Advanced Laser Technologies Empowering Back-Contact PV Manufacturing

Ben Lee
DR Laser Technology Co., Ltd.

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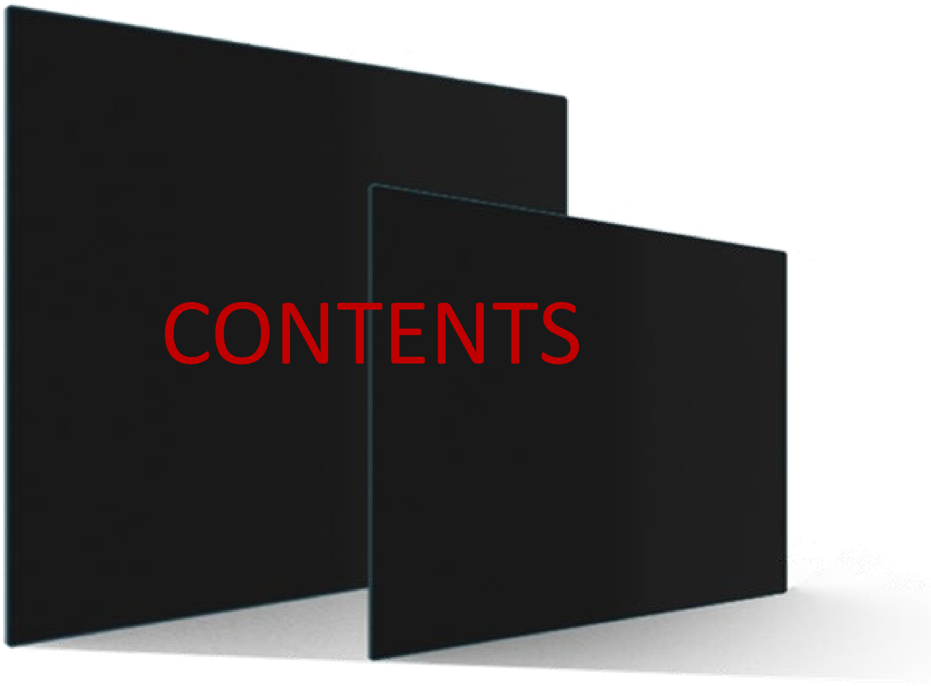

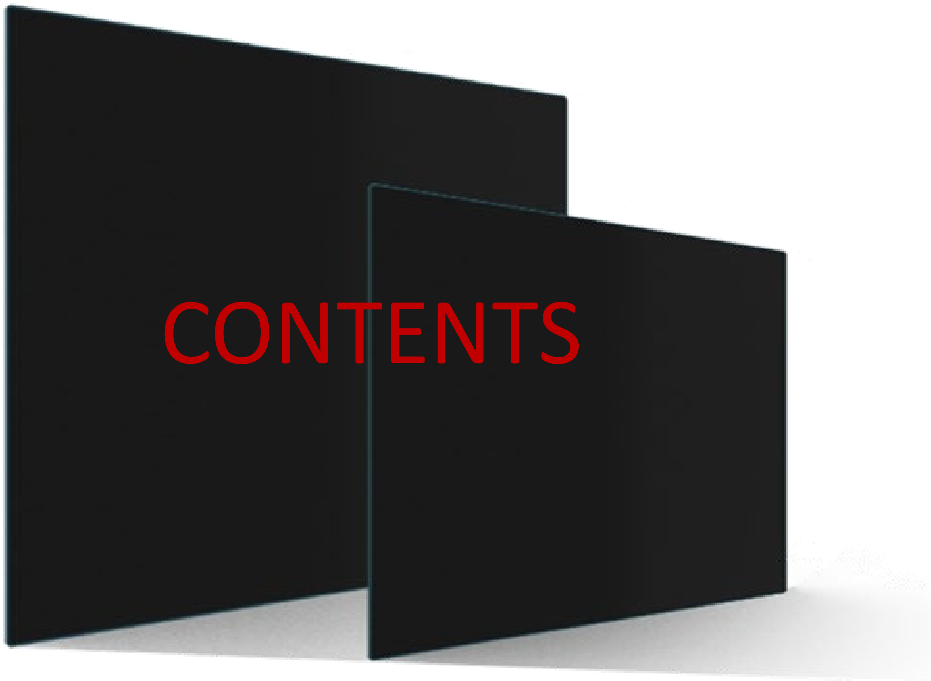

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Development of Back-Contact Solar Cell Technologies

