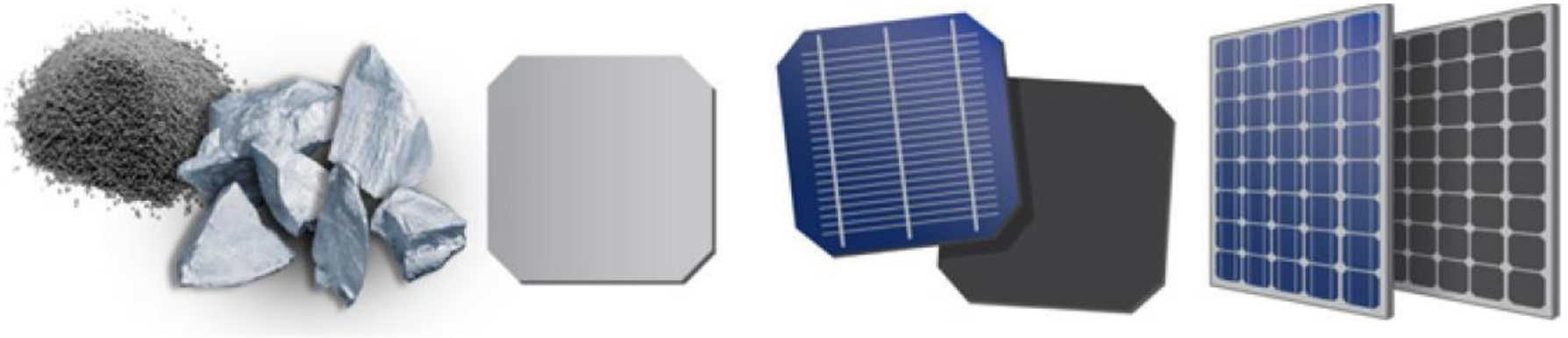
Standard c-Si cell – "product"



What are the "materials and process" to make this product?

c-silicon module materials and process

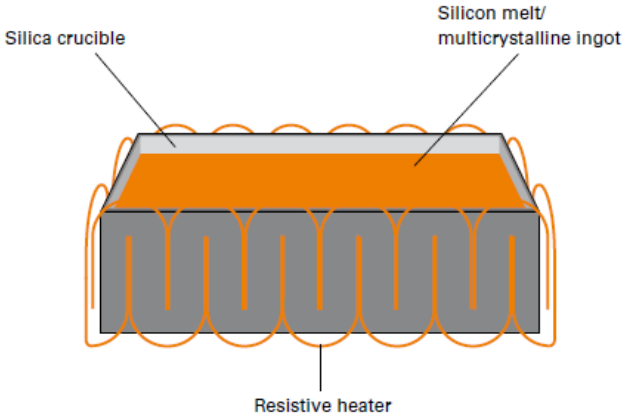
Poly Silicon → **Ingot and Wafer** monocrystalline or multi-crystalline → **Cell** → **Module**

