TAIYANGNEWS
ALL ABOUT SOLAR POWER

Solar Technology Conference India 2026

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Hotel Pride Plaza - Aerocity, New Delhi, India

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TOPCon 4.0, EPD Loss Analysis, Edge Passivation Mechanisms and Equipment Solutions

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2026.02.06

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Jiangsu Leadmicro Nano-Technology Co., Ltd.

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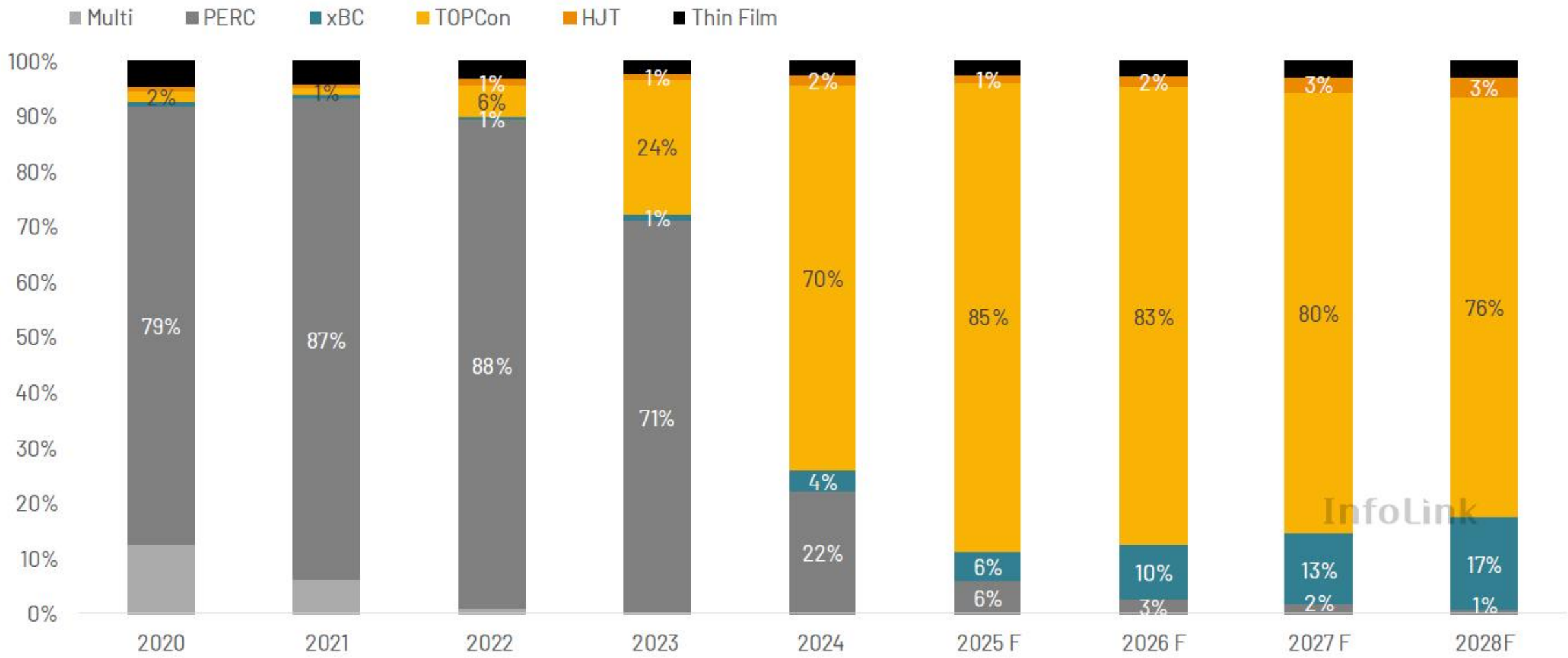
- Recent Progress of Cell Technologies
- TOPCon 4.0 Solutions
- EPD Loss Analysis
- EPD Equipment Solutions
- EPD Future Outlook
- Company Introduction
- Conclusion

01 Recent Progress of Cell Technologies

Trend of Cell Technology

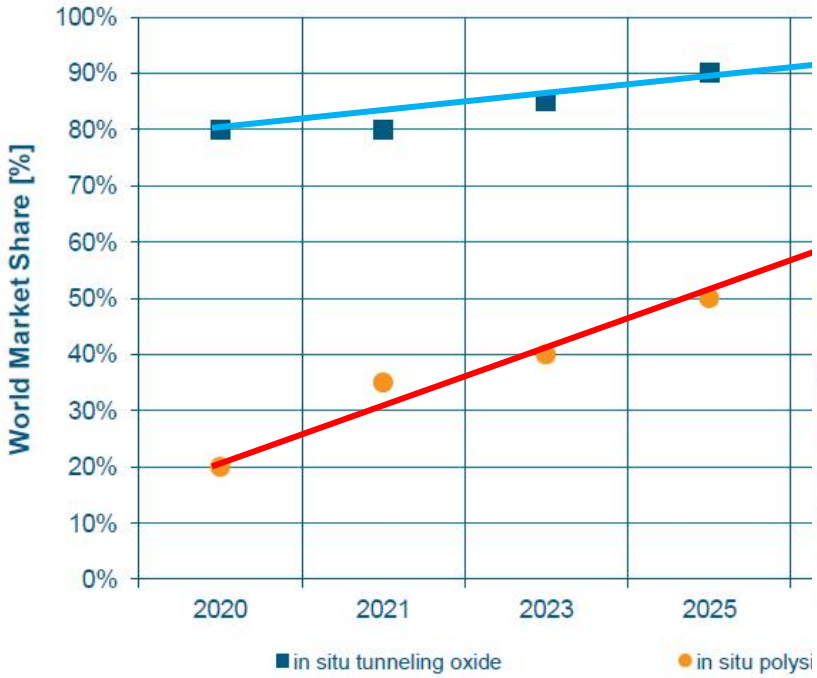
➢ Trend of Cell Technology

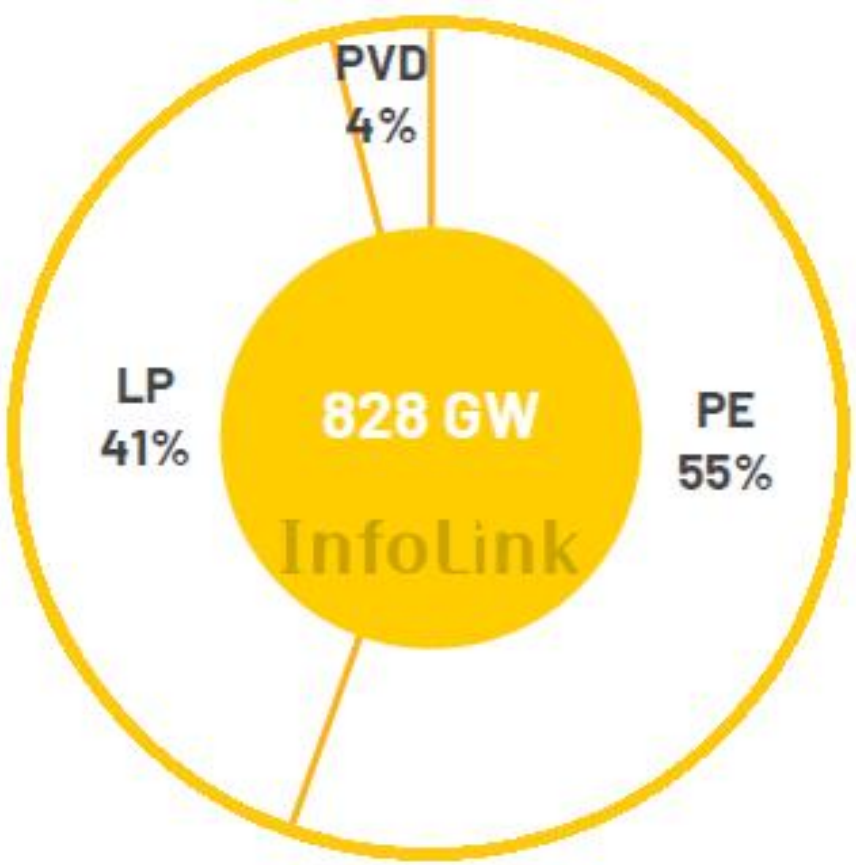


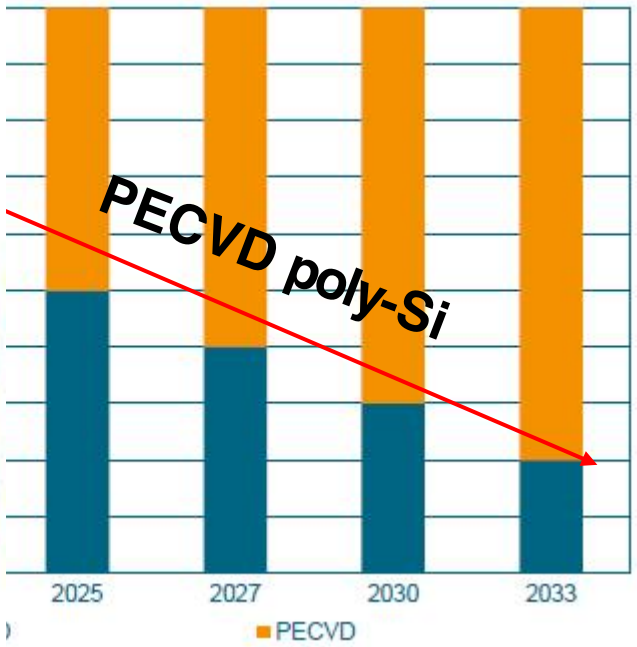
Source: PV InfoLink Report Aug_2026

Trend of TOPCon Cell Technology

- Tunnel oxide and poly-Si: in-situ
- Poly-Si：LPCVD VS PECVD (~ 80%)







ITRPV 2023

Source: InfoLink Report_Aug 2024

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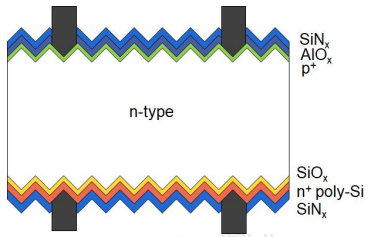
PE-TOPCon Development Milestones

24%

PE-TOPCon 0.0
(Pilot-line)

1. Completed feasibility pilot-line study
2. Solved process & equip. bottlenecks
3. Eta > 24%

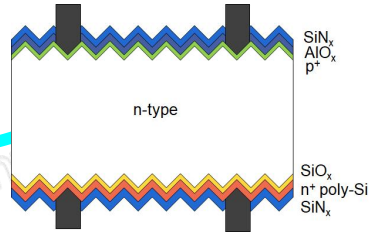


2021.06

26%

PE-TOPCon 1.0
(GW Scale mass-prod. evalu.)

1. Completed 1GW Mass-prod. study
2. Solved Yield bottleneck
3. Eta > 26%, Yield > 97%

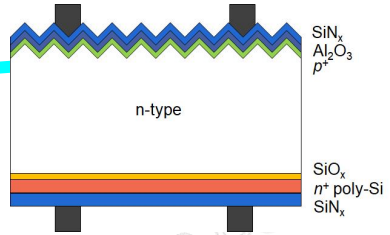


2022.06

26.6%

PE-TOPCon 1.6
(Factory level Mass-prod.)

1. Factory level expansion
2. Solved mass-prod. expansion problems.
3. Eta: rear morphology , anneal opt., screen-printing etc.

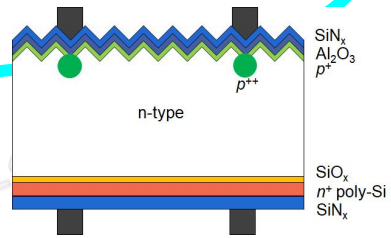


2023.06

26%

PE-TOPCon 2.0
(Mass-prod.)

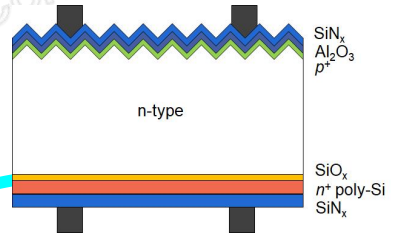
1. Cost: 2% PH3 → 8% PH3 (~3 times↓)
2. Eta : SE, rear opt. polish+paste , Tox+Poly etc.



2023.12

> 26%

PE-TOPCon 3.0
(Mass-prod.)



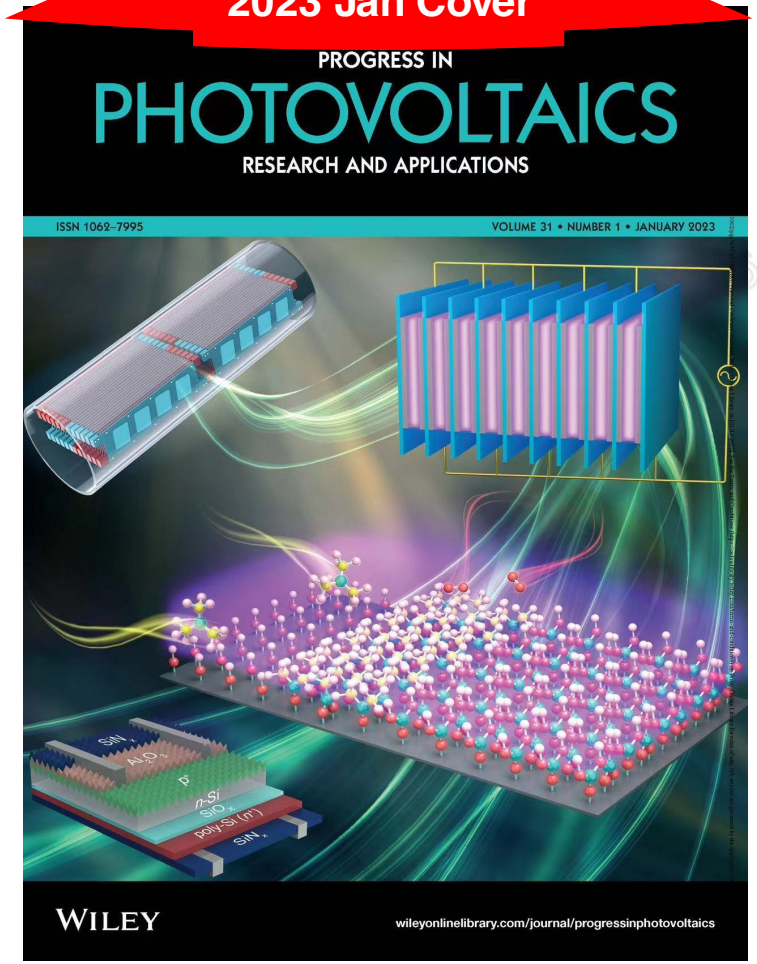
1. Laser assisted firing
2. Front-side opt.