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帝 尔 激 光

1975
Concept of BC cells proposed by Prof. Schwartzat, Purdue University

1985
IBC cell invented by Prof. Swanson, Stanford University
SunPower established

2004
SunPower
>20%
Gen. 1 IBC
in mass production

2007
SunPower
22.4%
Gen. 2 IBC
in mass production

2015
SunPower
24.5%
125X125mm^2
Gen. 3 IBC
in mass production

2016
Trina
23.5%
M2 IBC
released

2017
Kaneka
26.7%
HBC released

2018
Trina
25.04%
M6 IBC
released

2019
Longi
HPBC 1.0
in pilot
production

2020
Maxeon (SunPower)
24.8%
Gen. 6 M6 IBC
in mass production

SPIC /ISC Konstanz
>24.2%
ZEBRA IBC
in mass production

2021
Aiko
26.5%
ABC cells
released

2022
Longi
25.8%
p-type HPBC
in mass
production

Maxeon (TCL)
24.7% Gen. 7
M6 BC modules
released

2023
Aiko
27.2%+
ABC cells
24%+
ABC modules
in mass production

2024
Aiko
25.2%
ABC
modules
released

Longi
27.0%
n-type HPBC
in mass
production

2025
Longi
27.81%
HIBC
released

Longi
25.9%
HIBC modules
in mass
production

Back-Contact Technology Roadmap

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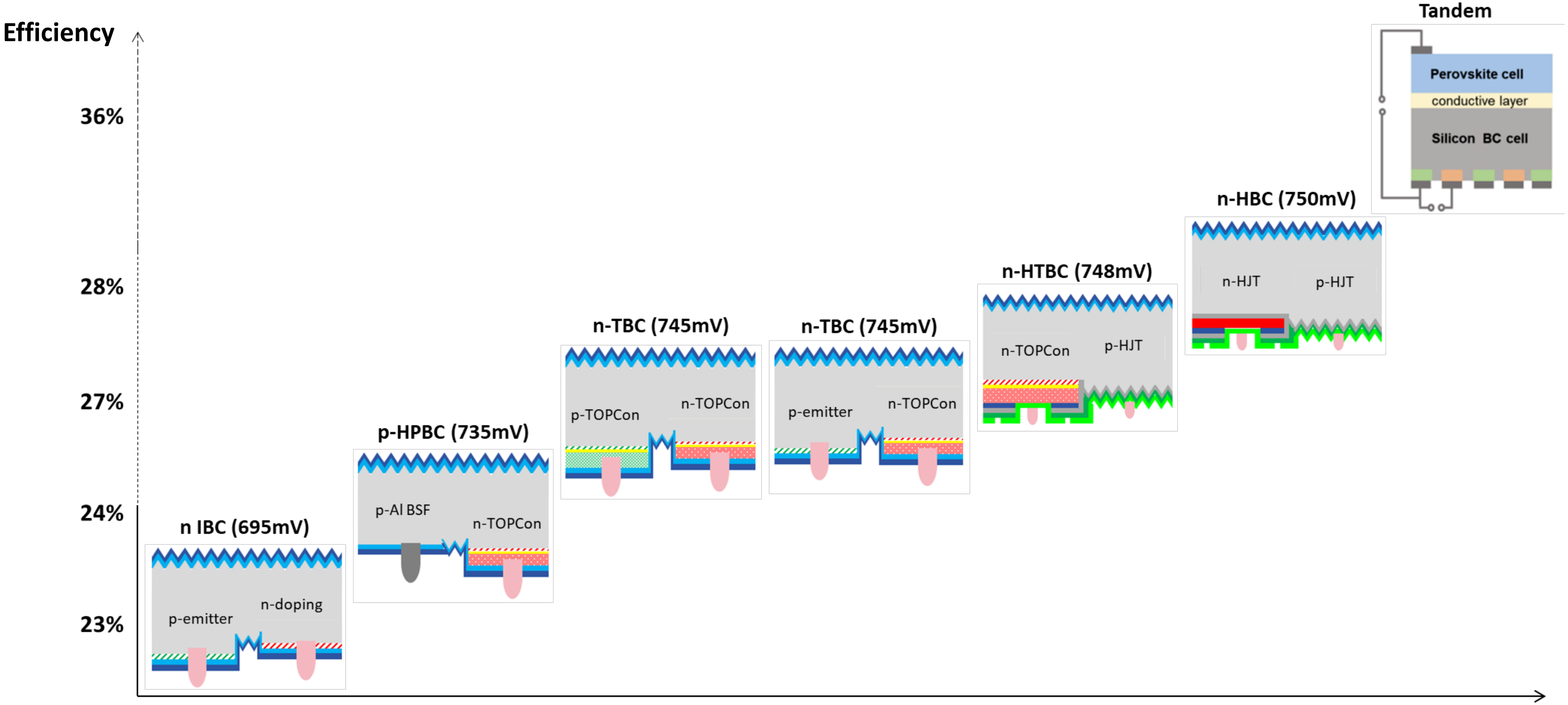

- BC is the ultimate architecture of high-eff. c-Si solar cell by its higher V_{OC} and lower shading loss