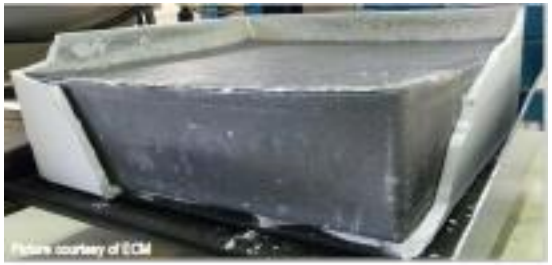


"9 nines" purity Si

99.9999999%
1 impurity atom for 10^7 Si atoms

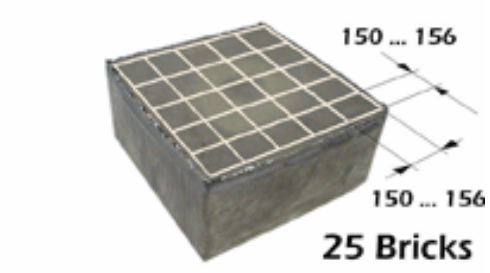
Multicrystalline ingot production





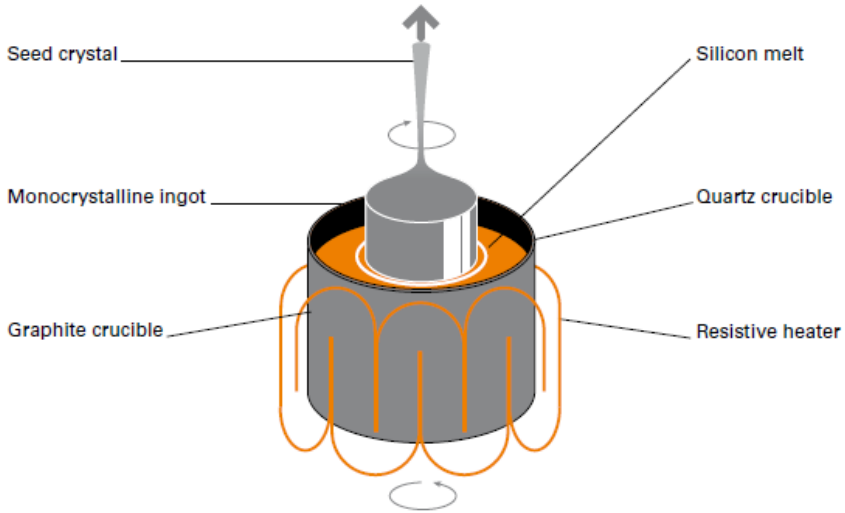
T_m(silicon)
=1414 C

$T_{softening}$ of silica
= 1665 C



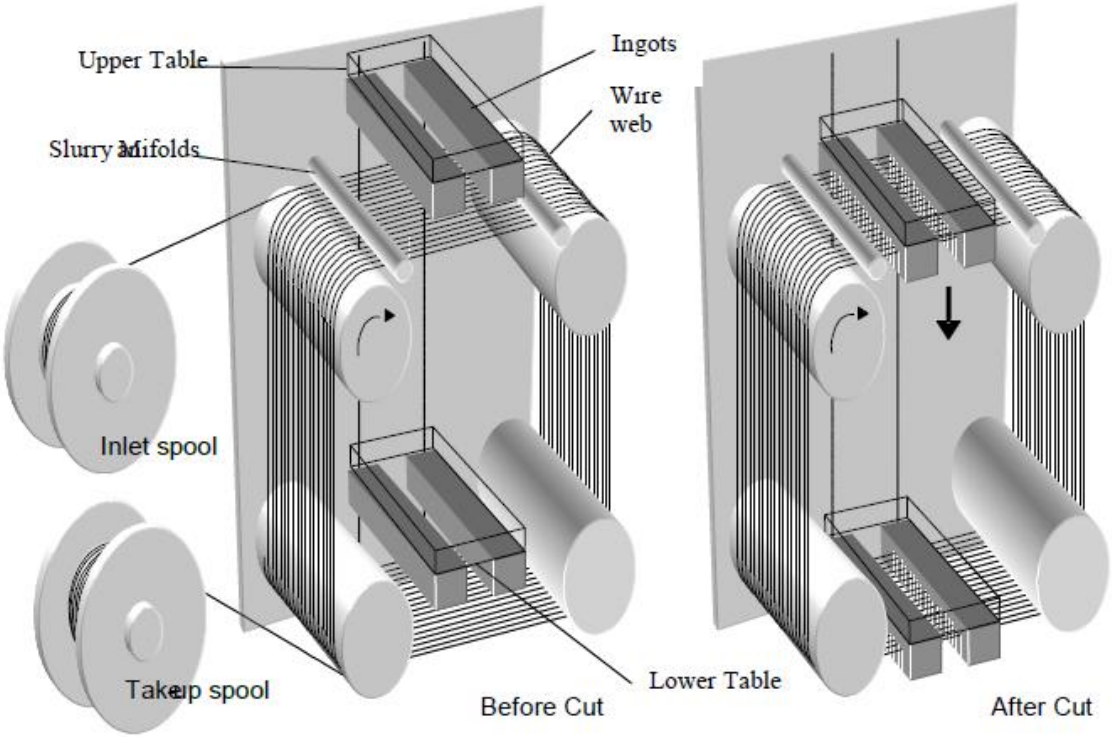
Gen 6
600-800 kg

Monocrystalline ingot production

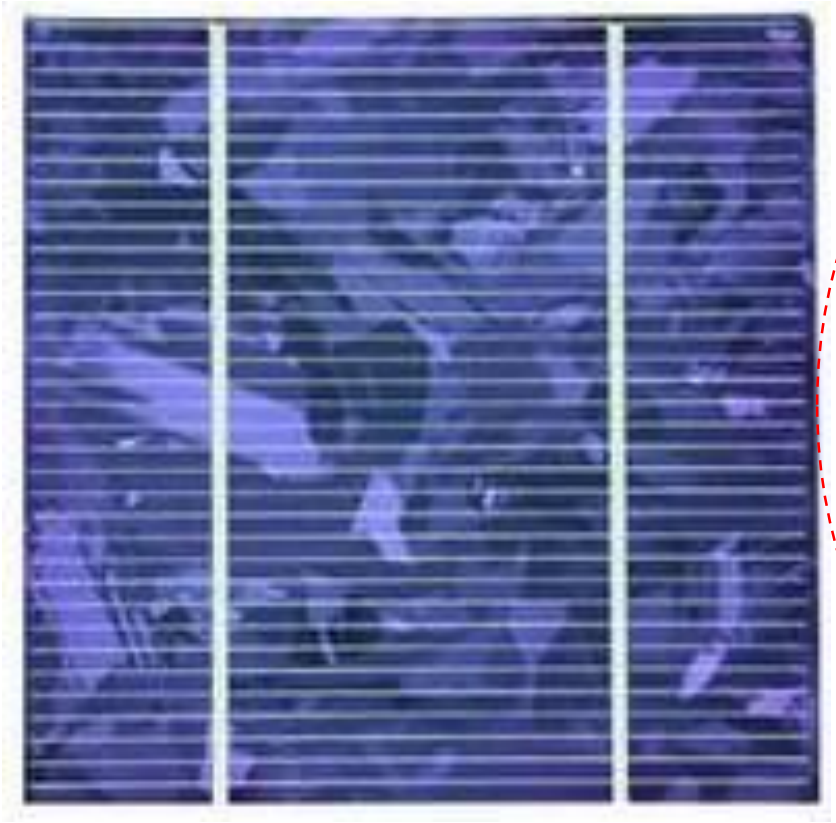


PVA TePla

Multiwire saw cuts ingots into wafers