2024.12

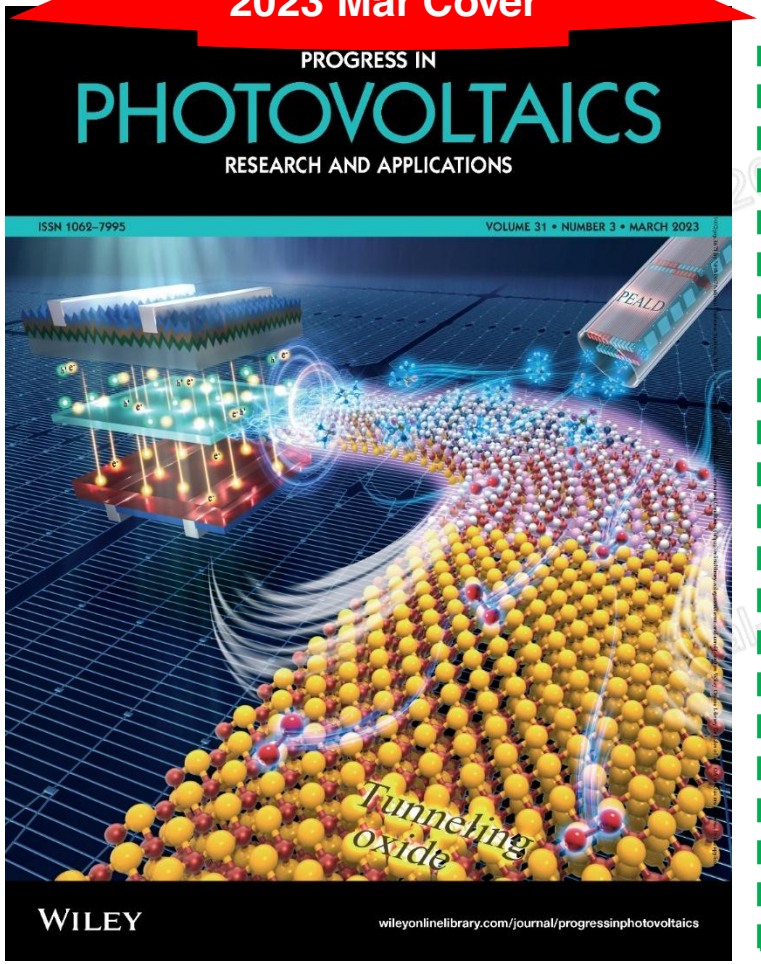
International Impact

- **Selected as PIP featured cover twice**
- **Well recognized internationally (including Europe, US, Lartin, Spain, India etc.)**

2023 Jan Cover



2023 Mar Cover



pv magazine

TOPCon solar cell a… 24.2% efficiency via plasma-assisted ato… deposition tech

A team o… depositic… TOPCon … atomic la… achieve … W TOPC…

OCTOBER

SOLAR NEWS

TOPCON SOLAR CELL ACHIEVES 24.2% EFFICIENCY VIA NEW PLASMA-ASSISTED ATOMIC LAYER DEPOSITION TECH

In Solar News, Sustainability by EISol / 17 October 2022 / Leave a Comment

An international research team has fabricated a tunnel oxide passivated contacts (TOPCon) solar cell through a new technique enabling the control of tunnel oxide deposition at the atomic scale.

The scientists described the proposed method as an innovative tube-type industrial plasma-assisted atomic layer deposition (PEALD) technique. They claimed that it can provide high-quality, dense tunnel silicon oxide (SiOx) films at

TECHNOLOGIE

nonocrystalline PERC solar module

La cellule solaire TOPCon atteint une efficacité de 24,2 % grâce à la nouvelle technologie de dépôt de couche atomique assistée par plasma

Les scientifiques ont décrit la méthode proposée comme une nouvelle technique de dépôt de couche atomique industrielle assistée par plasma (PEALD) de type tunnel. Selon eux, il peut produire des films d'oxyde… qualité, à faible coût et à haut r…

Selon les chercheurs, cette mét… dépôt chimique en phase vapeu… fabrication de modules solaires…

MERCOM clean energy insights

TOPCon Solar Cells Achieve 22.8% Efficiency With Plasma-Aided Atomic Layer Deposition

The tunnel oxide deposition thickness was controlled at the atomic scale for higher efficiency

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Interview – Baochen LIAO, Leadmicro

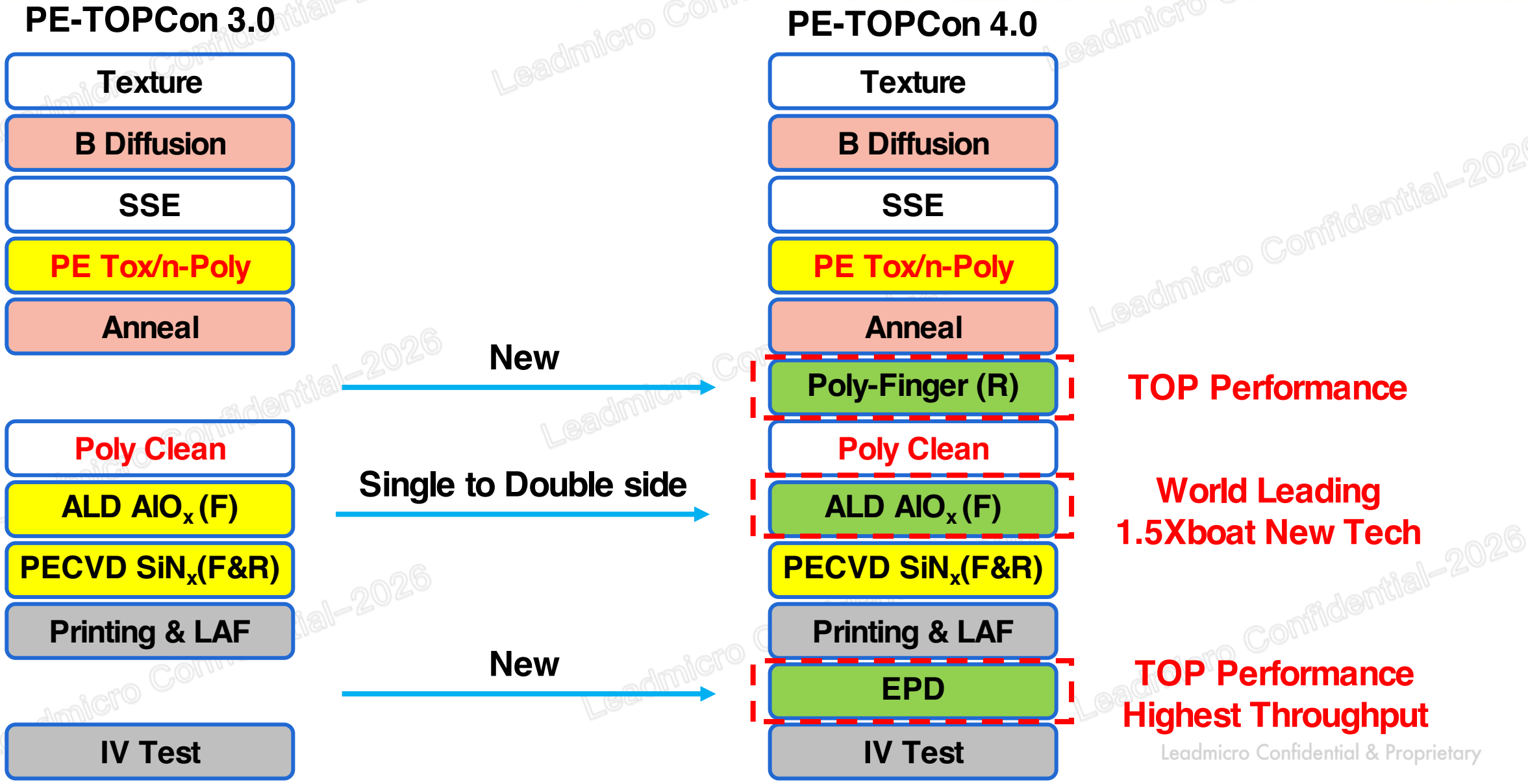
Single sided process with PECVD is the key enabler for TOPCon

…n method wherein they …ultrathin silicon oxide layer of …-Si (n+) interface.