Efficiency Ranking of Commercial PV Modules

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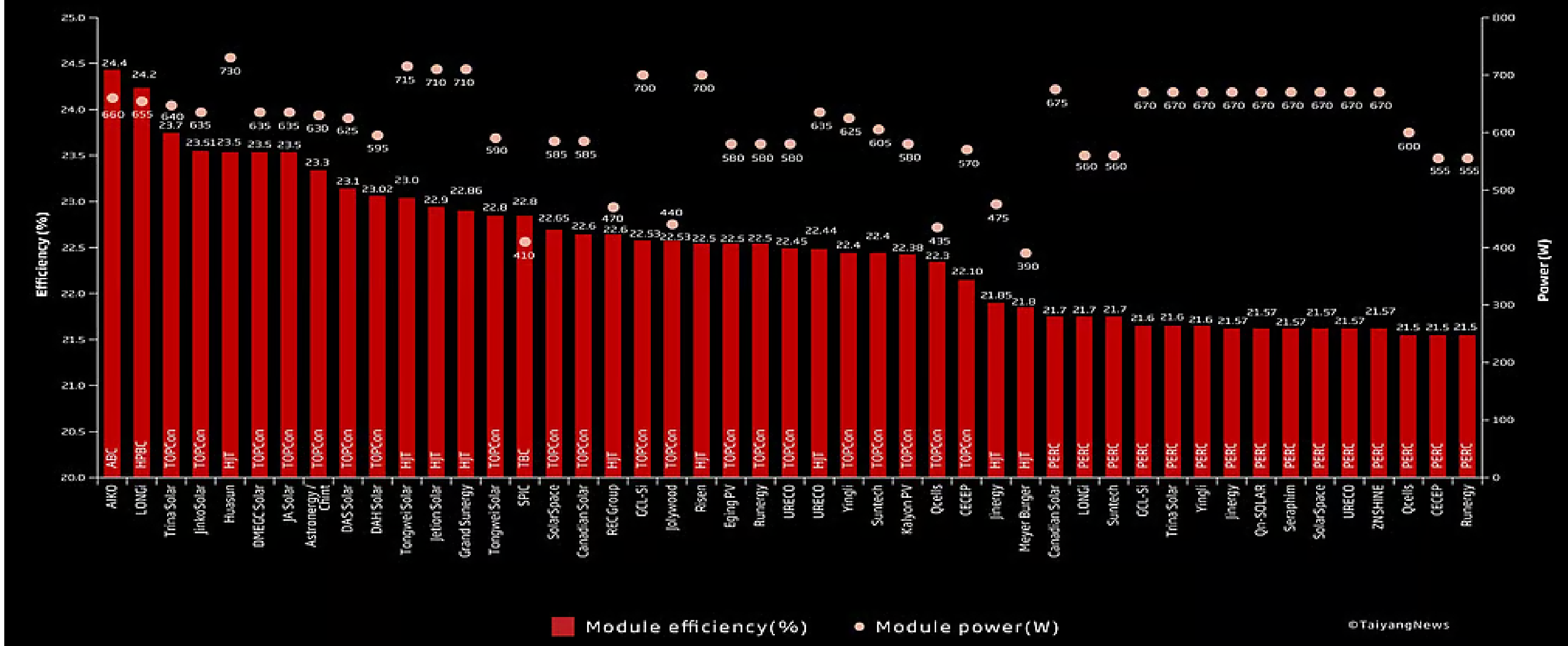
TAIYANGNEWS
ALL ABOUT SOLAR POWER

TaiyangNews Top Modules: Highest Efficient Commercial Solar Modules 11-2025

Rank	Company	Series	Model	Wafer type	Cell Size	Cells No.	Cell Tech	Module Technology	Power (W)	Efficiency (%)
1	AIKO	Comet 2U	AIKO-G660-MCH72Mw	n-type	182	144	ABC	Half-cell, Back Contact	660	24.4
2	LONGi	Hi-MO 9	LR8-66HYD 635-655M	n-type	182	132	HPBC	Bifacial, Half-cell, Back Contact	655	24.2
3	Trinasolar	Vertex N	TSM-NEG19RC.20	n-type	210R	132	TOPCon	Bifacial, Half-cell, MBB	640	23.7