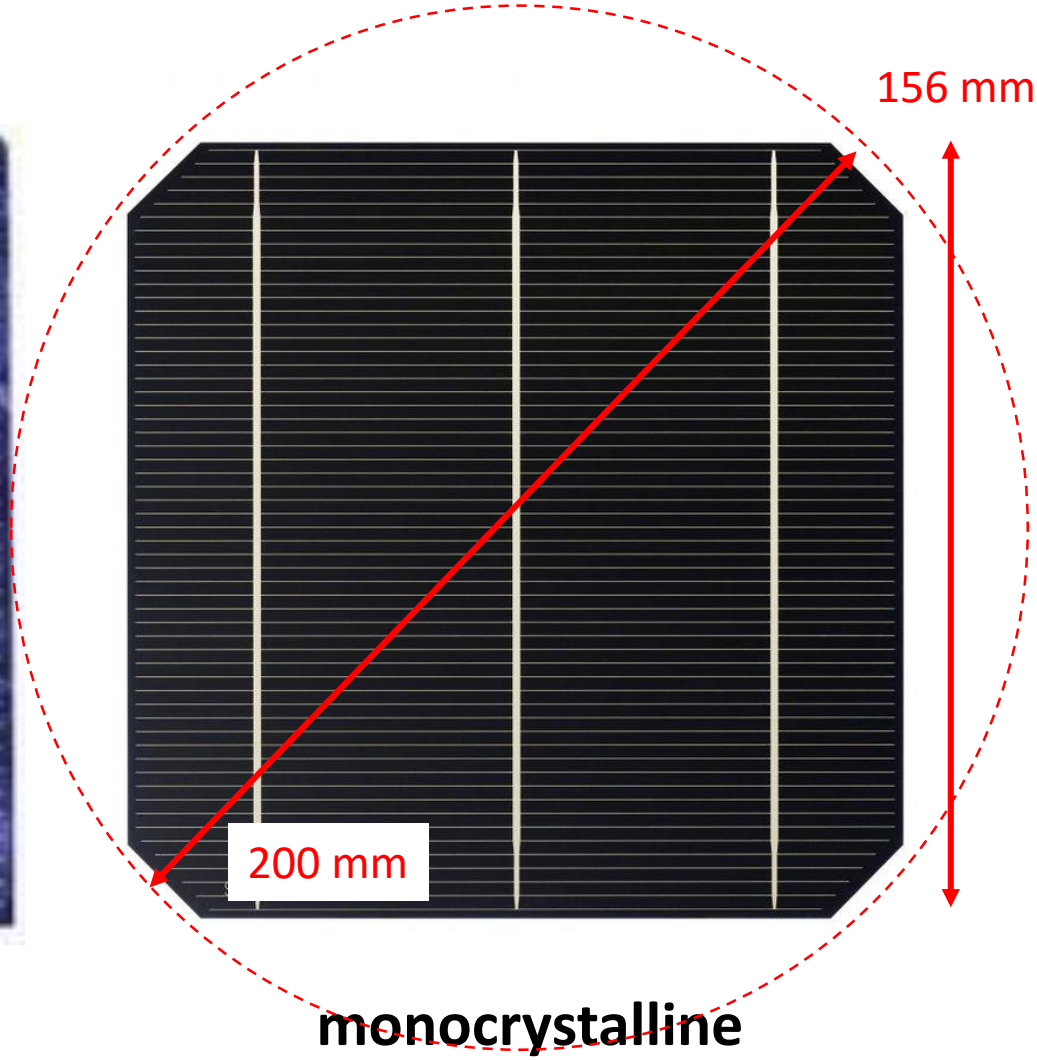


Finished 2-sided contact silicon cells



multicrystalline

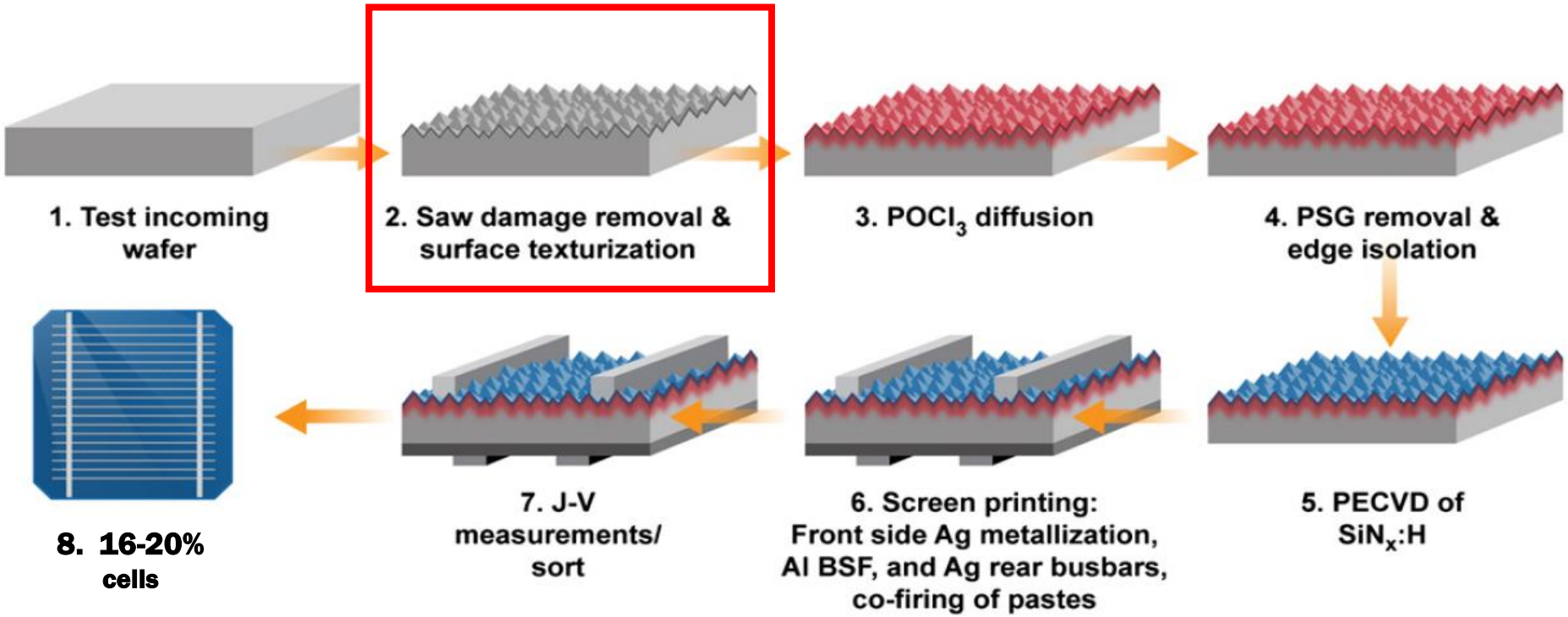
62% of PV cells installed in 2014



monocrystalline

30% of PV cells installed in 2014

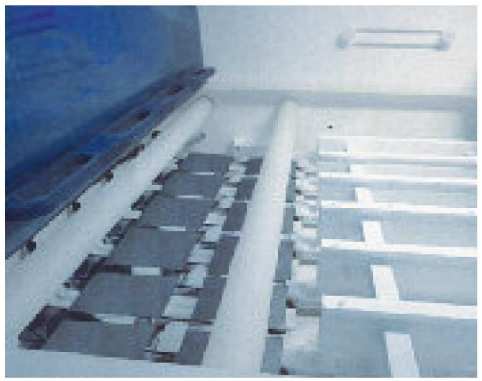
Standard c-Si cell manufacturing steps – “Process”



Saw damage removal and etching

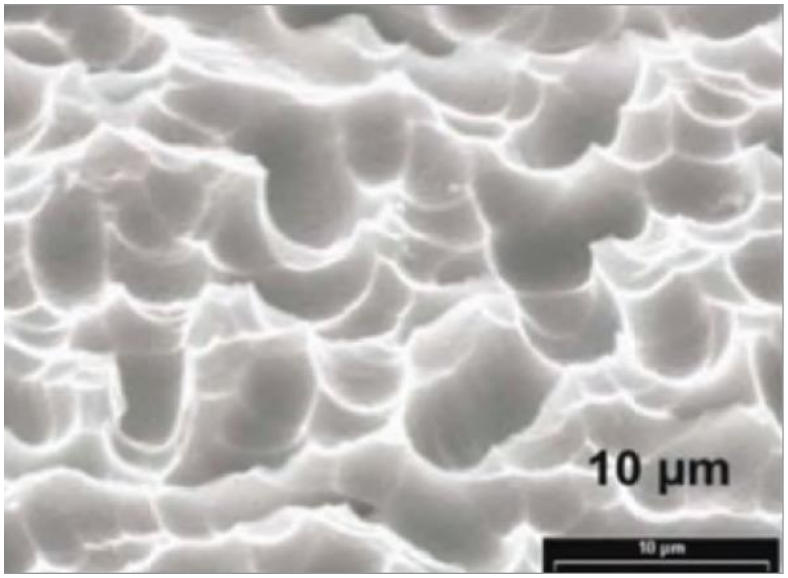
Tool throughput typically > 3000 wafers/hour ~ 1 per second