…he tunnel oxide thickness at …ess at the atomic scale for

02 TOPCon 4.0 Solutions

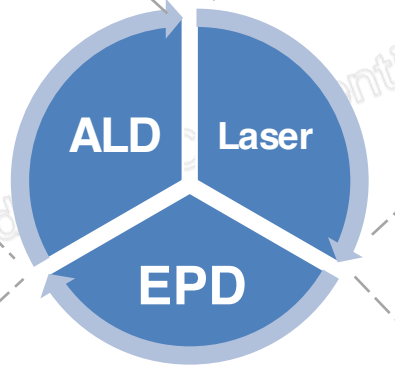
TOPCon 4.0 Solutions



TOPCon 4.0 Solutions

World Leading
1.5Xboat New Tech

TOP Performance



TOP Performance
Highest Throughput

Leadmicro Confidential & Proprietary

2.1 Rear Poly Finger by Laser

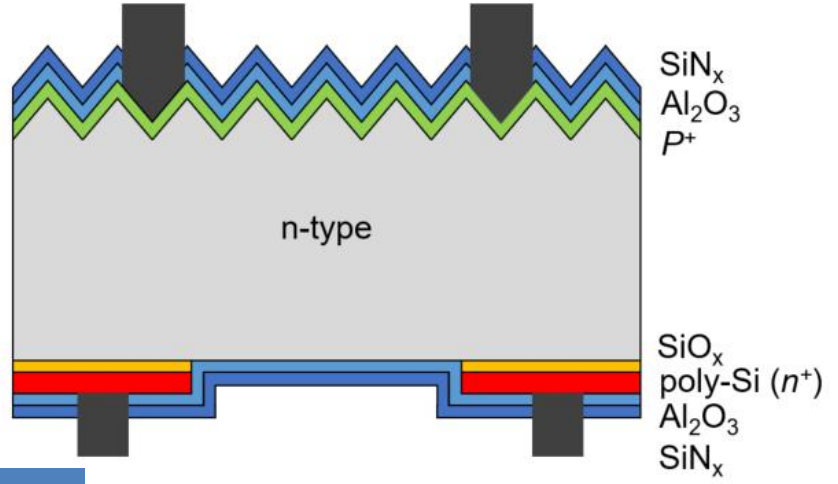
Laser Applications

- Laser Cutting for EPD
- Laser Assisted Firing
- Poly Thinning
- TBC Patterning

Capacity High

210R: 6300-7000 pcs/h

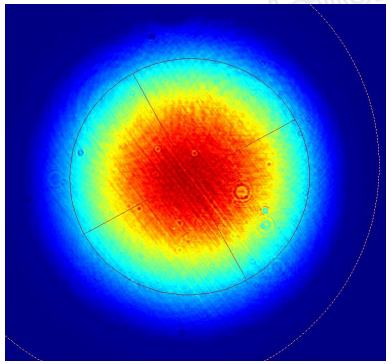
Stability High

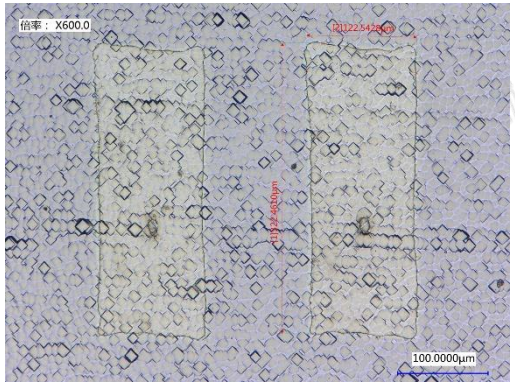


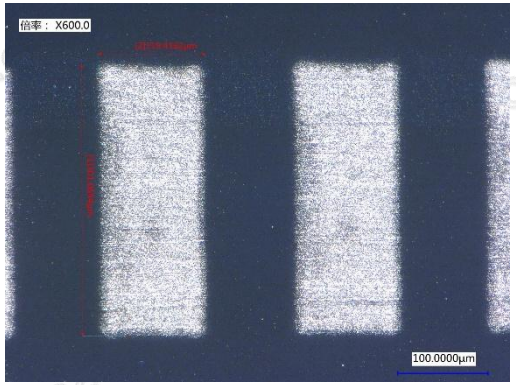
	Eta.
with rear poly finger	0.16% ↑

Laser Source

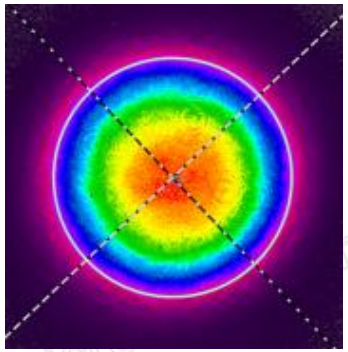
LM Laser:
~110W

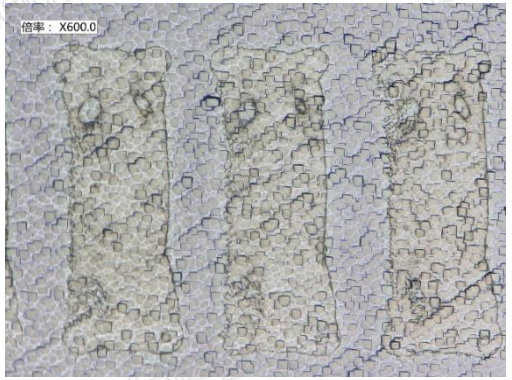


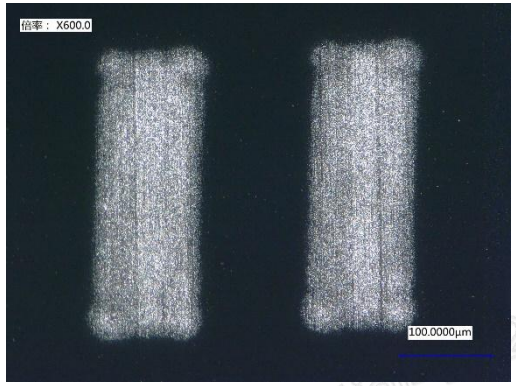




Others:
~100W

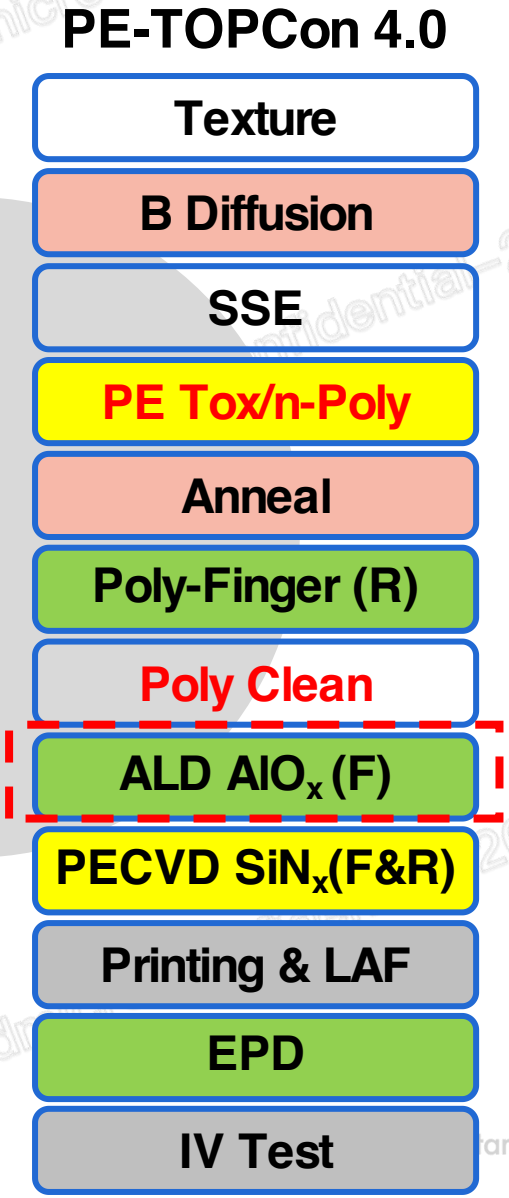






- Laser output power
- Laser spot roundness
- Shaping uniformity

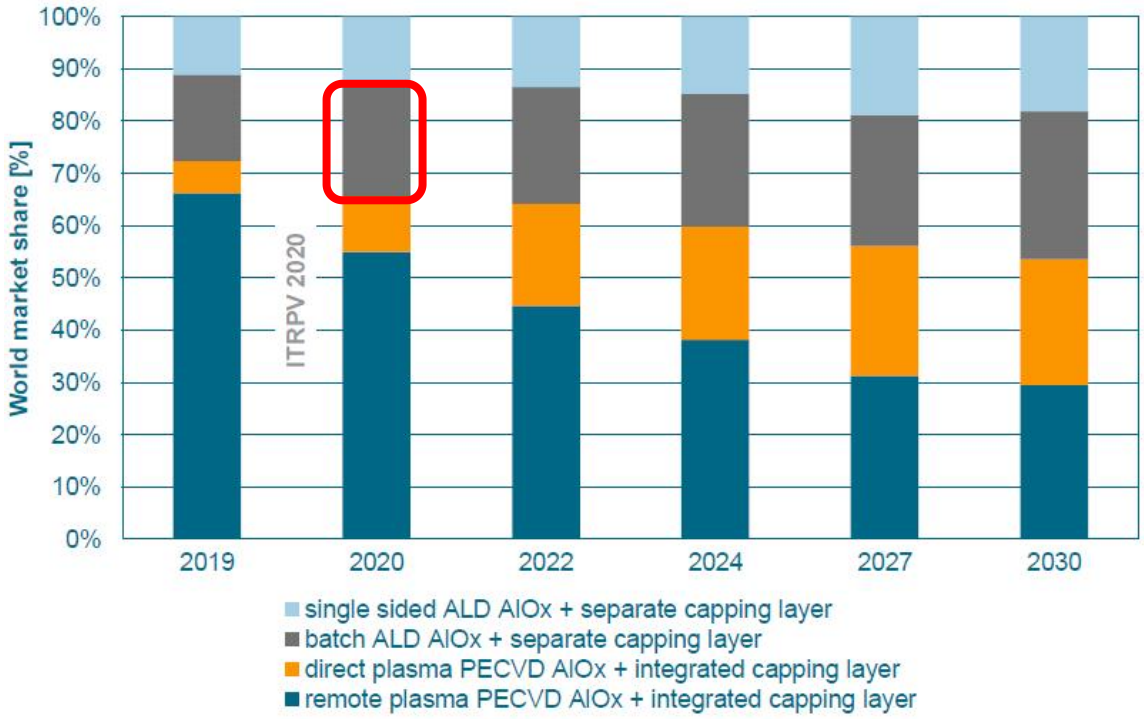
2.2 ALD

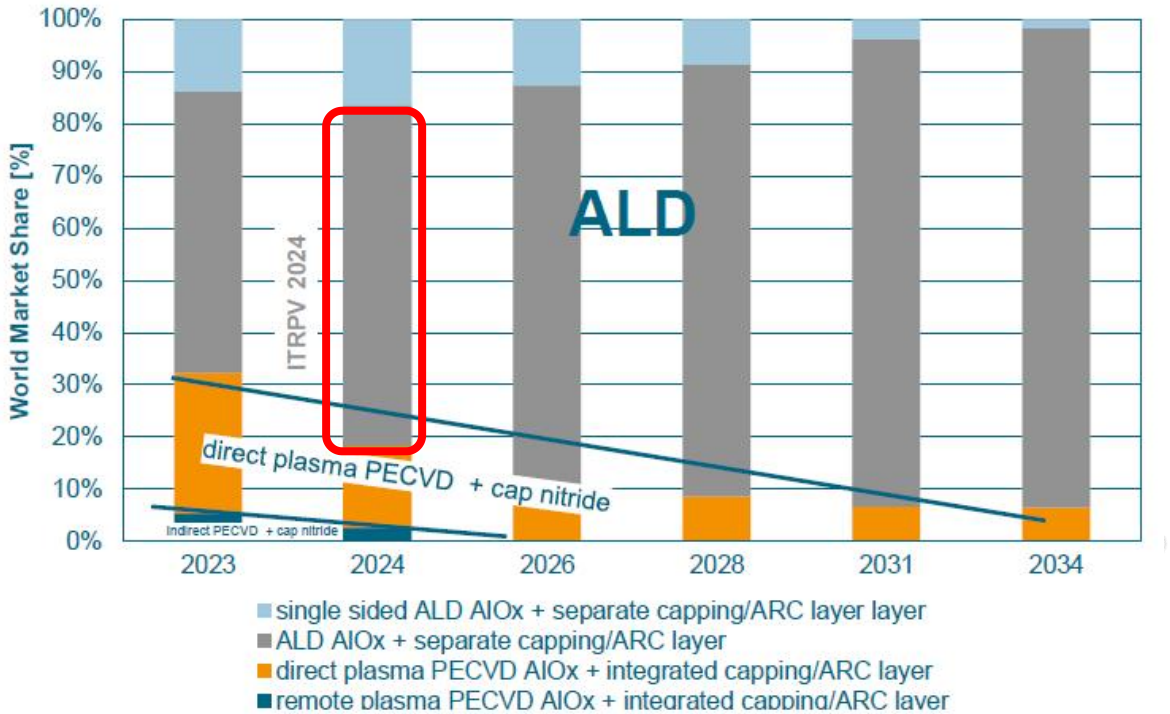


Trend: AlOx Deposition Technology

➢ Trend: AlOx deposition PERC/TOPCon/TBC

2020 VS 2024

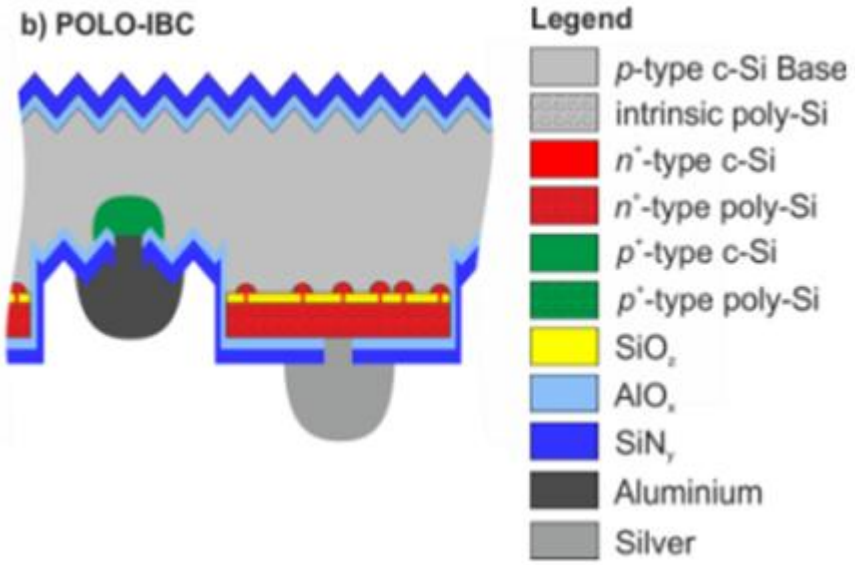




Source: ITRPV 2024

8th Gen. KF20000S Features

➢ TBC, HPBC ALD Al_2O_3 New Requirement: double-side coating



Technology	Batch ALD Al_2O_3	In-line ALD	PECVD two-in-one
Efficiency	☺	☺	☹
Equipment Price	☺	☹	☺
Maintenance Period	☺	☹	😐
Operating Costs	☺	☹	☺
Double-side Coating	☺	☹	☹
Wrap-around	😐	☺	😐

F. Haase, *et al.,* 46th IEEE PVSC, 2019

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KF Tube ALD

Market Share Highest

Capacity Highest

Capacity High

1.5XBoat Tech.
Capacity 50%↑

Unique Design

Each tube work/maint. independently

Uptime High

> 98%

Breakage Low

< 0.03%

Maint. Easy

Less powder

COO Low

Highly Automated

High-eff. Cell Tech.

Standard process for TOPCon, XBC, Perovskite,Tandem cells

Compatibility Good

Compatible with various rectangular size wafers

Publications (Original Works)

2012:

- Solved the bottlenecks for ALD Al_2O_3 from lab to PERC cell commercialization

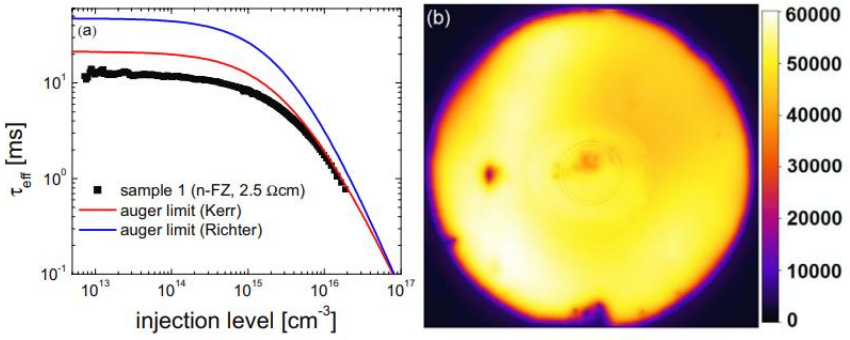


Table 3. A comparison of D_{it} and Q_f for Al_2O_3 under different anneal conditions and deposition methods.

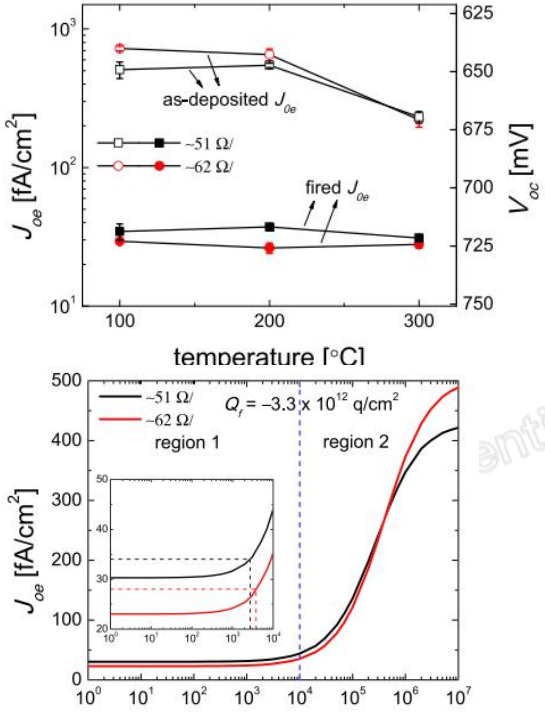
Deposition method	As-deposited D_{it} ($cm^{-2}\,eV^{-1}$)	As-deposited Q_f (q/cm^2)	Anneal condition	Annealed/fired D_{it} ($cm^{-2}\,eV^{-1}$)	Annealed/fired Q_f (q/cm^2)	Ref.
Plasma ALD	$\sim 10^{13}$	$(1–3) \times 10^{12}$	Annealed 400 °C, N_2, 10 min	1×10^{11}	5.8×10^{12}	[9]
O_3-ALD	$\sim 10^{13}$	5.3×10^{12}	Annealed 400 °C, N_2, 10 min	1×10^{11}	3.4×10^{12}	[9]
H_2O-ALD	3×10^{11}	1.3×10^{11}	Annealed 400 °C, N_2, 10 min	1×10^{11}	2.4×10^{12}	[9]
H_2O -ALD	3.3×10^{11}	1.4×10^{12} [a] 8.7×10^{11} [b]	Fired 800 °C (peak), air, 30 s	0.8×10^{11} [a]	3.3×10^{12} [a] 3.9×10^{12} [b]	This work

[a] Obtained by using C–V method.
[b] Obtained by using corona charger method.