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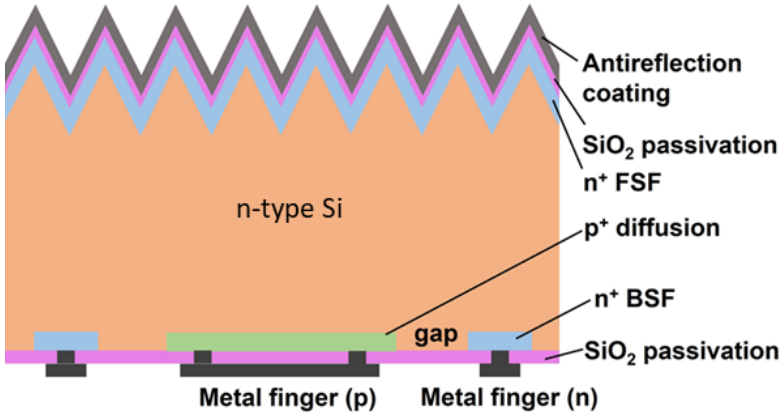
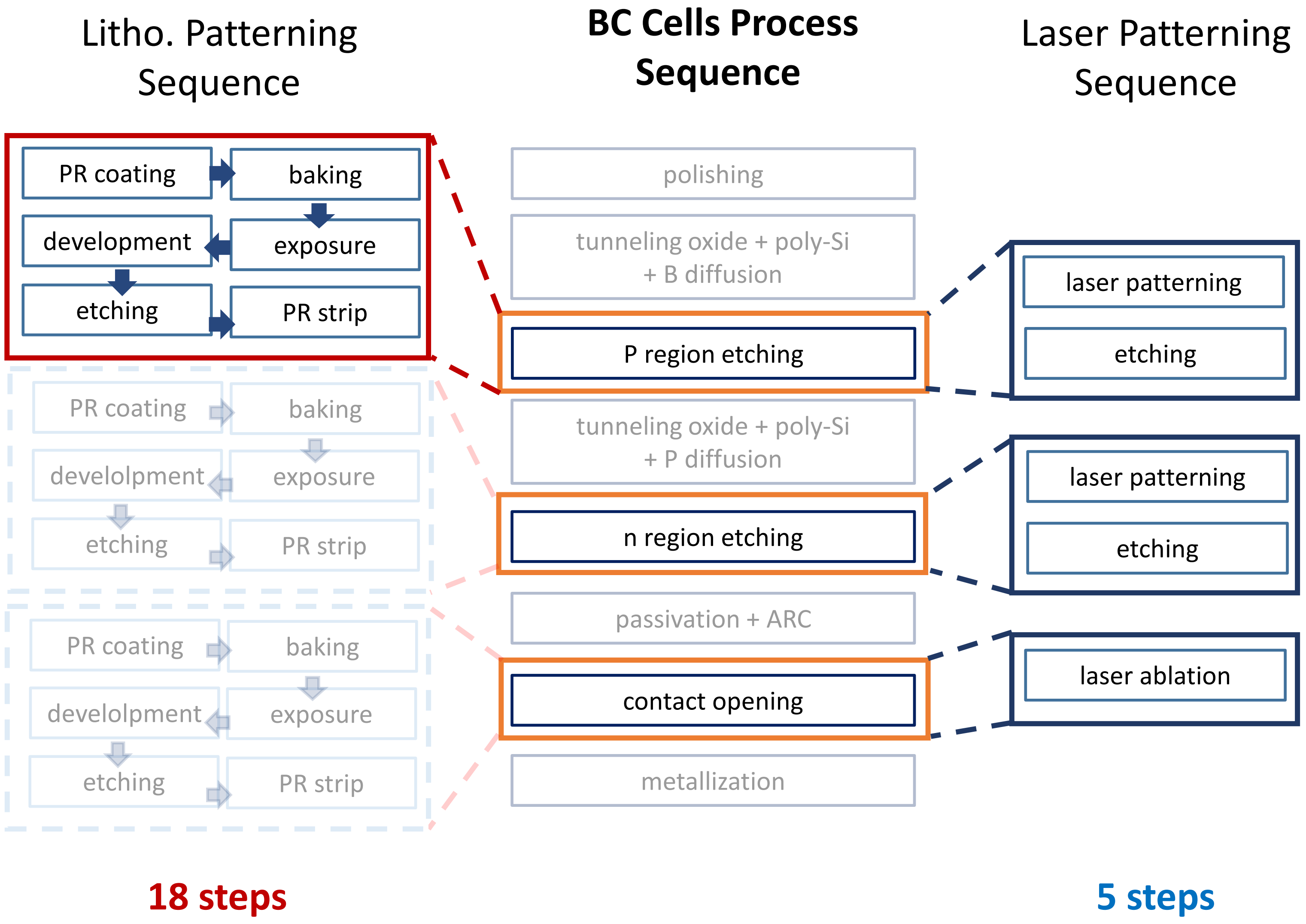
Laser Patterning Enables Cost-effective Production of BC Cells



- Laser patterning combined with wet etching significantly reduce capex by 60%, and increase throughput by 40 times without compromise of pattern accuracy, compared with conventional photolithography patterning
- Laser patterning simplify XBC cells process sequence, and realize GW-scale production of XBC cells cost-effectively



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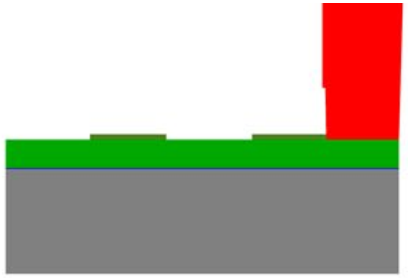
TBC Cell Process Sequence