Continuous process tool

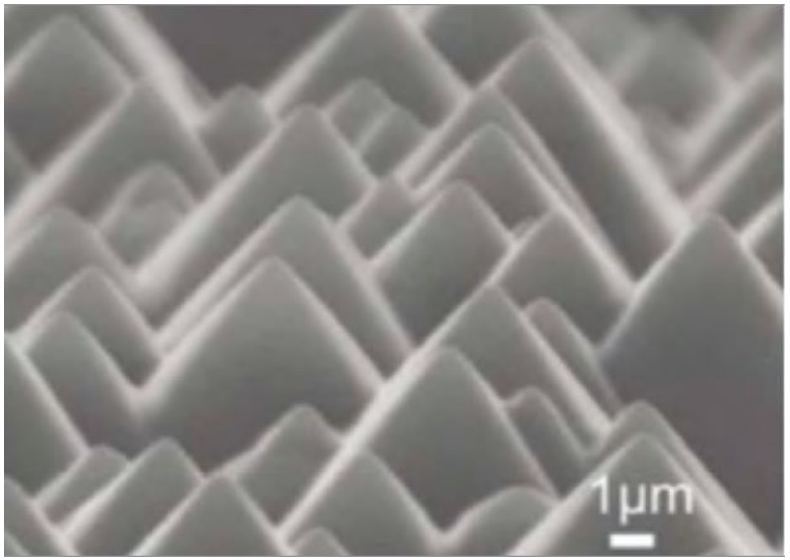


Batch process tool

Surface texture of c-Si cells

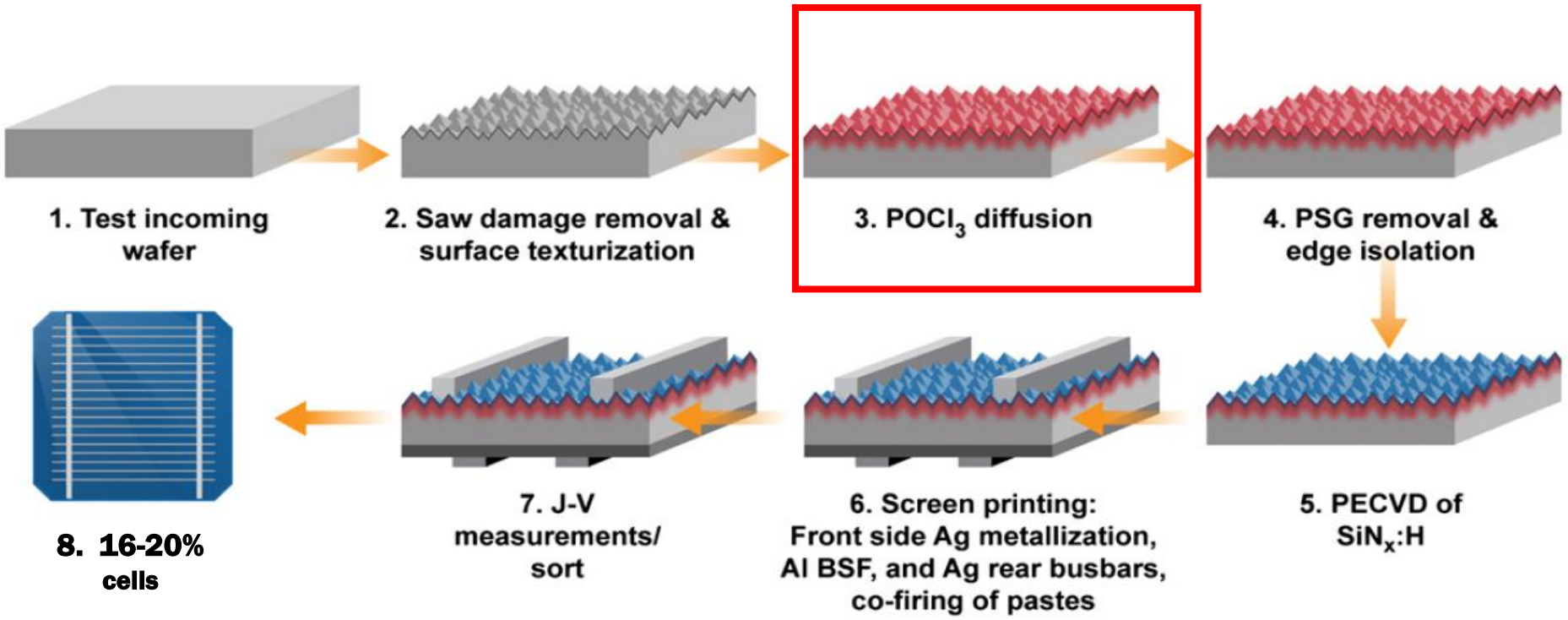


Multicrystalline
acid etch



Monocrystalline
basic etch

Standard c-Si cell manufacturing steps – “Process”