B. LIAO, B. Hoex, *et al.,* J. Phys. D: Appl.

2013:

- Proved ALD Al_2O_3 excellent surface passivation for boron surface
- Pave the way for today TOPCon's application



B. LIAO, B. Hoex, *et al.,* J. Appl. Phys., 2013

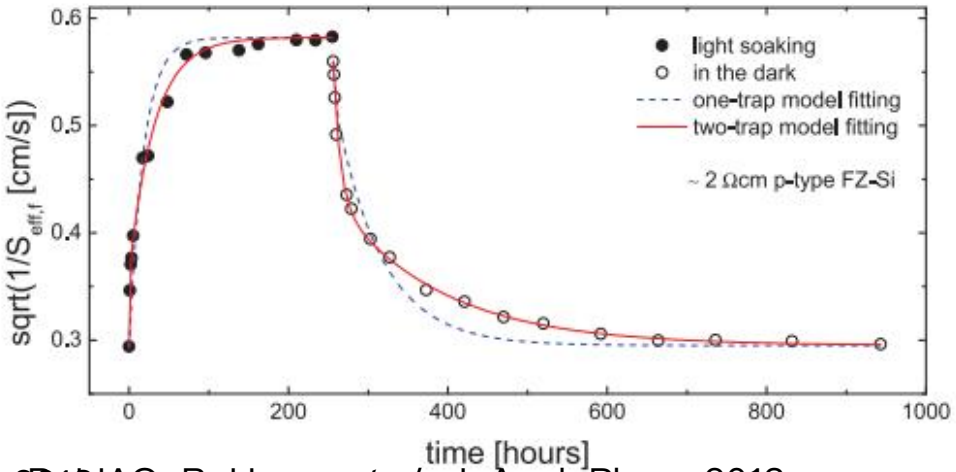
2013:

- Light-soaking mechanisms study

$$\frac{dn_i}{dt} = \frac{n_{0i} - n_i}{\tau_{ti}} - \frac{n_i}{\tau_{di}}$$

$$n_i(t) = \frac{n_{0i}\tau_{di}}{\tau_{ti} + \tau_{di}}\left(1 - \exp\left(-\left(\frac{1}{\tau_{ti}} + \frac{1}{\tau_{di}}\right)t\right)\right)$$

$$\sqrt{\frac{1}{s_{eff}(t)}} = a_o + \sum_{i=1}^{m} a_i\left(1 - \exp\left(-\frac{t}{\tau_i}\right)\right)$$



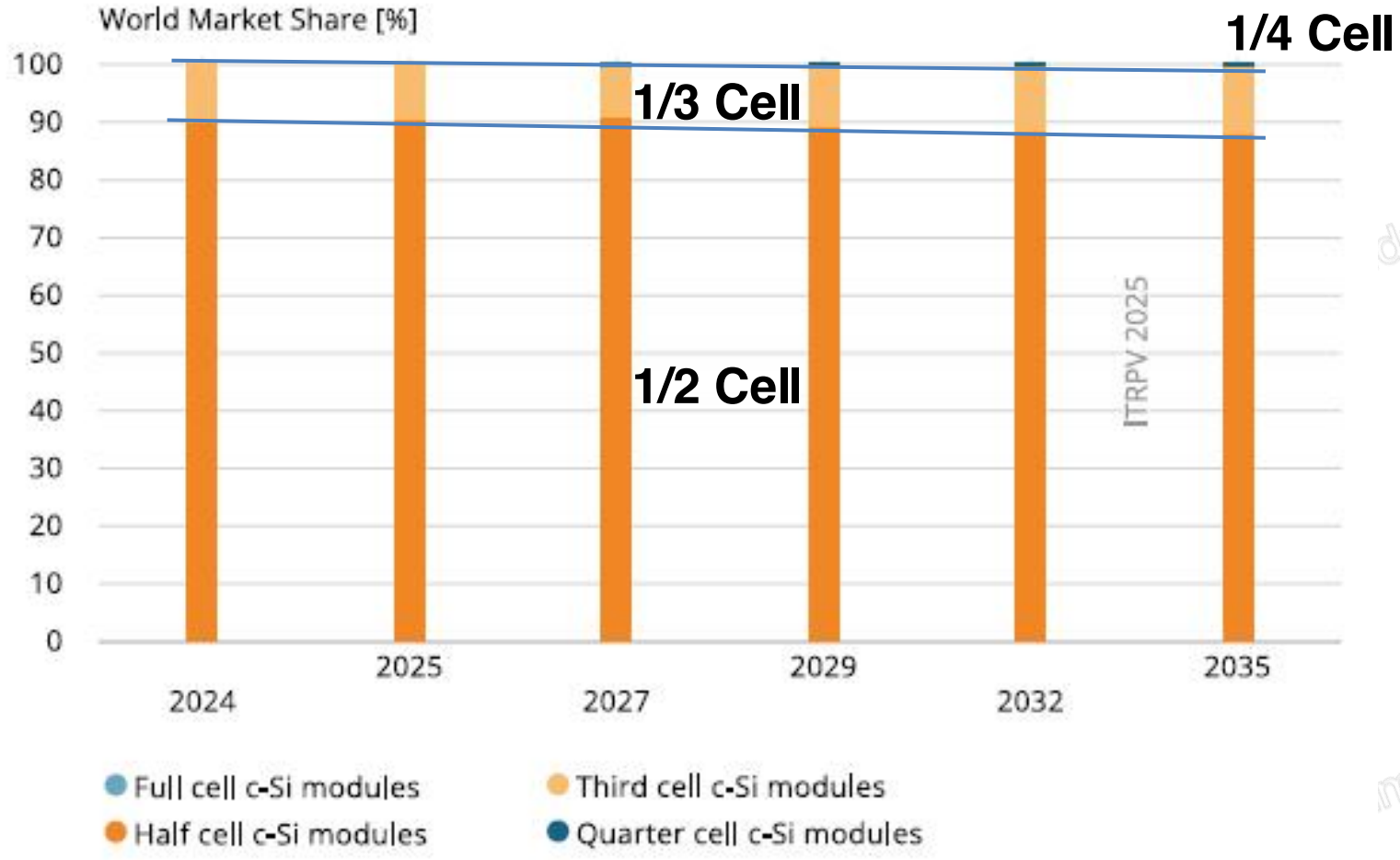
B. LIAO, B. Hoex, *et al.,* J. Appl. Phys., 2013

3.1 EPD

PE-TOPCon 4.0

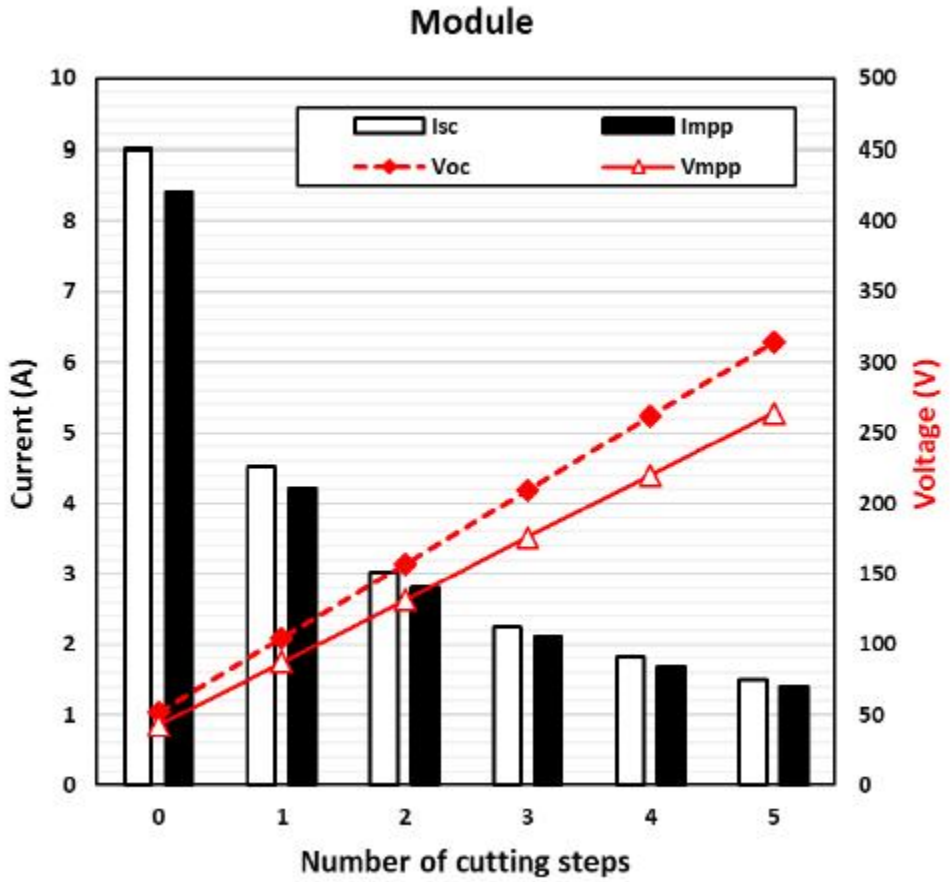
- Texture
- B Diffusion
- SSE
- PE Tox/n-Poly
- Anneal
- Poly-Finger (R)
- Poly Clean
- ALD AlO_x (F)
- PECVD SiN_x(F&R)
- Printing & LAF
- EPD
- IV Test

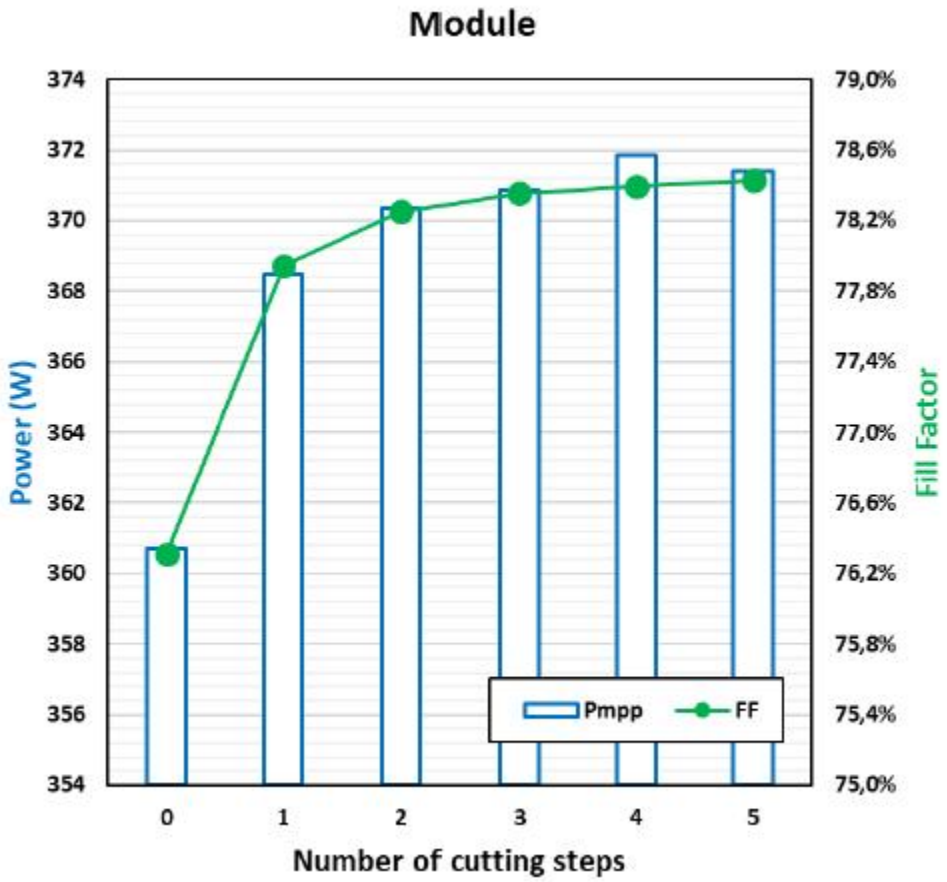
Market Trends (M10 < Wafer Size ≤ G12)



Source: ITRPV 2026

- No. of Cuttings: the more, the better?

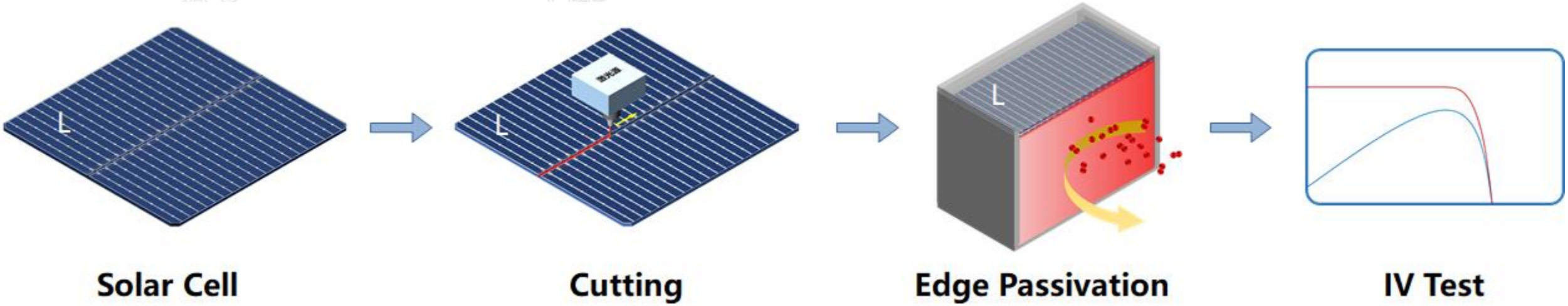




Source: J. Eymard, 2021

EPD Technology Background

- Process flow



Challenges

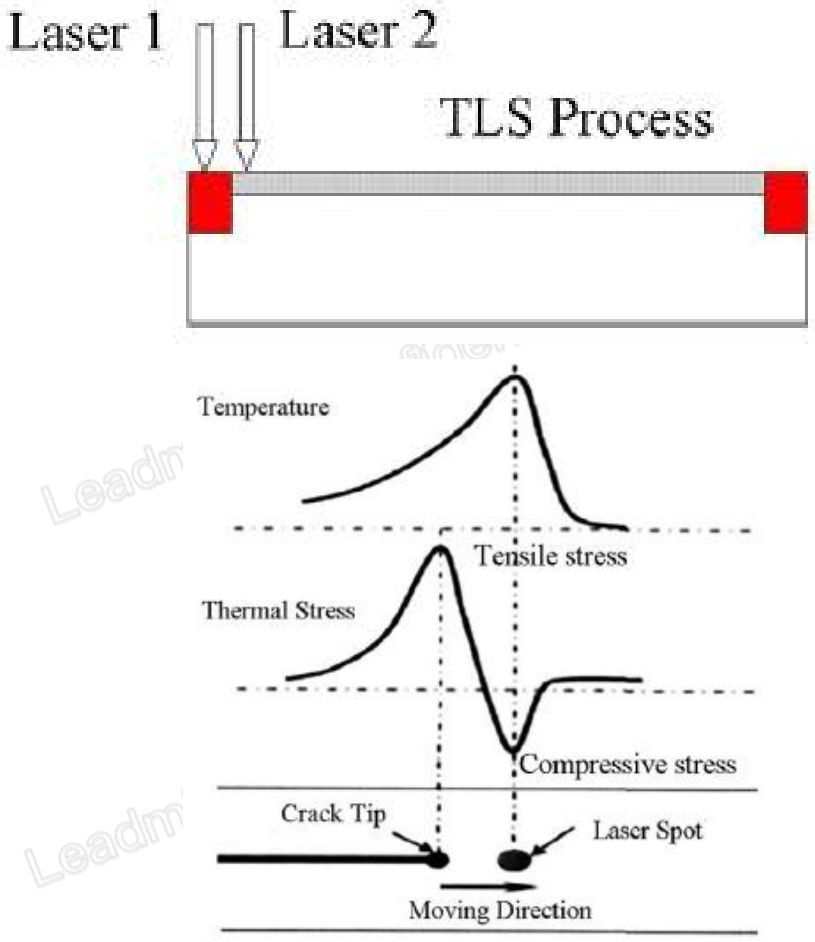
- Damage-free laser cutting ?
- Edge passivation

