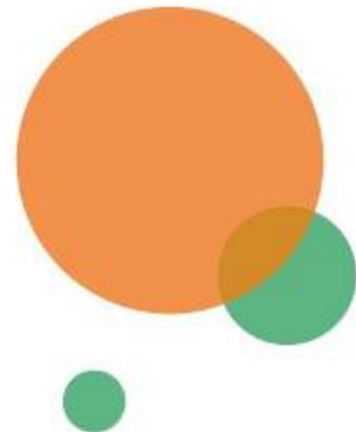


# **VIRTUS<sup>®</sup> MODULES**

**FROM SUPERIOR INGOT TO EXCELLENT MODULES**



# Outline

- Introduction of Virtus<sup>®</sup> Wafer manufacture
- Characteristics of Virtus<sup>®</sup> I module
- Characteristics of Virtus<sup>®</sup> II module
- Summary

# Introduction of Various Ingot Growth Methods

	Multi Ingot	Mono Ingot	Virtus® Ingot
<b>Growth method</b>	DSS	Cz method	Controlled DSS
<b>Crystalline way</b>	Seedless	Seed	Seed
<b>Crystalline growth control</b>	Random nucleation	Seeding	Controlled nucleation
<b>Ingot size</b>	450-800Kg	120Kg	450-800Kg
<b>Grain Orientation</b>	Random	Single	<b>Preferred</b>
<b>Grain uniformity</b>	Random	Mono	<b>Mono-like</b>
<b>Production cost</b>	Lower	High	<b>Low</b>

→ Directional Solidification System (DSS) provides a solution of high productivity and lower production cost.

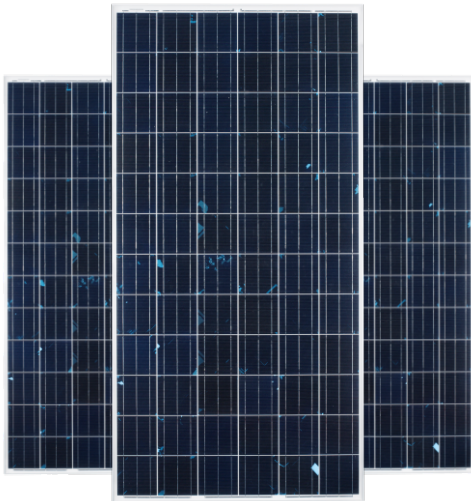
→ Cz method has advantage of excellent quality wafer, but with high production cost.

→ Controlled DSS combines the advantages of high productivity, high quality and lower production cost

# Characteristics of Virtus<sup>®</sup> I Modules

## (Compared to Mono Modules)

- Lower LID (Light Induced Degradation)
- Lower power loss in higher temperature
- Cost reduction (wafer and cell cost)
- Identical power output



Virtus<sup>®</sup> I module



Mono module

# Comparison between Virtus<sup>®</sup> I and Mono Ingot (Innovative improvement of ingot growth)

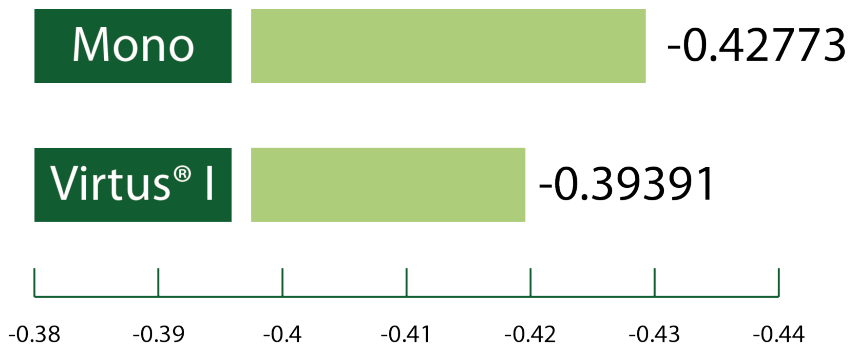
	Mono Wafer	Virtus <sup>®</sup> Wafer
<b>Growth methods</b>	Cz method	Controlled DSS
<b>Nucleation way</b>	Seed growth	Seed growth
<b>Crystalline growth control</b>	Seeding	Controlled nucleation
<b>Cell efficiency</b>	High	High
<b>Oxygen concentration</b>	High	<b>LOW</b>
<b>LID</b>	High	<b>LOW</b>
<b>Production cost</b>	High	<b>LOW</b>

→ Mono-wafer has high efficiency, oxygen concentration which cause high LID due to high recombination B-O complex.