$POCl_3$ diffusion furnace

Wafers held at ~ 950° C
for ~ 30 minutes

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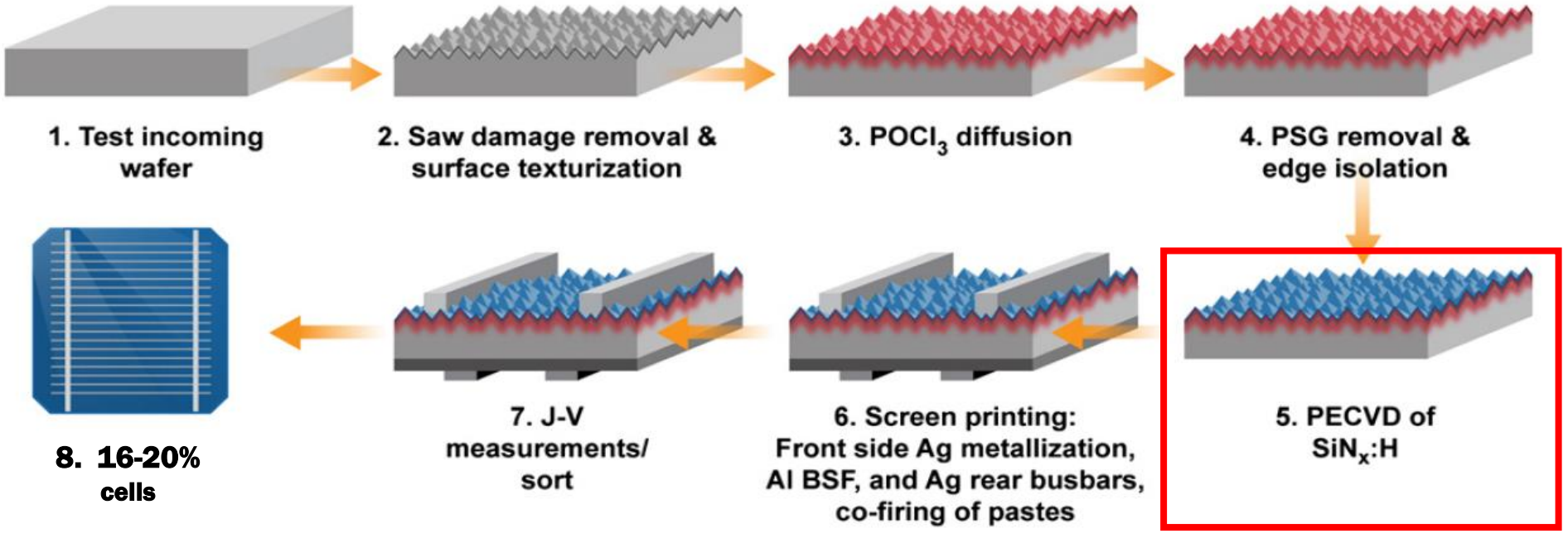
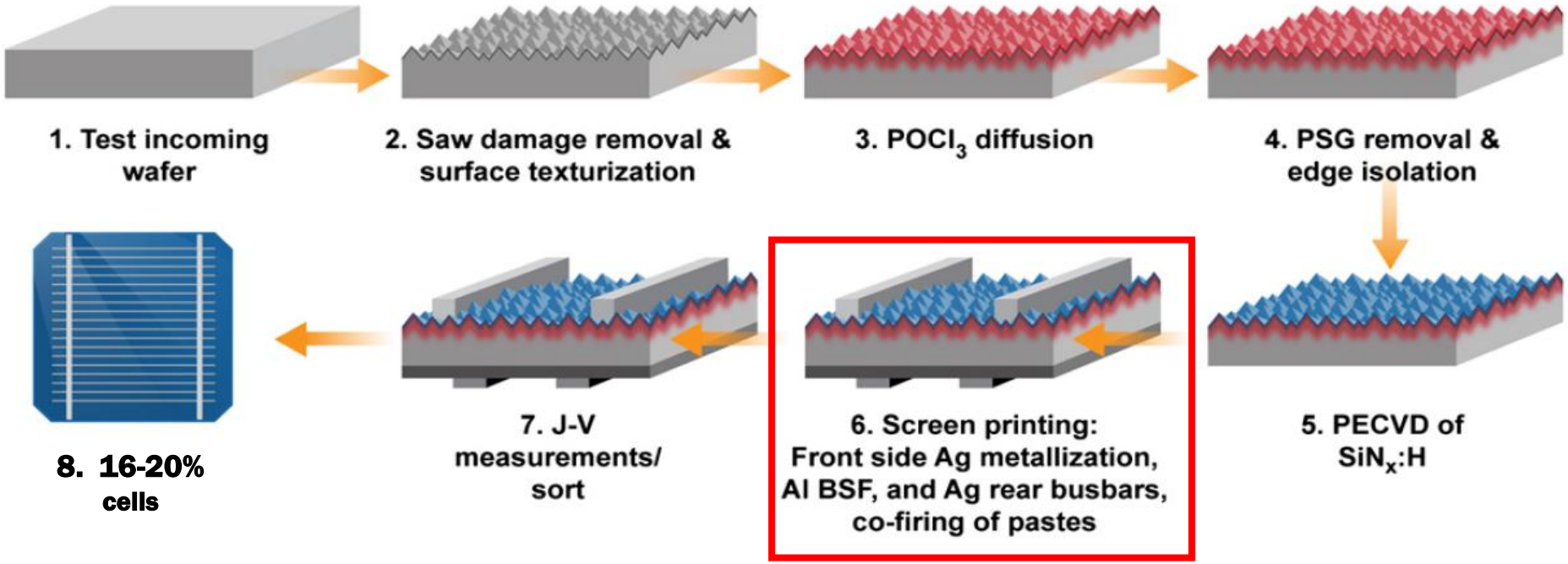


SiN_x:H layer deposition

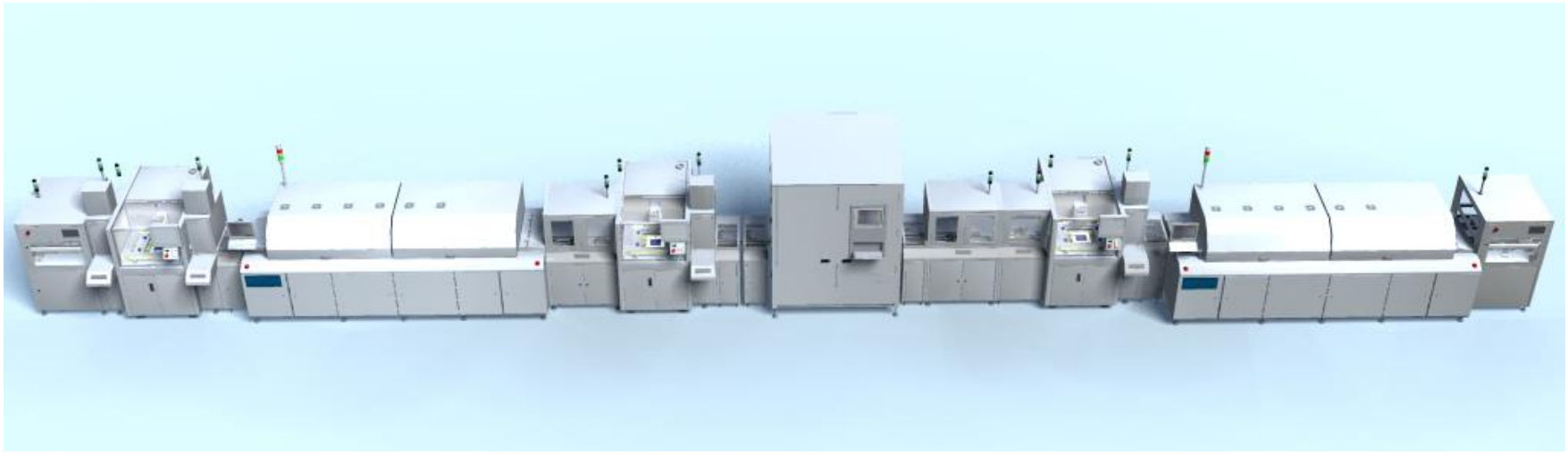
$SiH_4 + NH_3 \rightarrow SiNH + 3\ H_2$