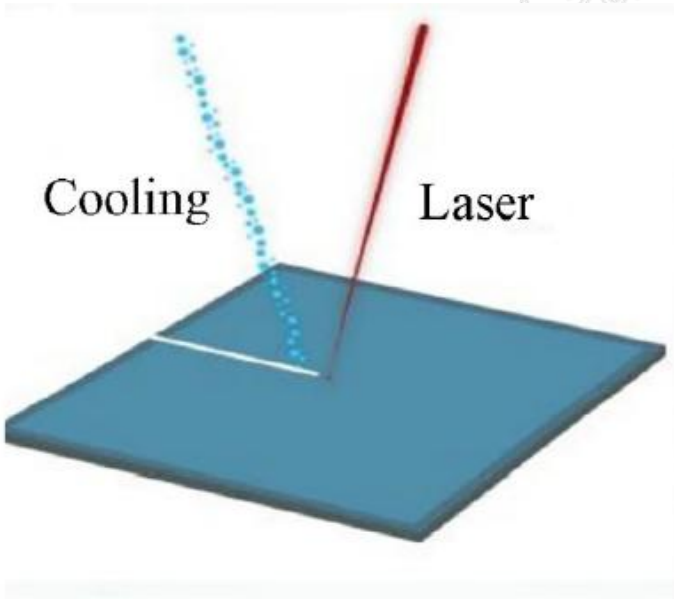
3.2 Cutting Loss Analysis and Edge passivation Mechanisms

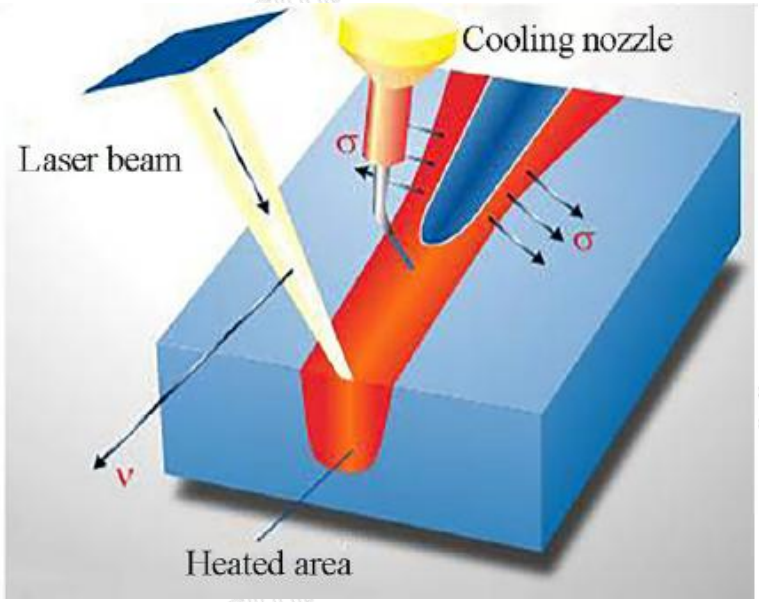
Laser Cutting Principle

Thermal Laser Separation (TLS) Cutting Technology

- Laser Cutting+ "hot" laser sweeping + cooling water → temp. & thermal stress





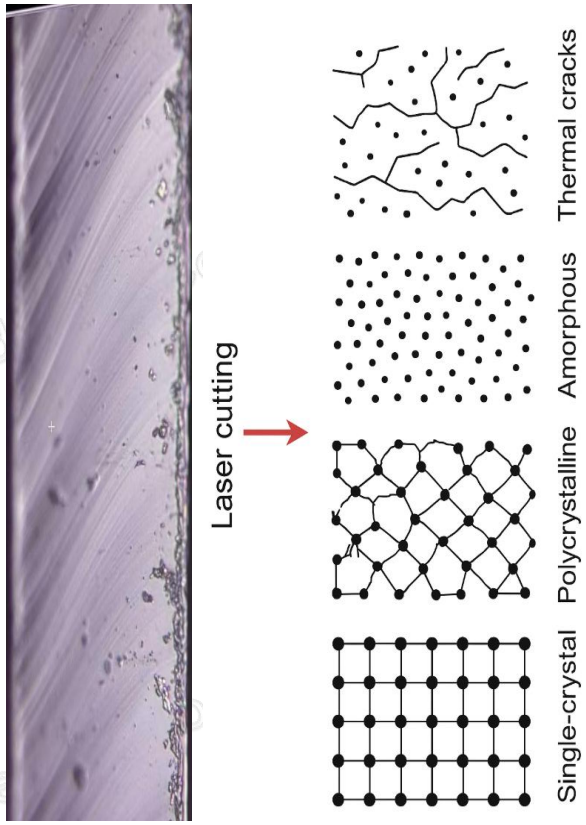


C. Zhang *et al.*, Int J Energy Res. 2022

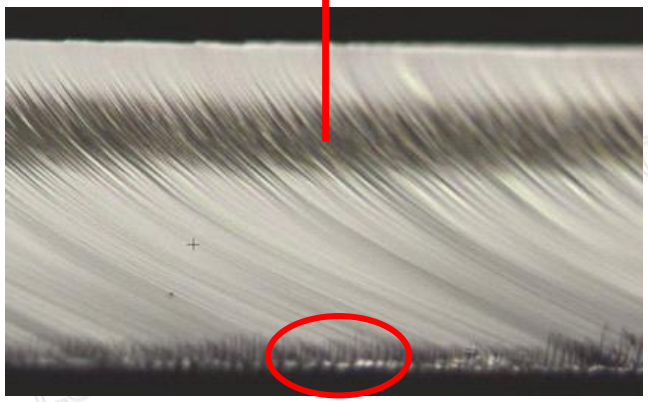
TLS Challenges

TLS Potential Damages

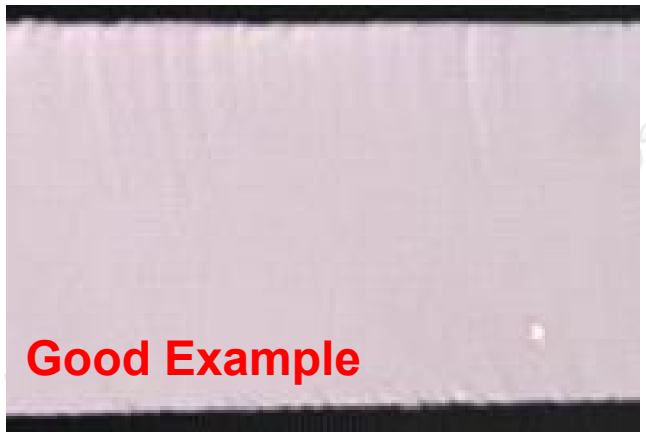
- Thermal damages (e.g. high-temp. melting, thermal cracks)
- Thermal stress (lattice dislocation)
- Dangling bonds
- Debris



uneven break surface
(**can be repaired by ALD**)



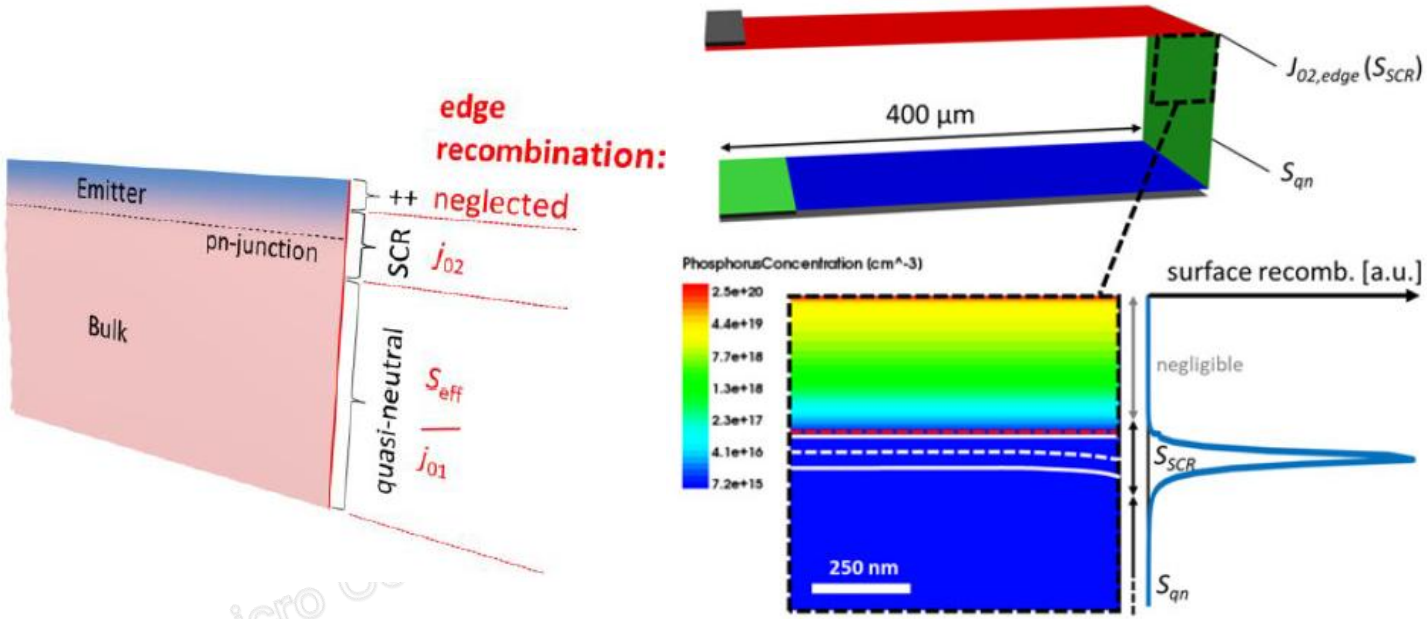
melting (**difficult to repair**)

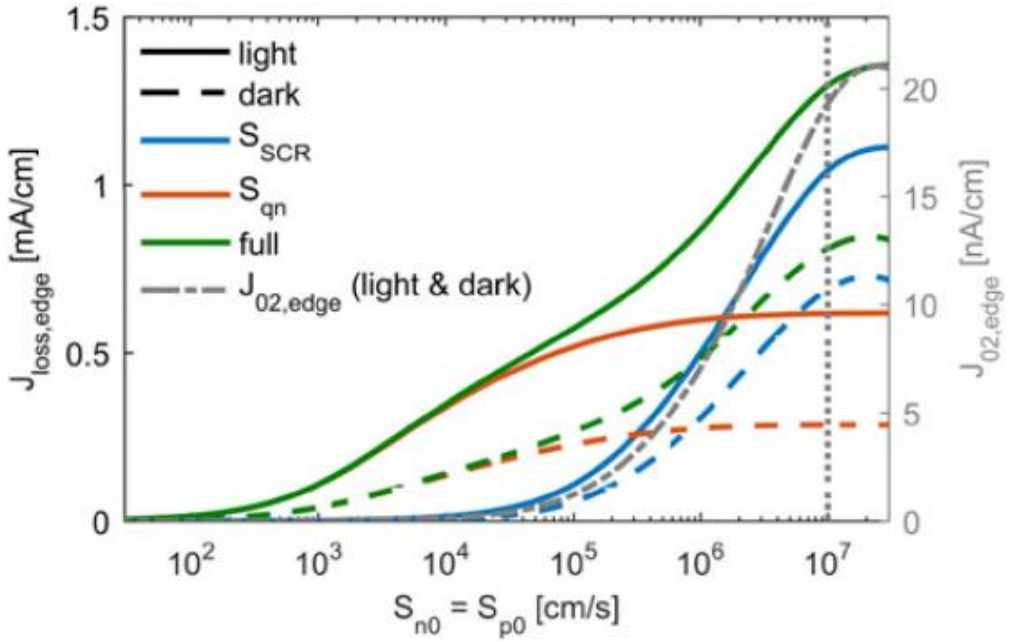


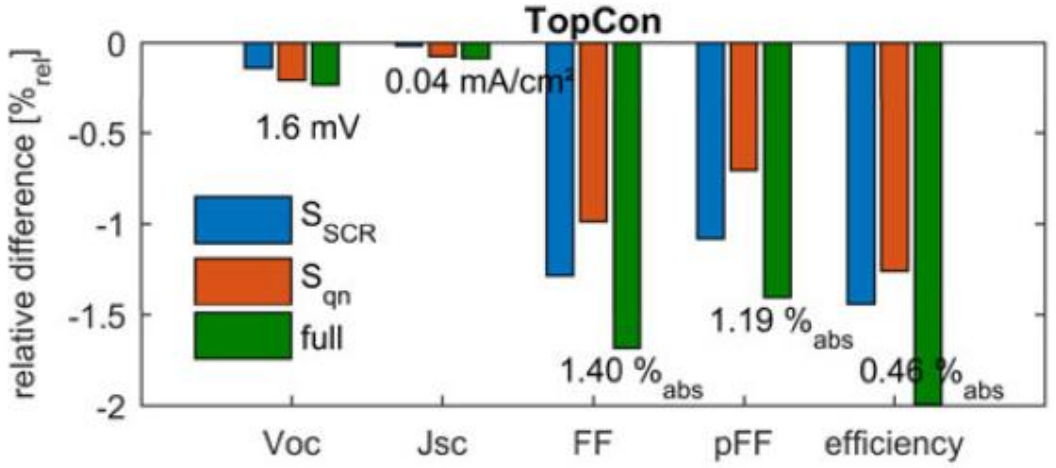
Cutting Loss Analysis

Cutting Loss Analysis (PERC Simulation Data)