1. Polishing

2. Tunneling Oxide + p-poly + BSG

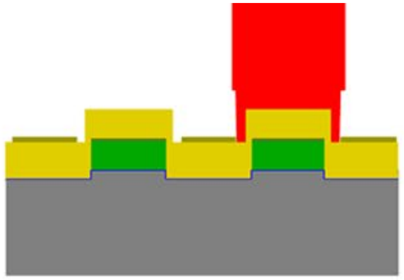
3. Laser Patterning (BSG)



4. Wet Etching

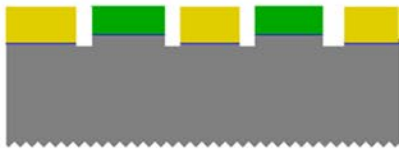
5. Tunneling Oxide + n-poly + PSG

6. Laser Patterning (PSG)

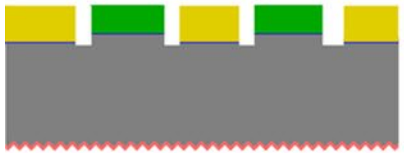


7. Wet Etching

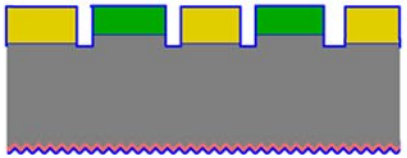
8. Texturing



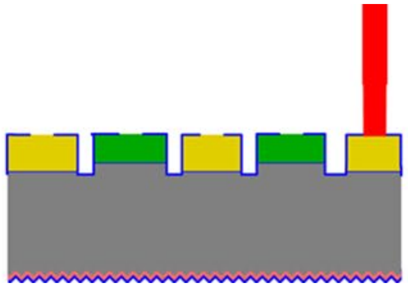
9. AlO_x Deposition



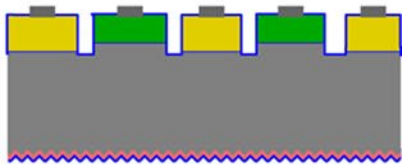
10. SiN_x Deposition



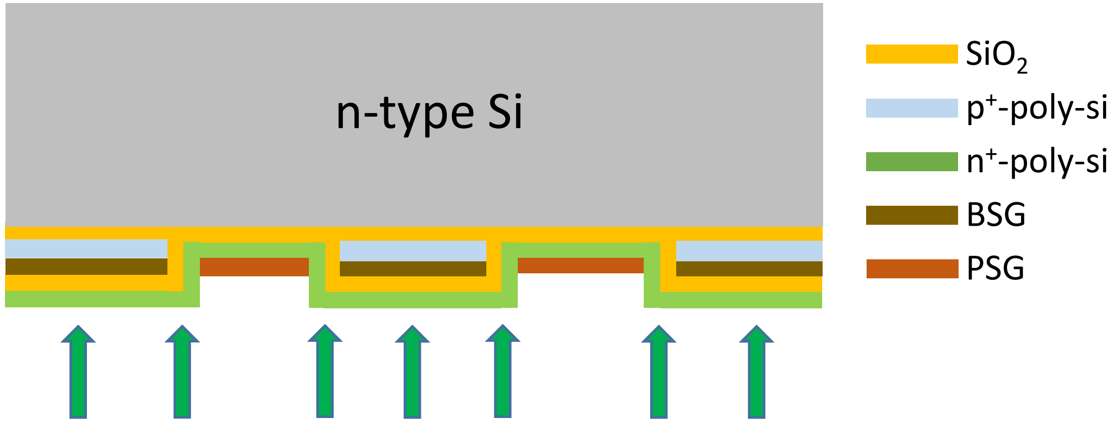
11. Laser Contact Opening



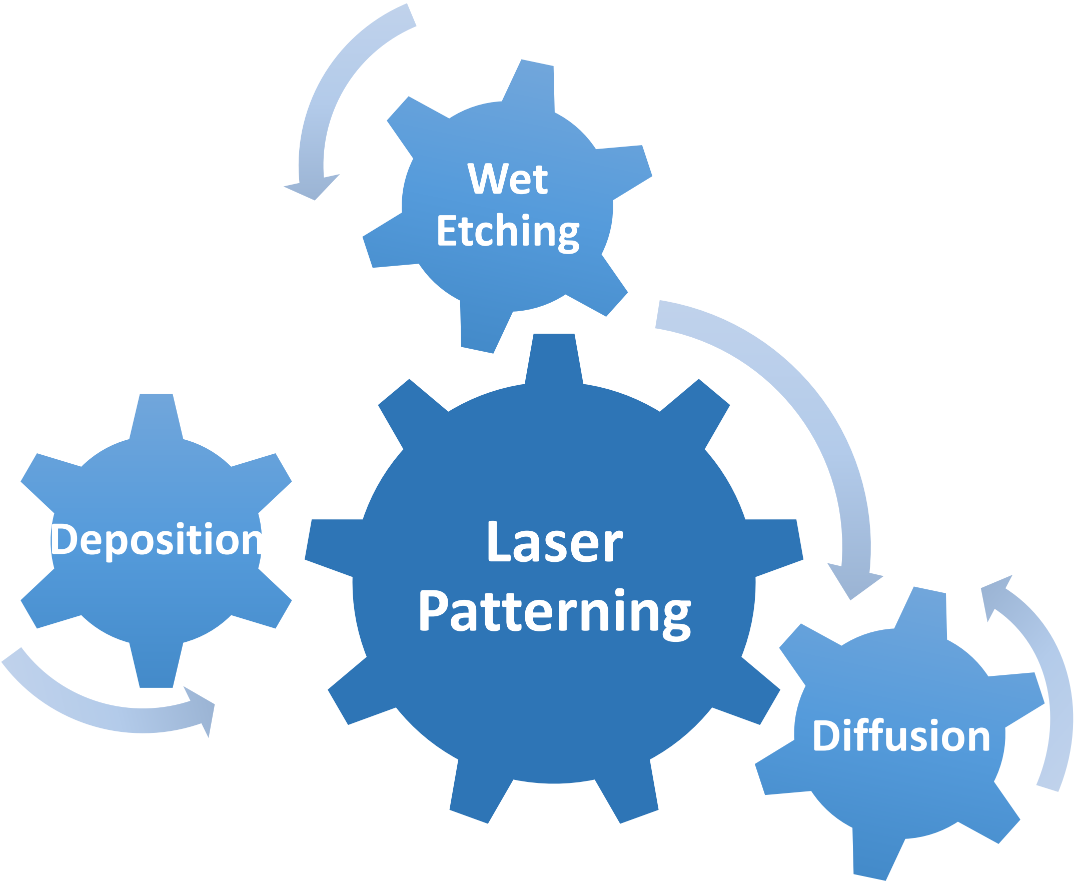