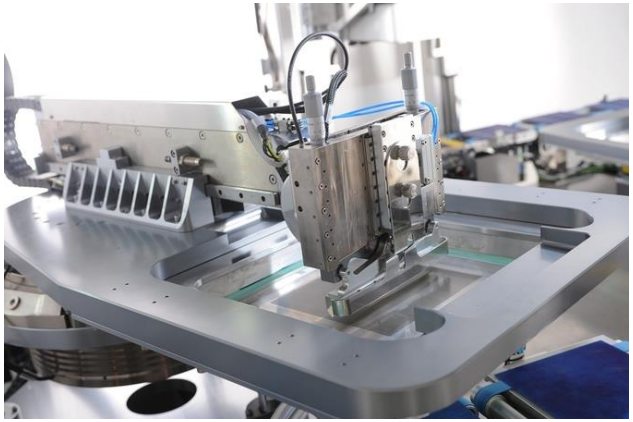
Use Plasma-enhanced
Chemical Vapor Deposition (PECVD)

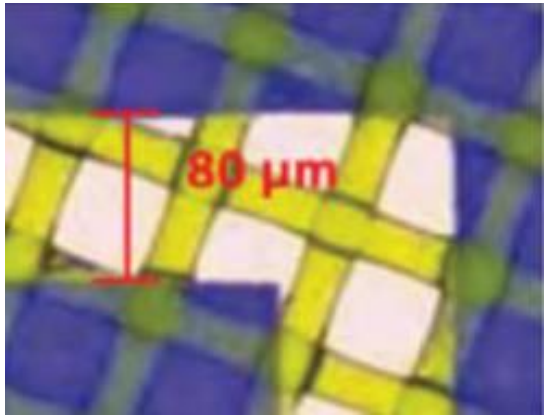
Standard c-Si cell manufacturing steps – “Process”



Screen printing of electrical contacts







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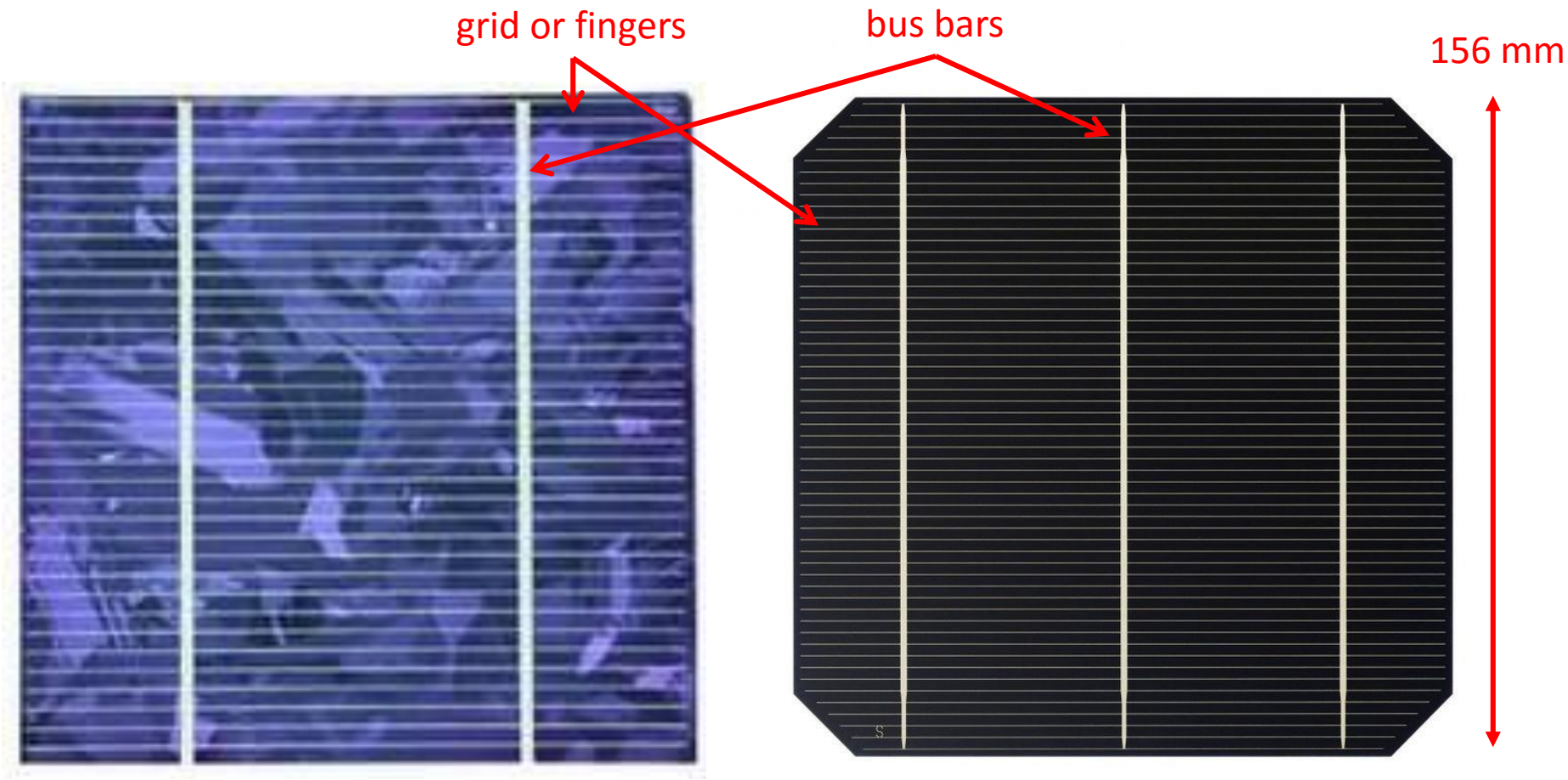