- $J_{02,edge}$ dominate，~19 nA/cm，
- Impact pFF and Voc





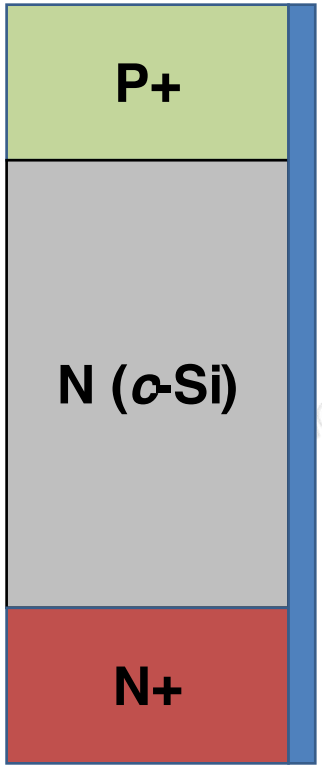


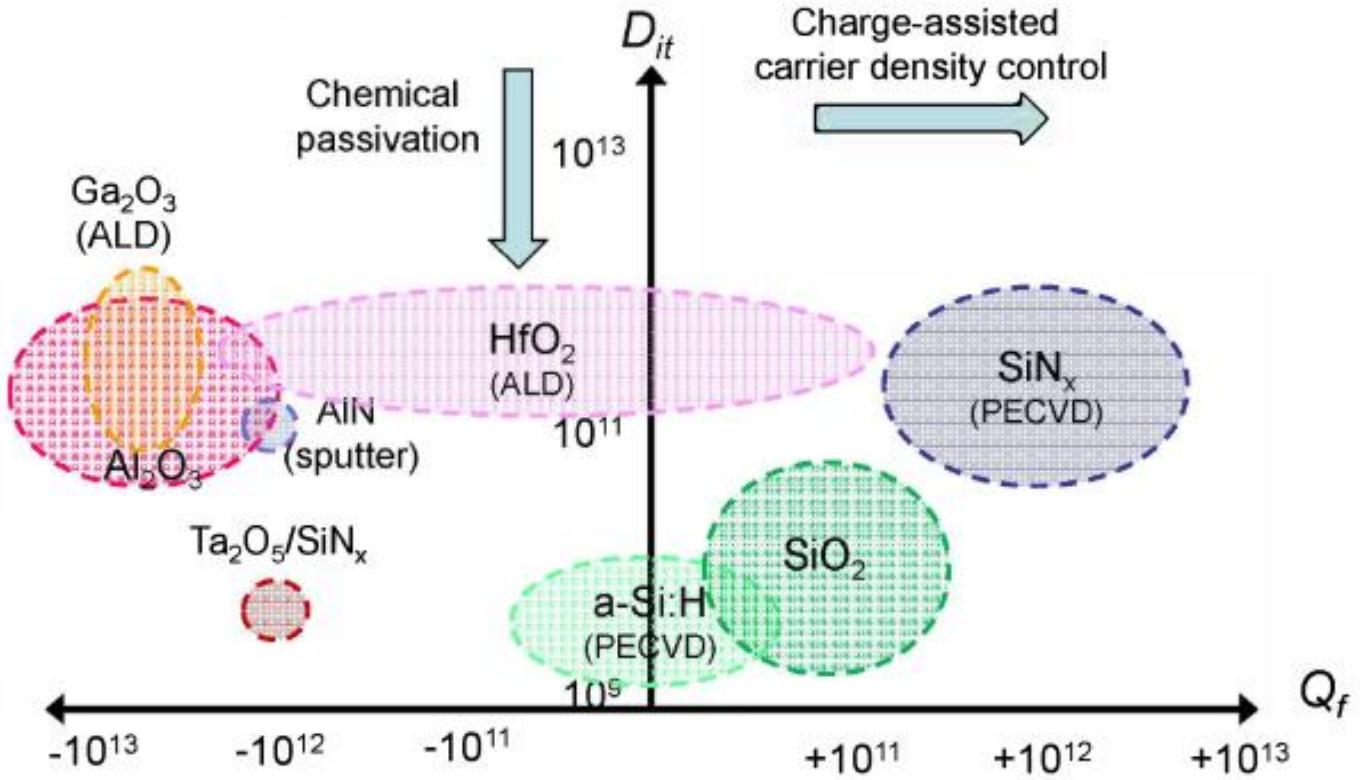
N. Wohrle *et al.,* EUPVSEC, 2017; A. Fell et al., IEEE JPV, 2018

EPD Passivation Mechanisms

Passivation Mechanisms

- Chemical passivation
- Field effect passivation
- H passivation
- Thermal treatment
- Light-soaking treatment





Cuevas *et al.*, 42nd IEEE PVSC, 2016

3.3 EPD Equipment Solutions

Leadmicro EPD Advantages

One-Stop Compatibility

- One-stop compatibility (TOPCon/0BB/Poly Finger/TBC)
- Half, Third, 1/4 Compatible
- M10, G12R , G12
- Cost effective

High Passivation

- Chemical + Field effect + H passivation + thermal + light treatment
- Half > 5 W
- Third > 8 W
- Quarter > 10 W

High Conformality

- Uneven cutting surface (ALD)

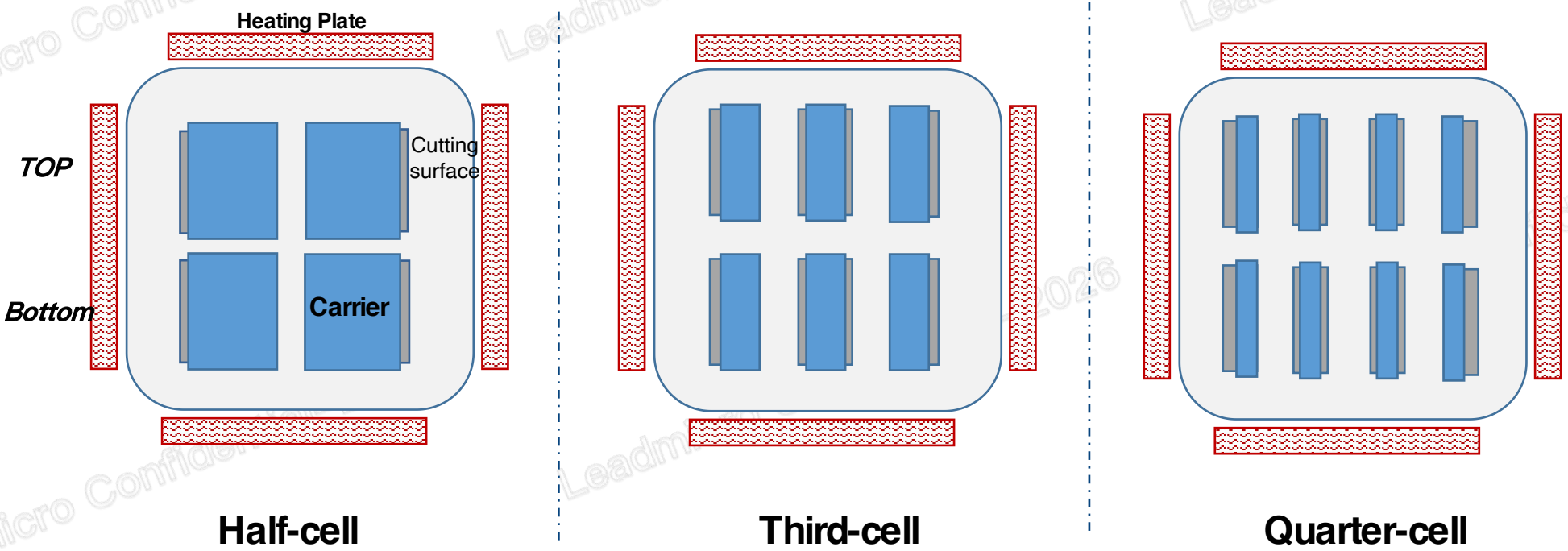
High Throughput

- > 20000 pcs/hr (full cell)

High Stability

- No need frequent maintenance
- Visualized Monitoring
- Mature in Production

Leadmicro Solution: One-Stop Compatibility



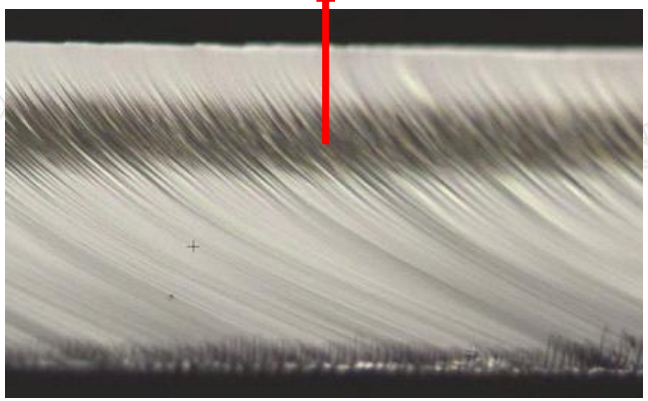
- One-Stop compatibility: TOPCon/0BB/Poly Finger/TBC
- Half, Third, 1/4 Compatible: by changing carriers
- M10, G12R , G12 Compatible

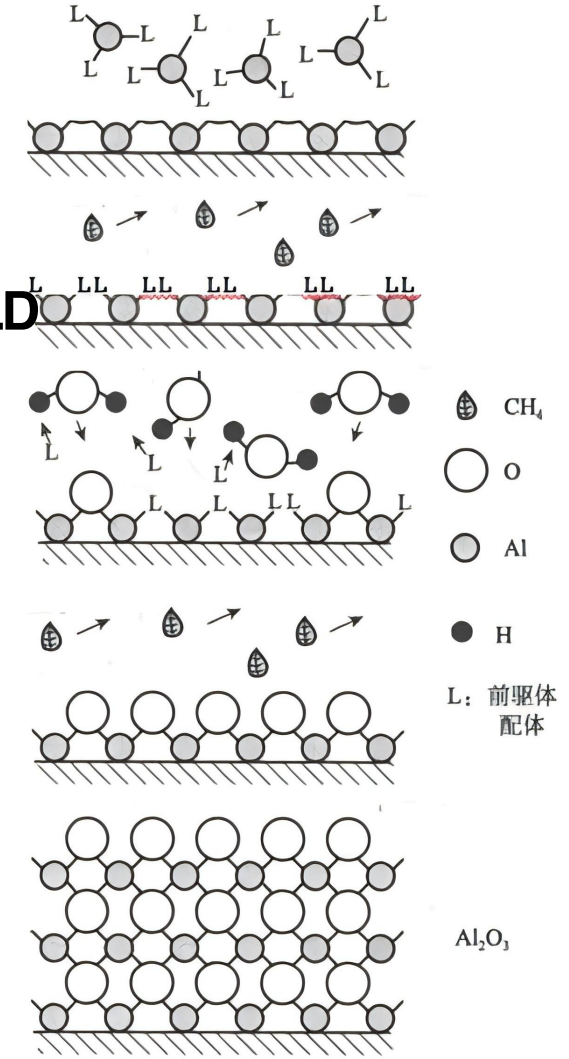
Leadmicro Solution: High Passivation

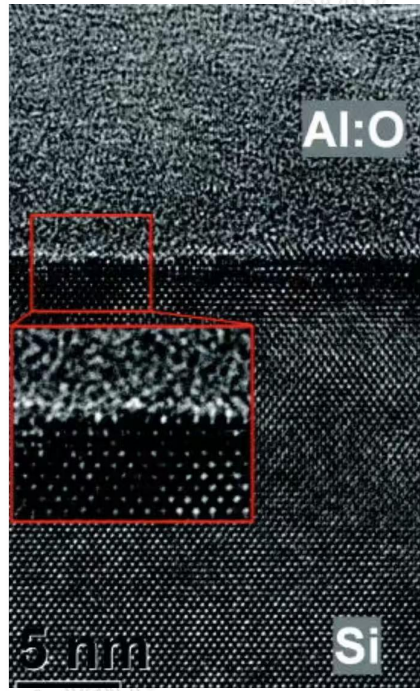
Leadmicro Solutions: **Chemical + Field-effect + H Passivation + Thermal + Light treatments**

- **Tube ALD: High film density → Good D_{it}**
- **AlO_x: High neg. Q_f → Good Field-effect, esp. P+layer**
- **Interface Treatment: "step1-OH pretreatment"+"step2-ALD Al_2O_3" → Eta ~0.03%↑**
- **High conformality → Excellent for uneven surface**
- **Half-cell > 5 W**
- **Third-cell > 8 W**
- **Quarter-cell > 10 W**

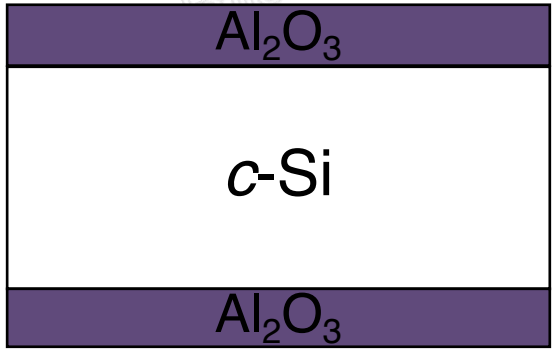
uneven break surface (**can be repaired by ALD**)



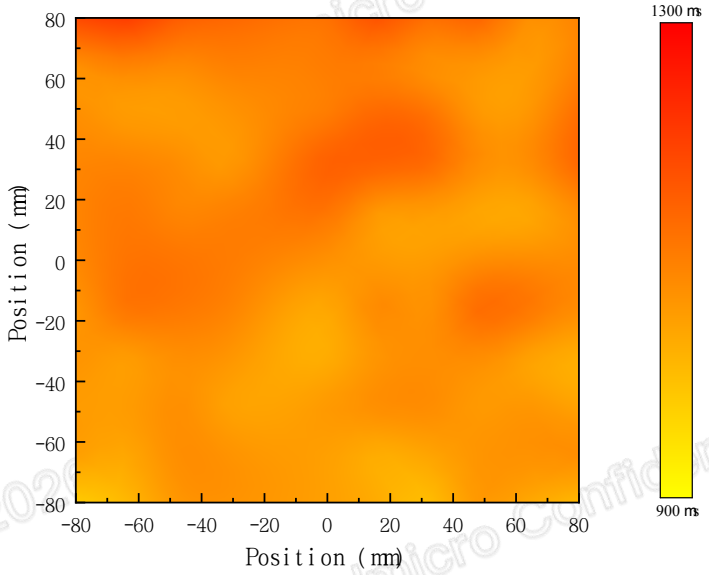




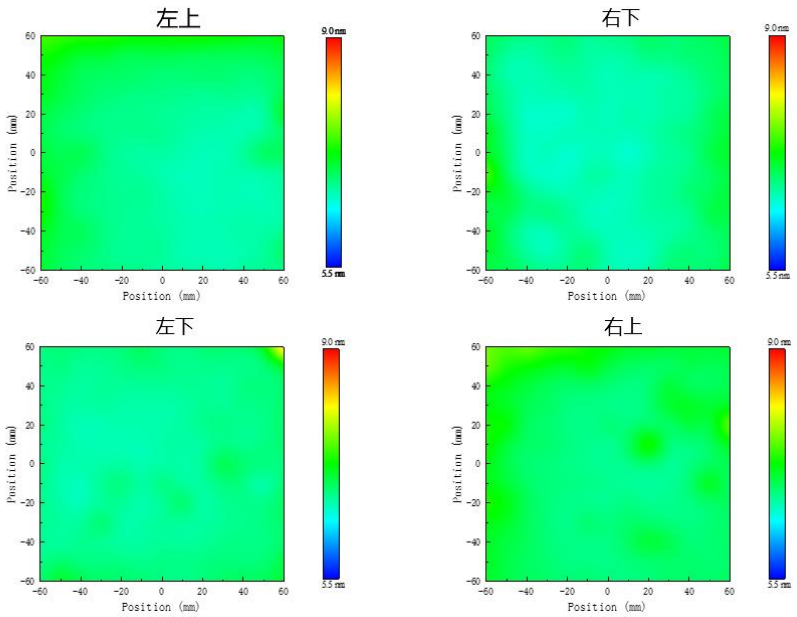
Film Thickness and Passivation Monitoring