12. Metallization



Process-Integrated Laser Patterning Technology



50 ~ 200nm multi-layer heterogeneous thin films processed by laser patterning

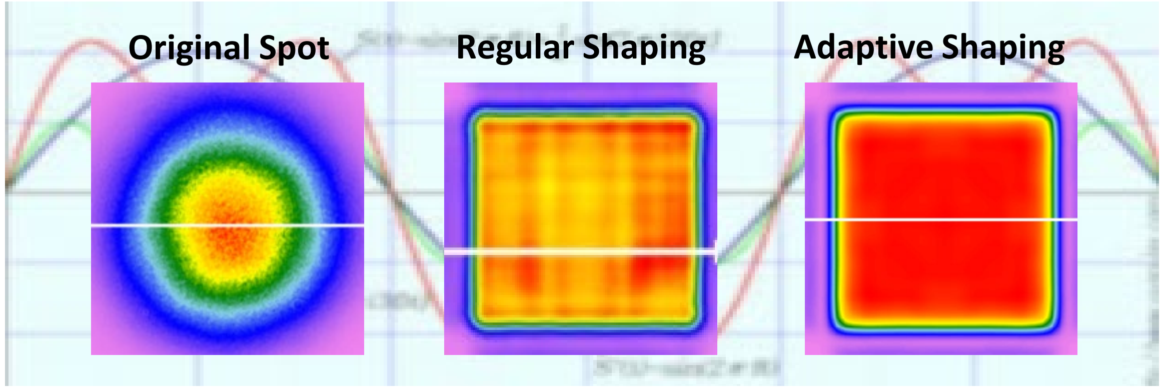


- Building up a complete laser process integration database including deposition, diffusion and wet etching
- Matching the requirement of laser patterning processes for IBC, TBC, HBC and HTBC

Core Platform: Adaptive Shaping & Intelligent Control

- Excimer 248 nm
- UV 355 nm
- Green 532 nm
- IR 1064 nm
- ……

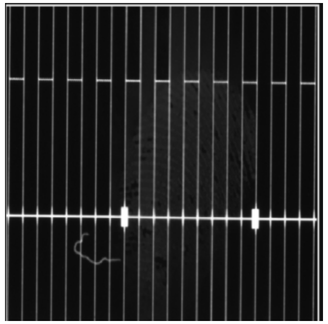
- CW
- QCW
- Nanosecond
- Picosecond
- Femtosecond