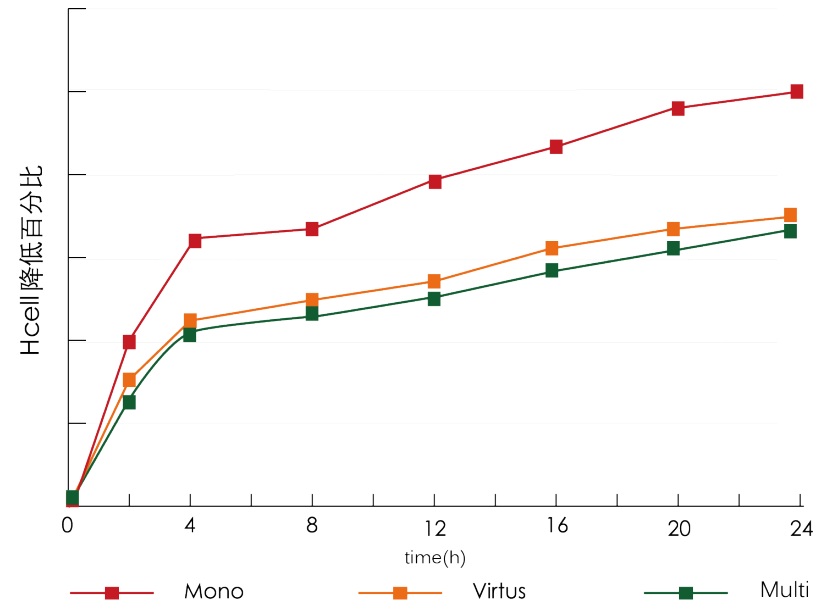
→ Virtus<sup>®</sup> wafer has high efficiency, low oxygen and LID.

# Performance between Virtus<sup>®</sup> I and Mono Cells

Temperature coefficient of power (%/°C)



Light Induced Degradation (%)



- Lower oxygen concentration creates less B-O complex in Virtus<sup>®</sup> wafer
- Lower temperature coefficient of power output.

# Comparison of Module Performance

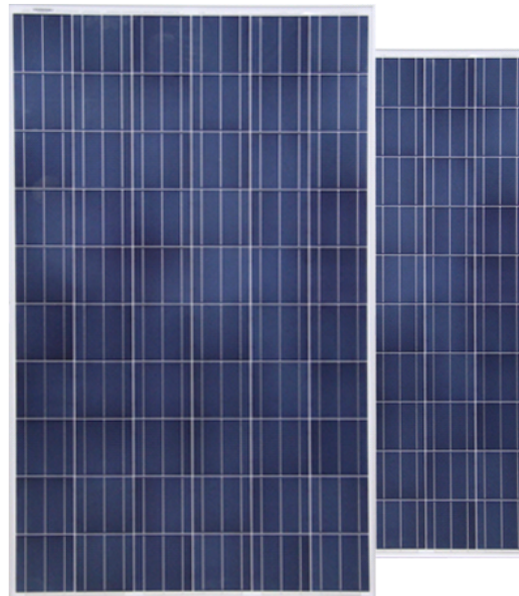
Module level	Mono module	Virtus® I module
Power range (W)	245-260	245-260
Maximum power (W)	260	260
Average power (W)	255	255
Average efficiency	15.7%	15.7%
Power loss (CTM loss)	4.5%	<b>4.0%</b>
Temperature coefficient of power	-0.43%/°C	<b>-0.39%/°C</b>
Light induced degradation (LID)	-3%	<b>-2%</b>
Module cost	High	<b>Low</b>

# Characteristics of Virtus<sup>®</sup> II Module

(Compared to Multi Modules)

- Higher power output
- The same LID
- The same CTM loss
- The same production cost

The logo for Virtus II, featuring a stylized orange sun icon above the word "Virtus" in a green, serif font, followed by "II" in a smaller, green, serif font.



The ReneSola logo, featuring the word "ReneSola" in a green, sans-serif font, with a stylized orange sun icon above the letter "o".



# Comparison between Virtus<sup>®</sup> II and Multi Ingot (Innovative improvement of ingot growth)

	Multi Wafer	Virtus <sup>®</sup> II Wafer
<b>Crystalline way</b>	Seedless	Seedless
<b>Crystalline growth control</b>	Random nucleation	Controlled nucleation
<b>Growth orientation</b>	Random	<b>Preferred</b>
<b>Grain uniformity</b>	Random	<b>Uniform</b>
<b>Production cost</b>	Low	<b>Low</b>