■ Monitoring Sample



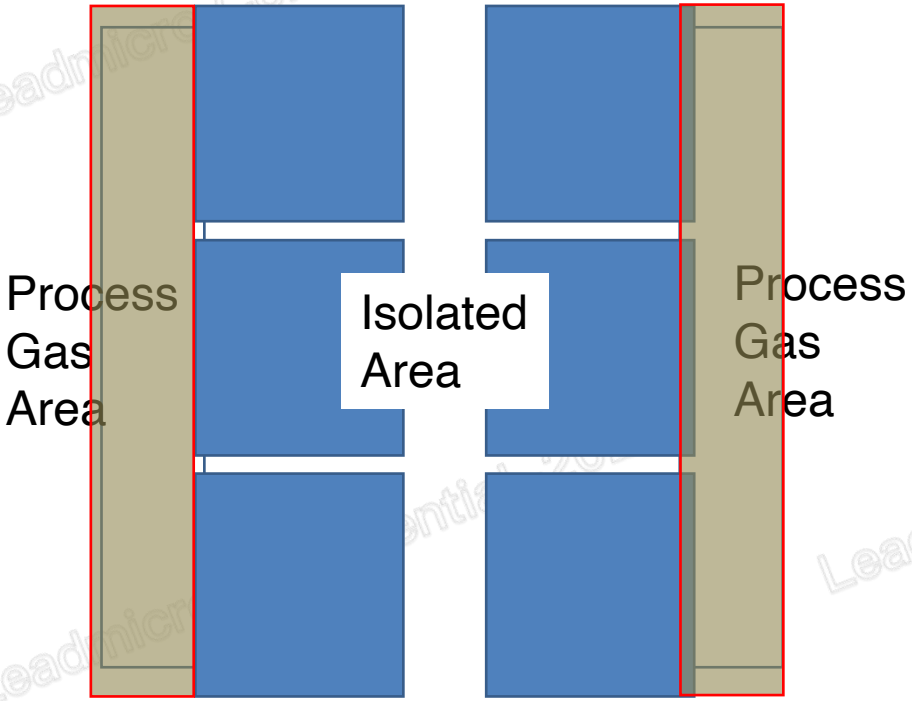
■ Passivation Uniformity



■ Thickness Uniformity

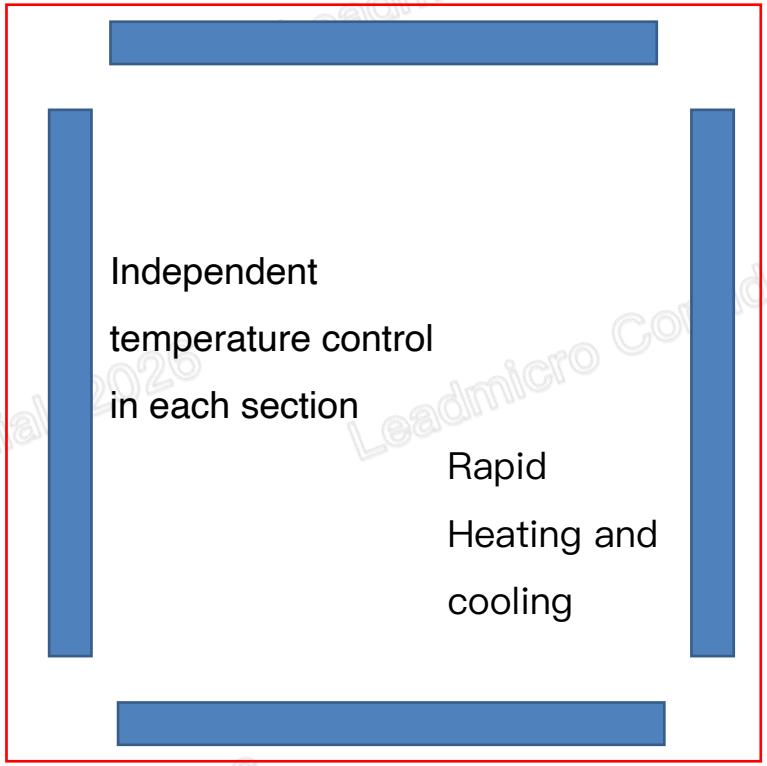
- Live Visualized Monitoring: monitor equipment/process stability while production
- Passivation Avg. Lifetime > 760μs;
- Film thickness: WIW < 3%, WTW < 3%;

Equipment Features: Tailored Temp.and Gas Flow Design



Completely New Gas Flow System Design

- **Low chemical consumption**
- Individual gas line control system



Unique Temp. Field Design and Control System

- **Better passivation performance**
- **Avoid wafer stick issue**

3.4 Future Outlook

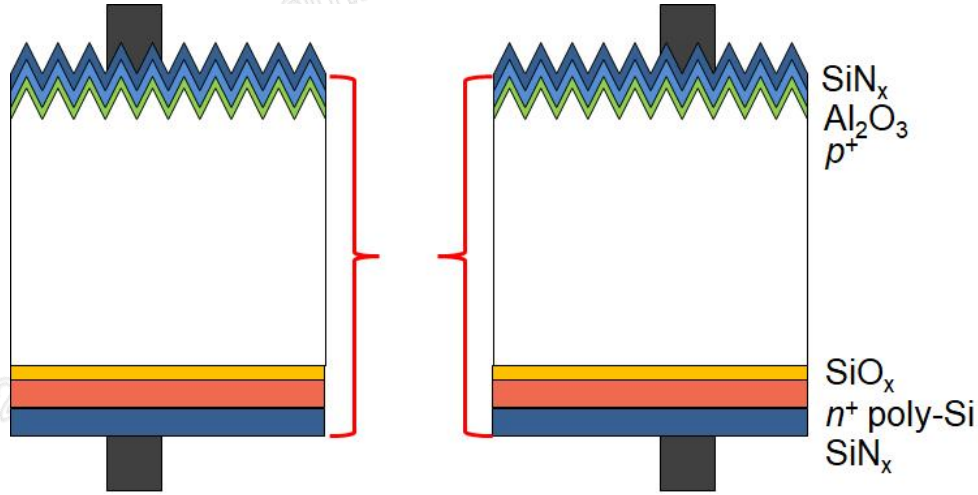
EPD Product Highlights

Leadmicro AEPD 1.0 Tech.

TMA + H2O

Wrap-around

< 3mm

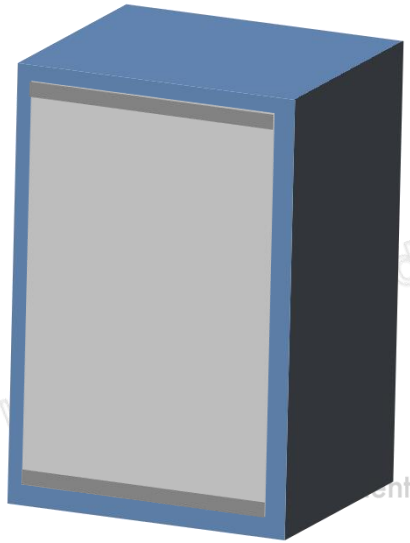


Leadmicro AEPD 2.0 New Tech.

TMA + O3

Wrap-around

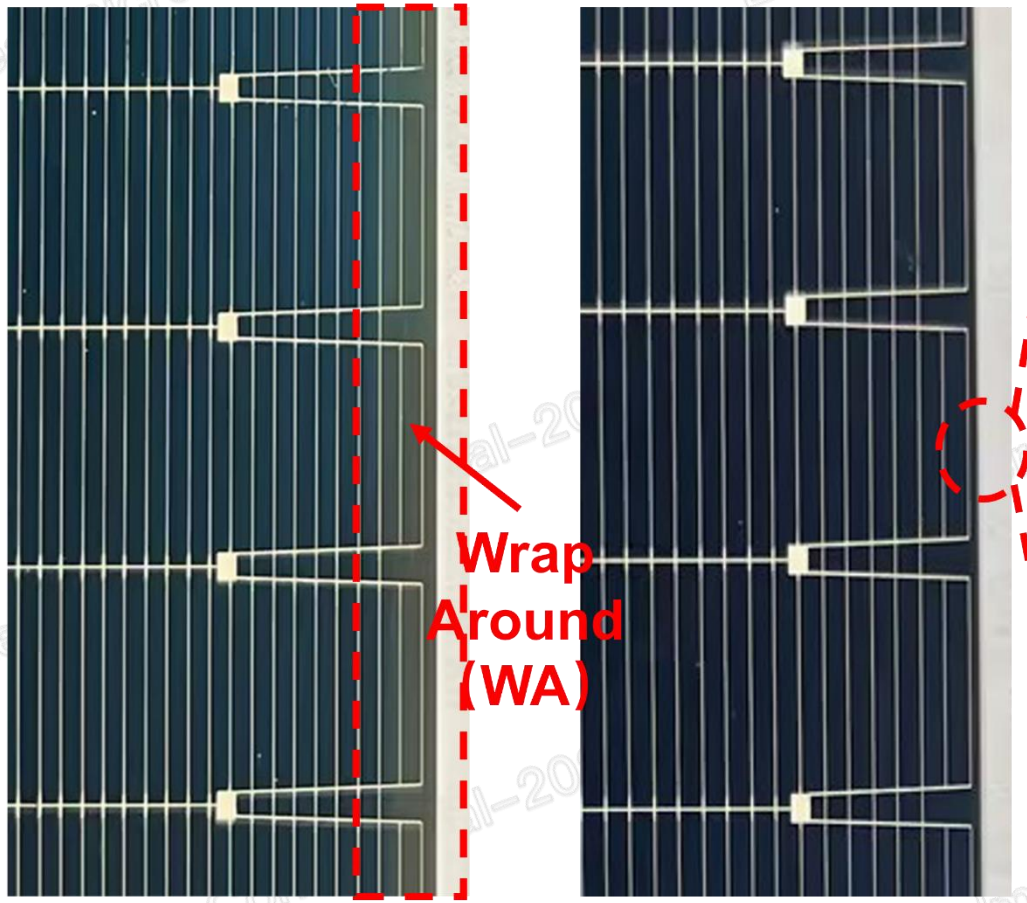
< 0.01mm



Wrap-around EPD 2.0 New Tech.

EPT 1.0 Tech.

EPT 2.0 New Tech.

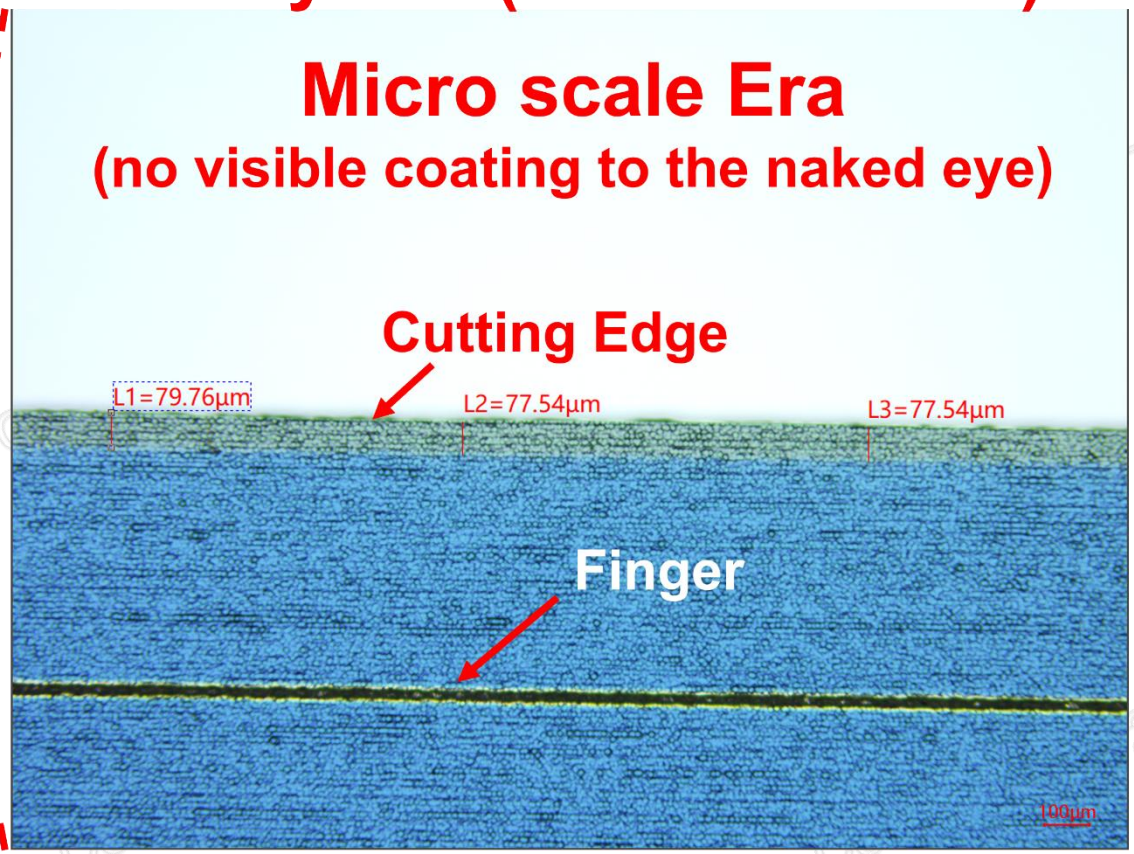


WA > 3 finger lines
Visible

WA << 1 finger line
Not Visible

400 cycles (WA < 0.01 mm)

Micro scale Era
(no visible coating to the naked eye)



04 Company Introduction

About Leadmicro

One of the world largest ALD company

- World 1st IPO company with ALD core technology
- >2000 employee with >36% R&D staff
- >20% R&D expenditure (> 20M USD in 2023)