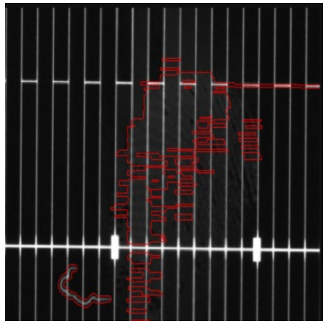


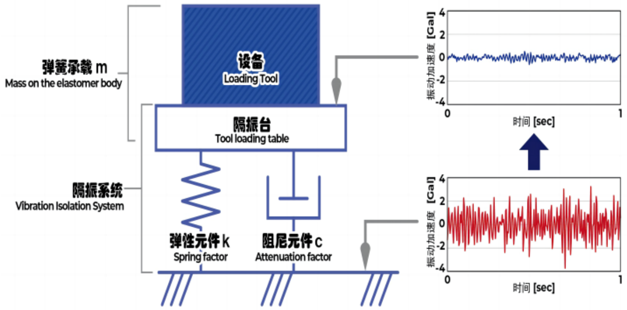
High-accuracy AI-assisted Inspection

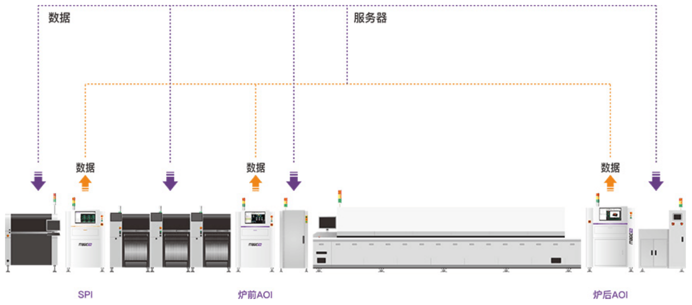
Micro-vibration Monitoring & Compensation

Real-time AOI Monitoring & Feedback Control









Laser Patterning Production Equipment for BC Solar Cells

- Integrating laser process, optical design and pattern accuracy in one platform from lab., pilot line and mass production
- More than 1,000 sets of production-proven laser processing equipment in GW scale of BC solar cells running in 7-24

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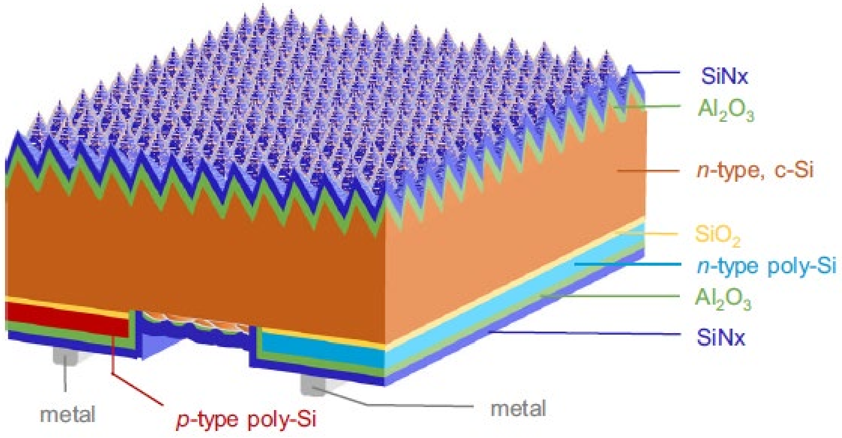
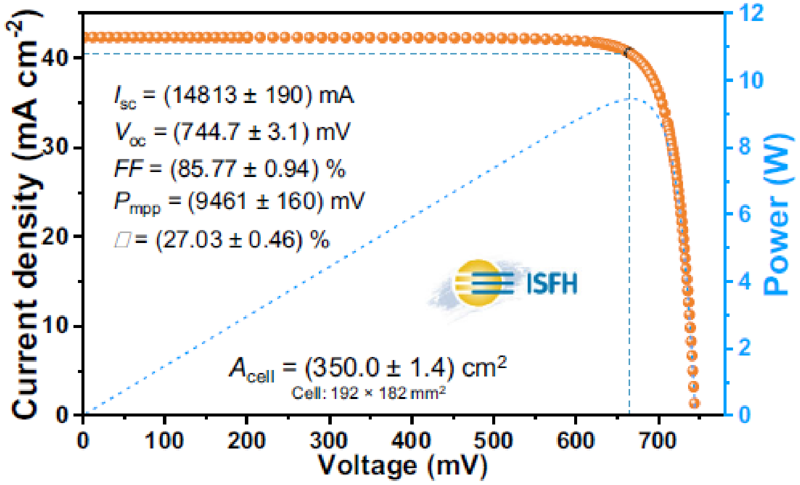
Laser Patterning for TBC Solar Cells