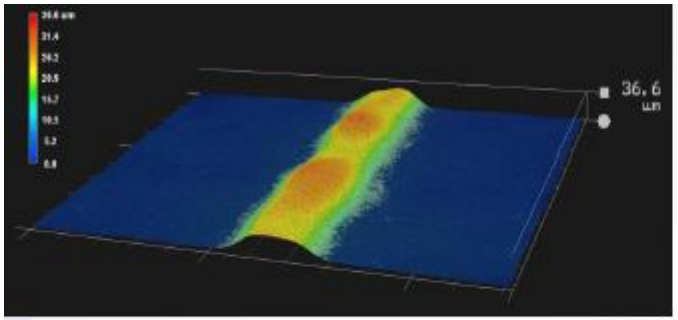
multicrystalline

62% of PV cells installed in 2014

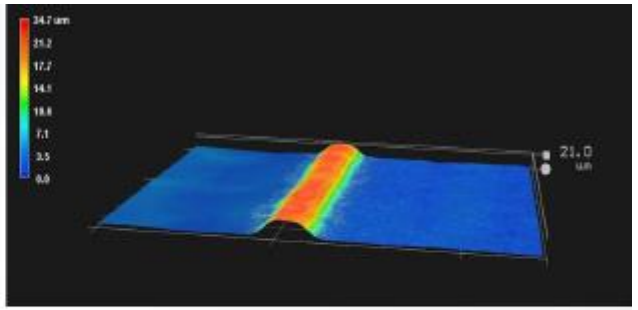
monocrystalline

30% of PV cells installed in 2014

Improvements in screen printed grids



Width:	100	5	µm
Height:	20	5	µm
Shading:	8		%
Aspect Ratio:	0.2		



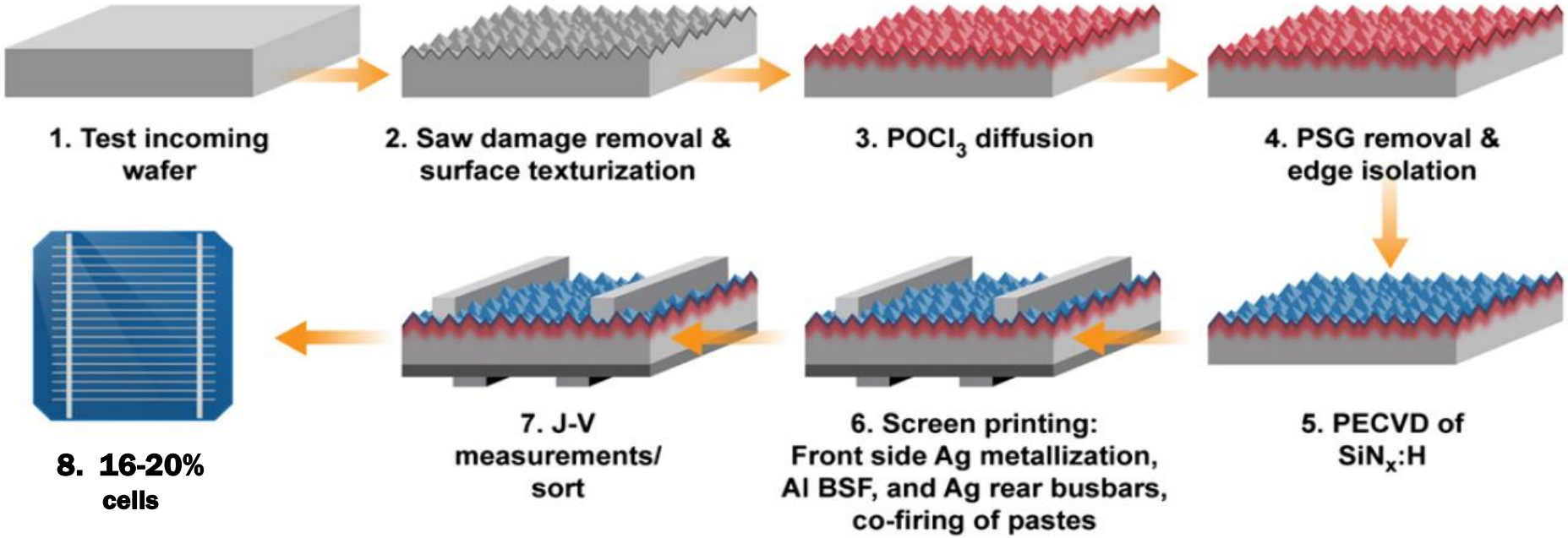
Width:	65	5	µm
Height:	25	5	µm
Shading:	6.3		%
Aspect Ratio:	0.38		

Cross sectional area

2000 μm^2

1625 μm^2

Standard c-Si cell manufacturing steps – “Process”