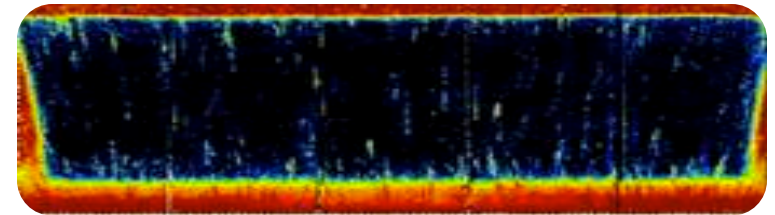
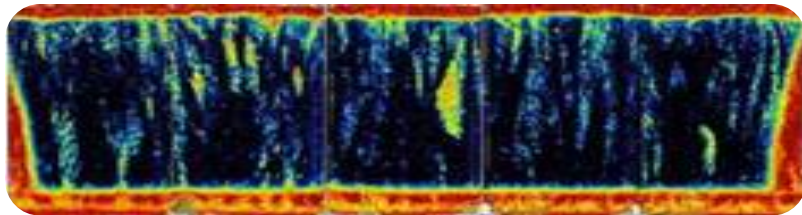
→ Ingot growth modification improves the uniformity of the grain size and preferred orientation.

# Results of Ingot Growth

Conventional multi-ingot



Virtus® II ingot



1. Conventional multi-ingot has disadvantage of poor grain distribution and low-lifetime.
2. Virtus® ingot improves the distribution of grain size and lifetime.
3. Virtus® ingot provides higher lifetime and lower dislocation density.

# Differences of Wafer Appearance



Multi wafer

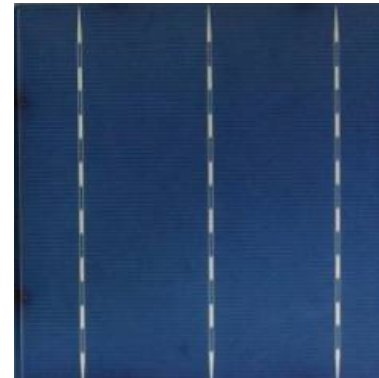
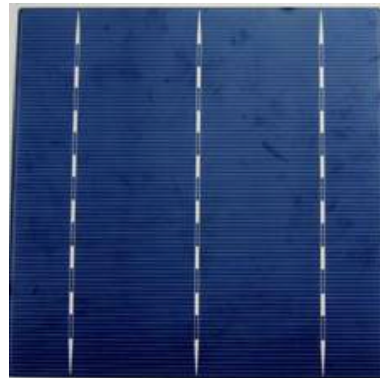
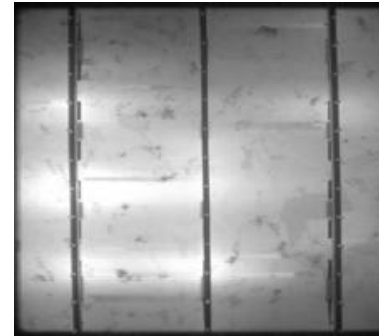
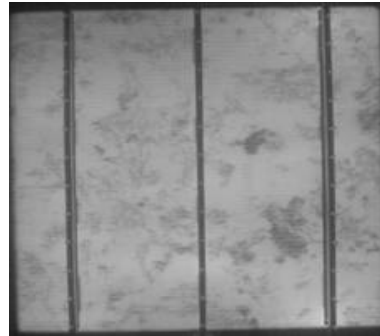
Virtus® A++ wafer

- **Multi-wafer** → Many regions contain dislocation and microcrystalline → Nonuniform distribution
- **Virtus® A++ wafer** → Uniform grain distribution with less defects

# EL images between Multi- and Virtus<sup>®</sup> II Cells

Multi-crystalline cells

Virtus<sup>®</sup> II cells



Efficiency~17.0%

Efficiency~17.6%

- The EL images shows that the multi-crystalline wafer has many defects.
- Virtus<sup>®</sup> A++ wafer has much lower defects.

# Comparison of Module Performance

Module level	Multi- modules	Virtus® II modules
Power range (W)	235-250	<b>250-260</b>
Maximum power (W)	250	<b>260</b>
Average power (W)	245	<b>255</b>
Average efficiency (%)	15.1	<b>15.7</b>
Temperature coefficient of power	Low	Low
Light induced degradation (LID)	Low	Low
Module cost	Low	Low

# Summary

- Major defects of conventional multi-crystalline wafers can be reduced by the innovative controlled DSS method
- Virtus® I module provides lower thermal coefficient of power and light induced degradation compared to mono modules
- Virtus® II wafer increases cell efficiency due to higher lifetime, lower dislocation and uniform grain size.
- Virtus® II module shows better performance and the same production cost of multi module.

Module types	Wattage Range (60 pcs module)	Production Cost	Defect ratio	Appearance
Mono	250-260 W	Higher	lower	Even
Virtus® I	245-260 W	Medium, lower than Mono-	Medium	Uneven pattern
Multi	235-250 W	Lower	Higher	Even
Virtus® II	250-260W	Lower, the same as Poly-	Medium	Even

**THANK YOU**  
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