No.1 ALD provider for PV industry in the world

- >3000 ALD reactors delivered
- >800 GW capacity cumulatively

No.1 ALD provider in SEMI industry in China

- >100 delivered/to be delivered ALD systems
- >300% rapid growth in 2023
- Only production proven supplier of 300mm ALD tool in China

半导体 Semiconductor

光伏 Photovoltaics

新能源 New Energy

新材料 New Material

产业化应用中心 IAC

Intellectual Property

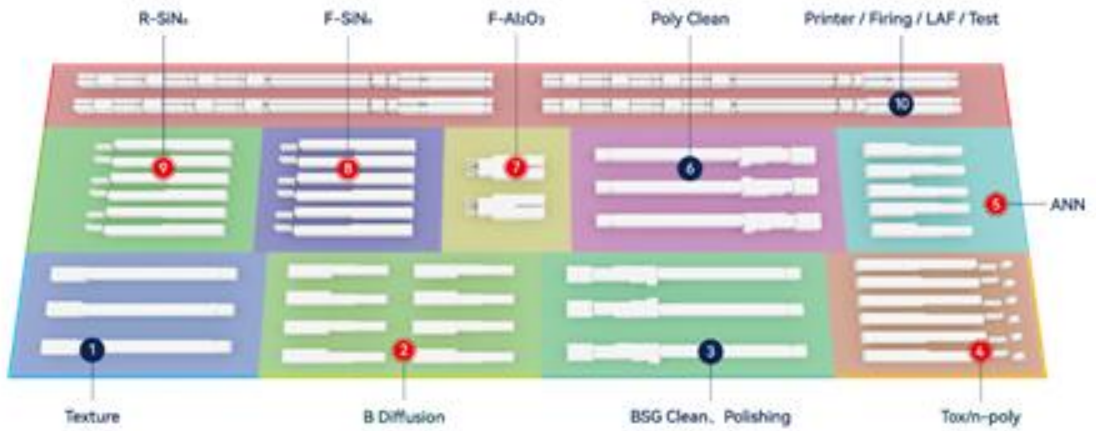
- The intellectual property across China, United States, continental Europe, Japan, Germany，India，South Korea and other countries and regions.
  - Patent Application ＞760；
  - Granted IP ＞230；
  - Proprietary Technologies ＞3,000；
  - Global Registered Trademarks ＞110.

The number of patent applications maintains a stable growth, with invention patent applications accounting for more than 60%.

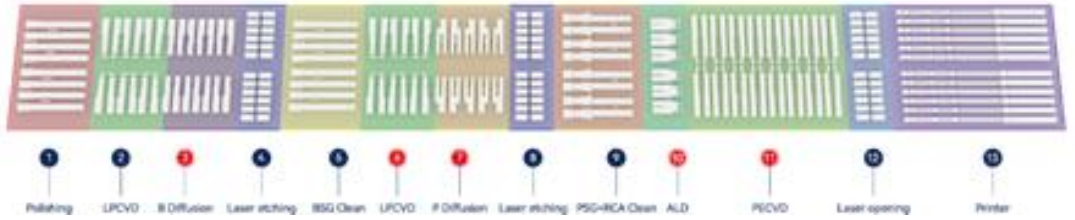
The IP conversion rate exceeds 80%, of which the industrialization rate of the company's effective invention patents exceeds 76%

Leadmicro PV Turnkey Solutions

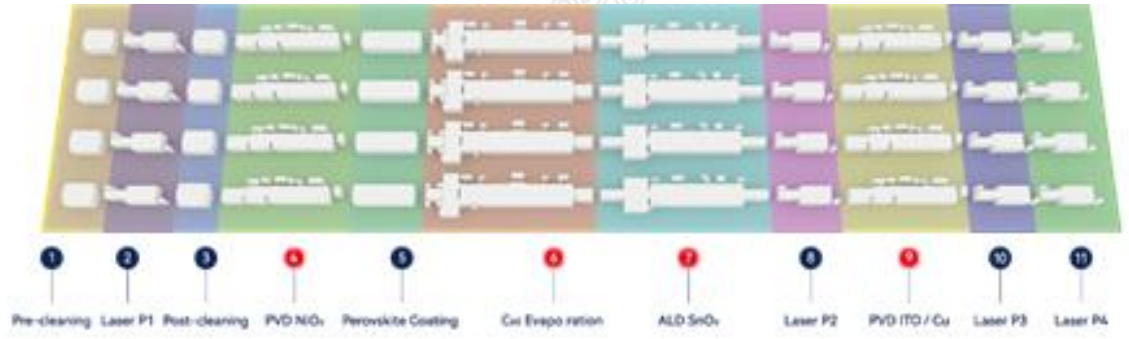
PE-TOPCon 4.0 Turnkey Solution



TBC Turnkey Solution



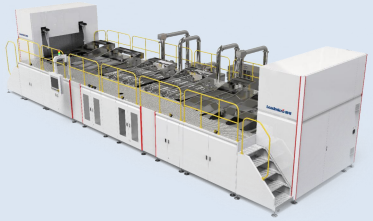
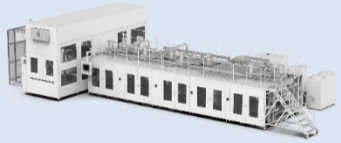
Perovskite/Tandem Turnkey Solution



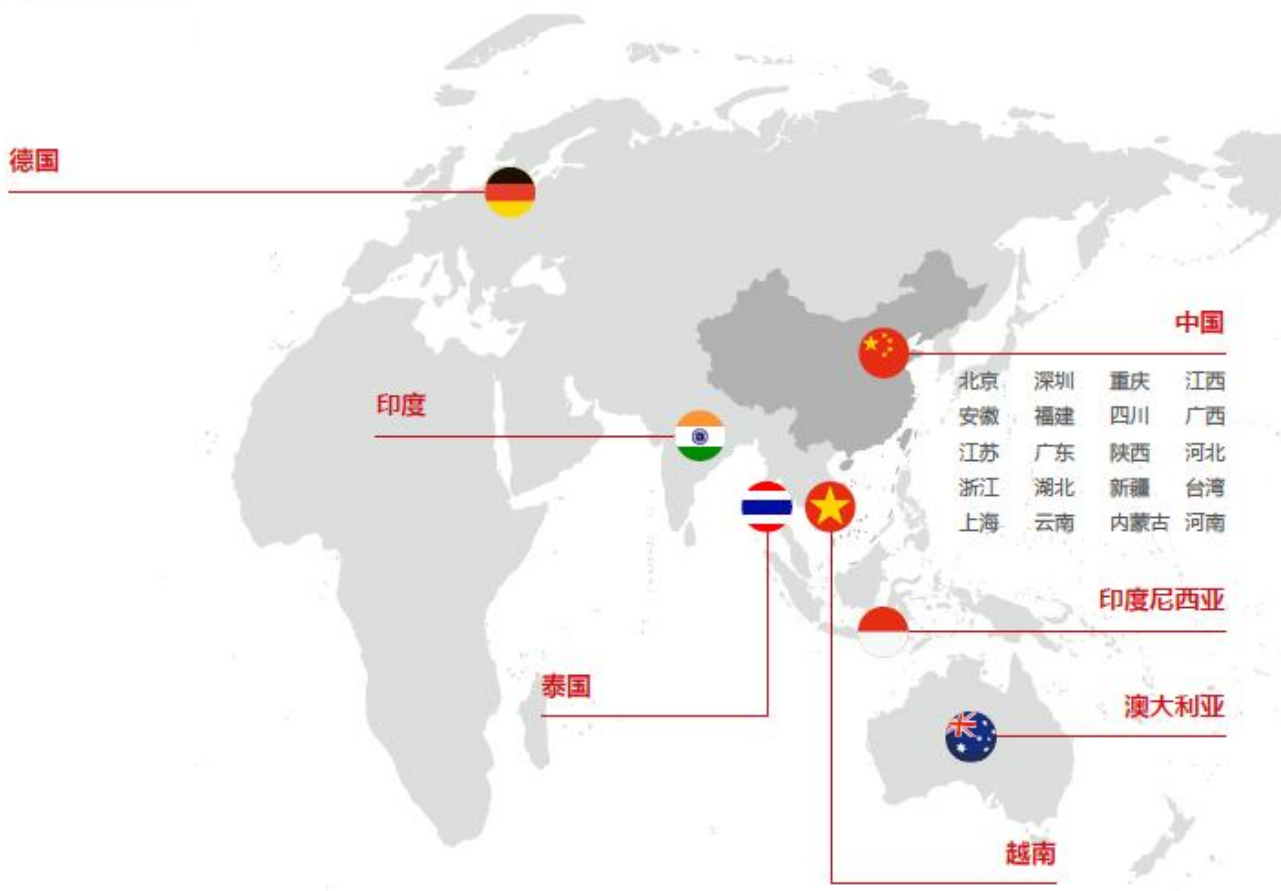
Leadmicro PV Product Series

KF	ZR	XH	JW	Laser	HY
KF20000S	ZR6000	XH10000	EPD40000		HY10000
					
Batch ALD/CVD	PECVD/PEALD	Diffusion Anneal Oxidation LPCVD	Edge Passivation	SE LAF Poly Thinning TBC Patterning Laser Cutting	In-line ALD/PEALD /PECVD
Al_2O_3, SiO_2, TiO_2, SnO_x, TCO	Al_2O_3, SiN_x, SiO_2, poly-Si (n&p), a-Si	O_2, BBr_3, BCl_3, $POCl_3$, poly-Si	Al_2O_3		Al_2O_3, SiN_x, SiO_2, poly-Si (n&p), a-Si

Leadmicro PV Product Series

HY	iSparol	SuiR MS	SuiR EVA	Laser
				
In-line ALD/PEALD /PECVD	RTR Platform ALD	Magnetron Sputtering	Evaporation	P1-P4
Al_2O_3, SiN_x, SiO_2, poly-Si (n&p), a-Si	Al_2O_3, SiO_2, TiO_2, SnO_x	NiOx, ITO, Cu/Ag	LiF, C60	

Global Market Leader in ALD technology for PV industry



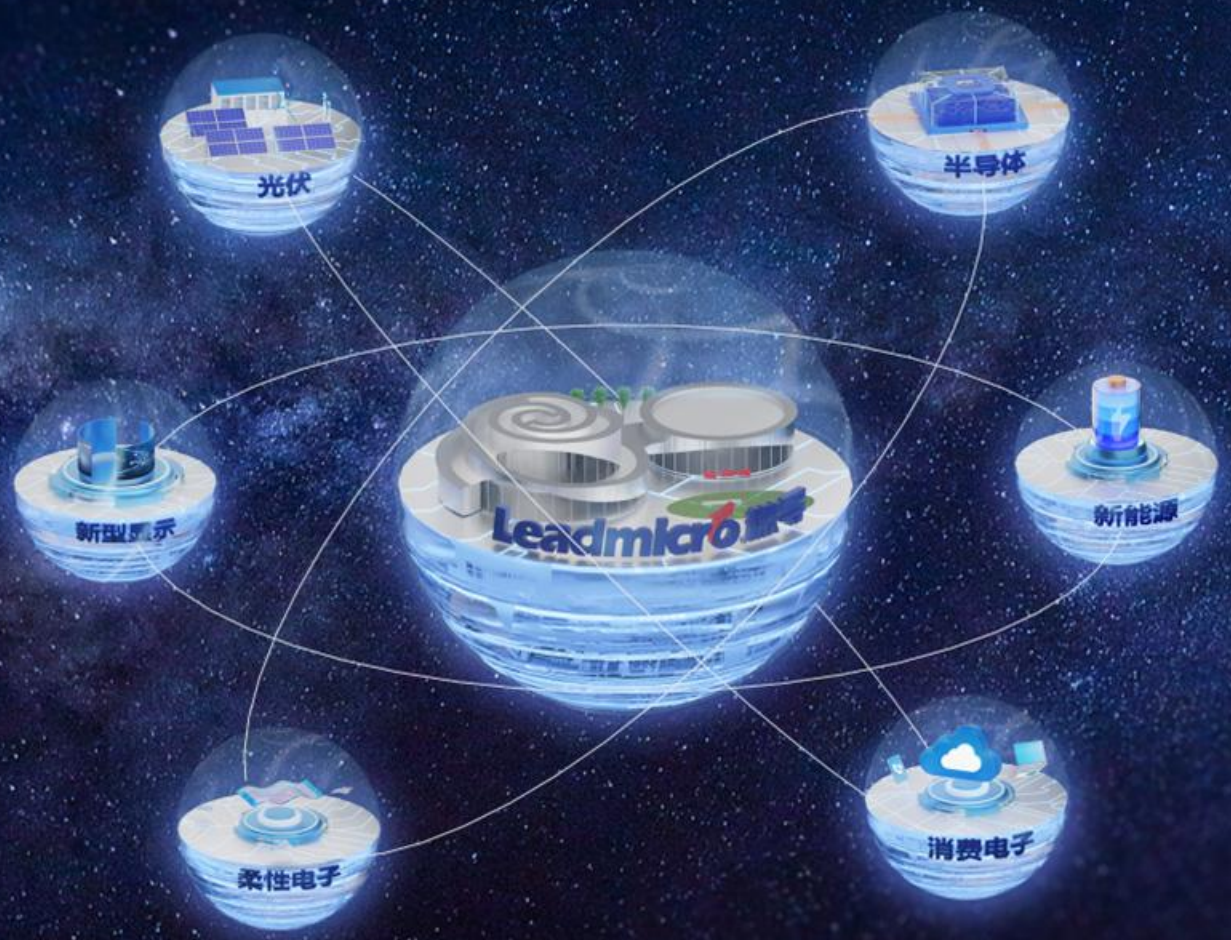
900GW+ ALD Equipment Delivered

200GW+ PECVD-ToxPoly Equipment Delivered

20 GW+ PE-TOPCon Turnkey Project Delivered

Conclusion

- Recent Progress of Cell Technologies
- TOPCon 4.0 Equipment Solutions
  - ✓ Rear Poly Finger: Laser Solution
  - ✓ ALD： 1.5X Boat Tech., capacity improved ∽50%
  - ✓ EPD: Half Cell in production > 5W
    - Cutting Loss Analysis and Edge passivation Mechanisms
    - Leadmicro EPD Equipment Solutions
      - Excellent Compatibility: TOPCon/Poly Finger/TBC, Half, Third, ¼ Cells, M10, G12R, G12
      - Excellent Passivation: Chemical + Field effect + H + thermal + light treatment
      - High Throughput (> 20000 pcs/hr)+Conformality (uneven surf.)+Stability (Live monitoring)
    - EPD Future Outlook: nil wrap-around technology, 1/3, 1/4 cell technology



谢谢

THANK YOU