Outline

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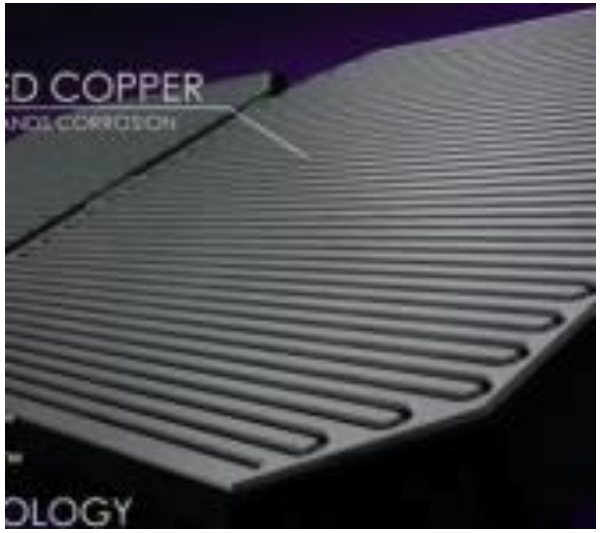
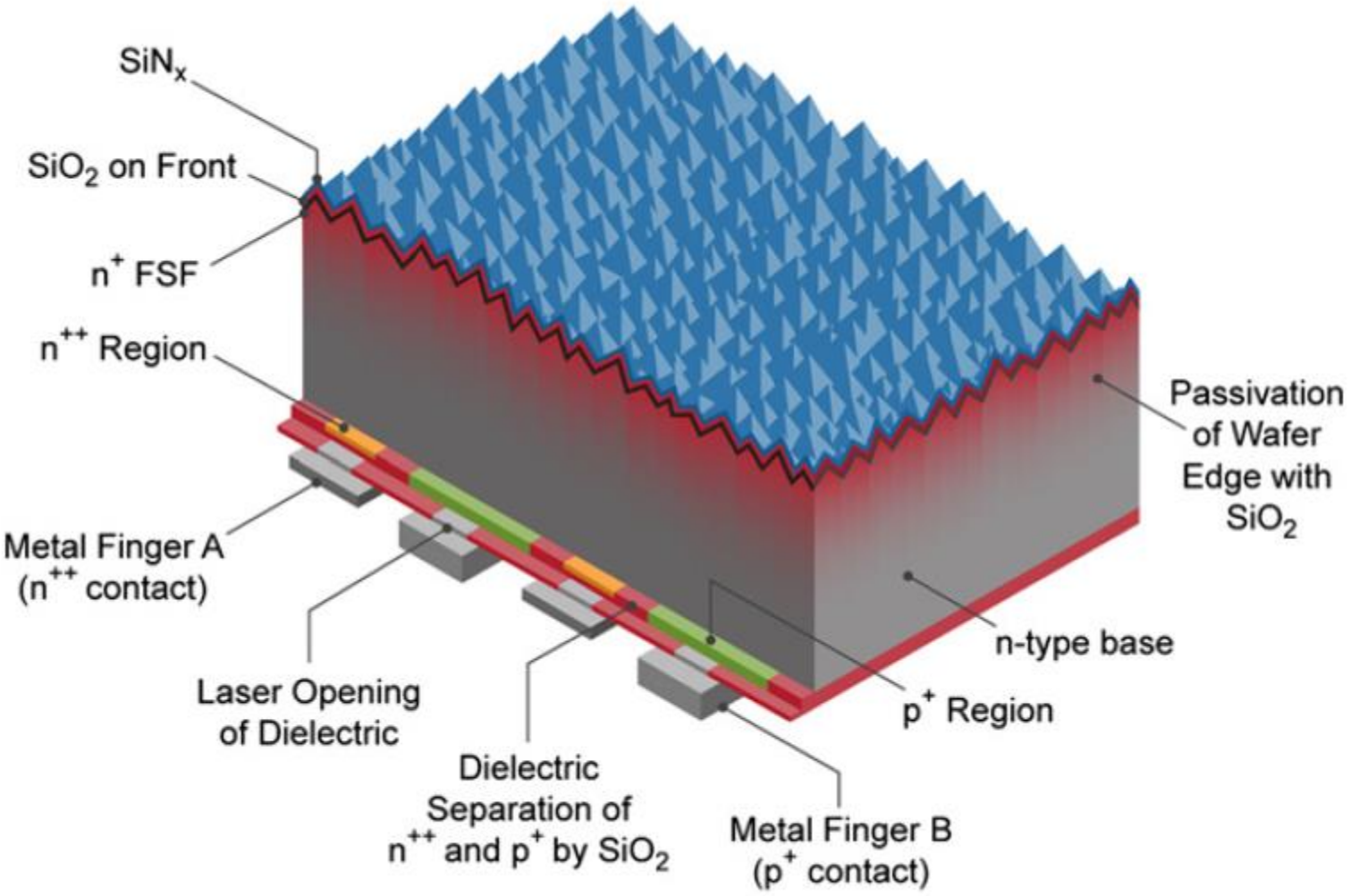
    - **SunPower Cells are different !**
2. Why (and how) cells are made into modules

3. How modules are fabricated
4. Types of crystalline photovoltaic modules
5. Module Specs

SunPower monocrystalline silicon cell

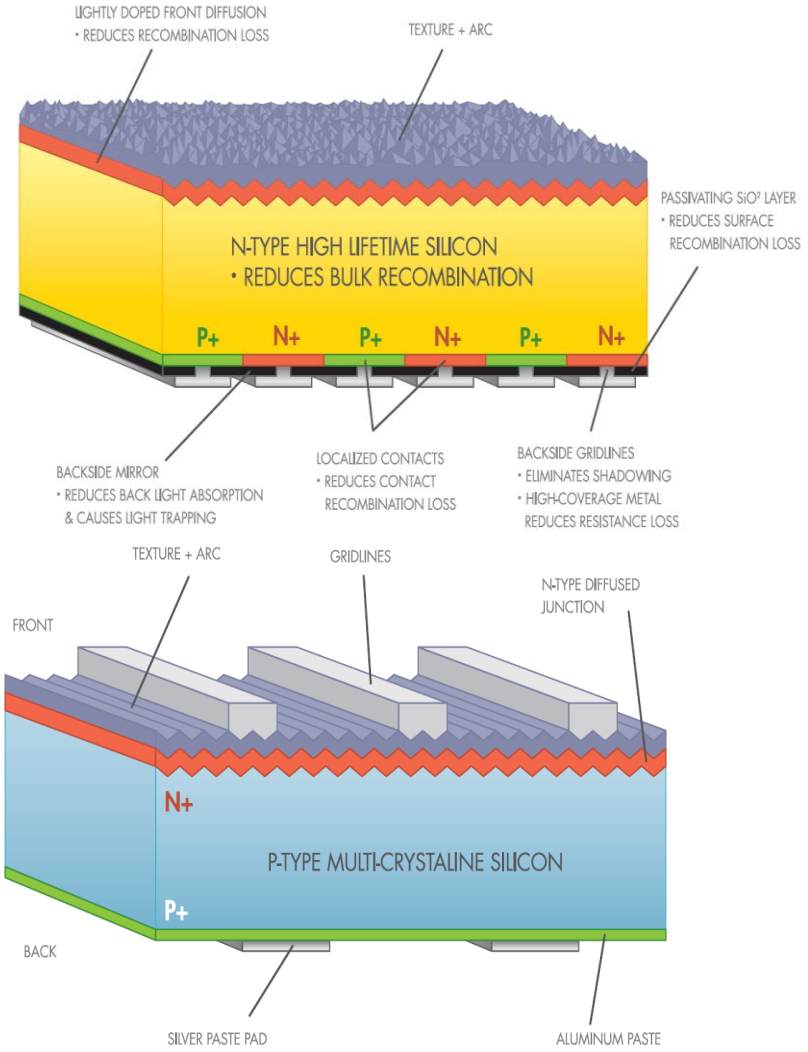


Interdigitated back contact (IBC) cell



How SunPower Panels Achieve Record Efficiencies

SunPower Solar Cell



- **Maximum light capture**
  - Up to10% more sunlight on cell surface
- **Reduced Resistive losses**
  - Back contacts enable wider and thicker, lower resistance contacts
- **Minimum Recombination Loss**
  - Passivating Silicon dioxide on front and back of cell minimizes recombination loss
- **Maximum Absorption of Light**
  - Back-side mirror gives photons a second chance to generate power

Type of cell	Typical Production Cell Efficiency (%)
multicrystalline	18
monocrystalline, two sided contact	20
Interdigitated back contact	24