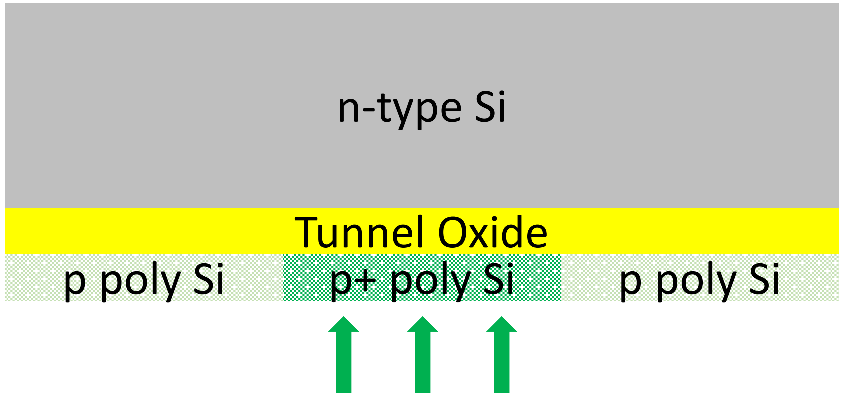


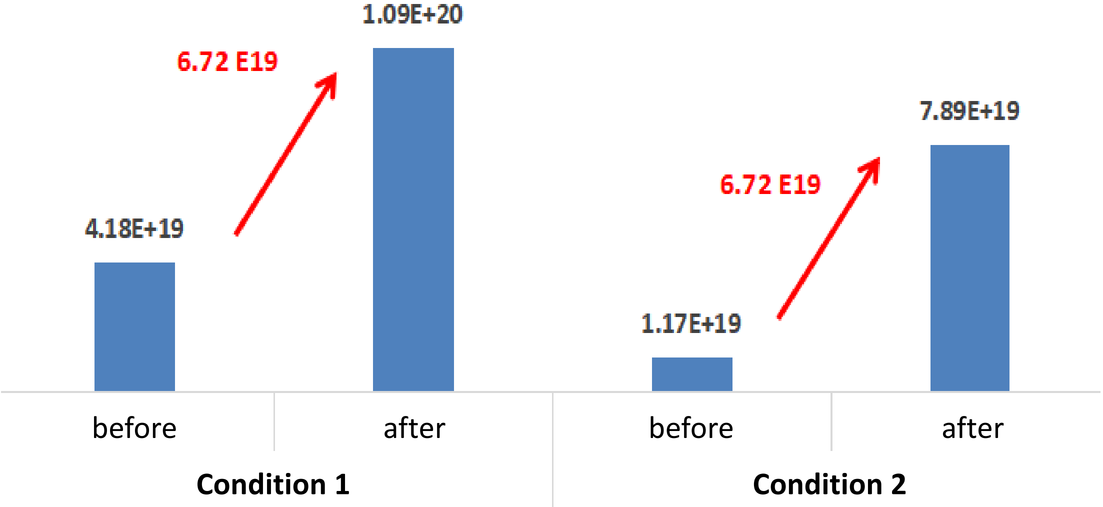


- **Enabling TBC Tech**: Laser patterning is essential for defining the interdigitated p/n/gap structure
- **Optical Optimization**: Enables >80% bifaciality through precise p/n pitch control (200 – 300μm)
- **Low-Temp Metallization**: UV picosecond lasers open contacts without damaging the tunnel oxide, allowing for 250°C processing
- **Eco-Friendly Process**: Selective laser ablation of BSG/PSG reduces chemical waste and protects the wafer
- **Cost & Precision**: Eliminates photolithography by combining laser patterning with wet etching for a mask-free process.

Hongbo Tong, et al., Total-area world-record efficiency of 27.03% for 350.0 cm^2 commercial-sized single junction silicon solar cells[J], Nature (2024)
背接触(BC)电池技术发展白皮书，中国电力企业联合会太阳能分会

Laser Activation for Poly-Si Contact Optimization

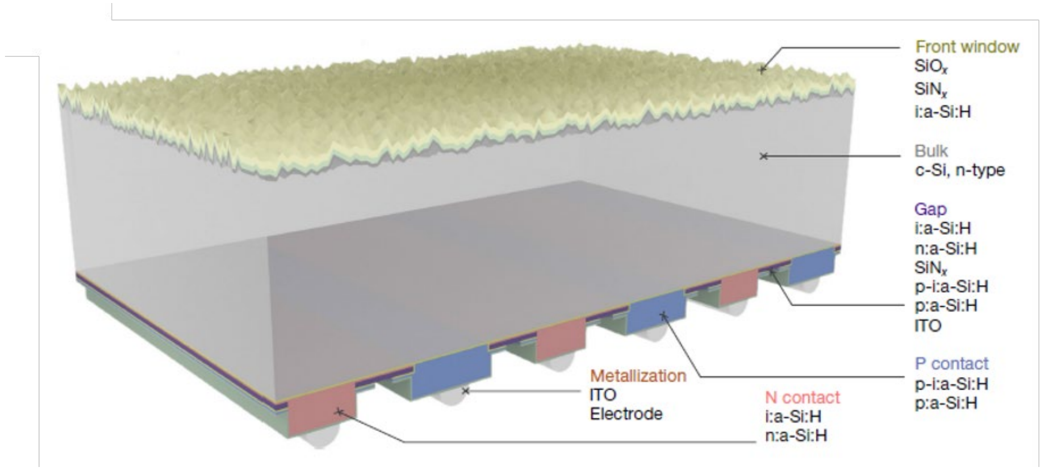


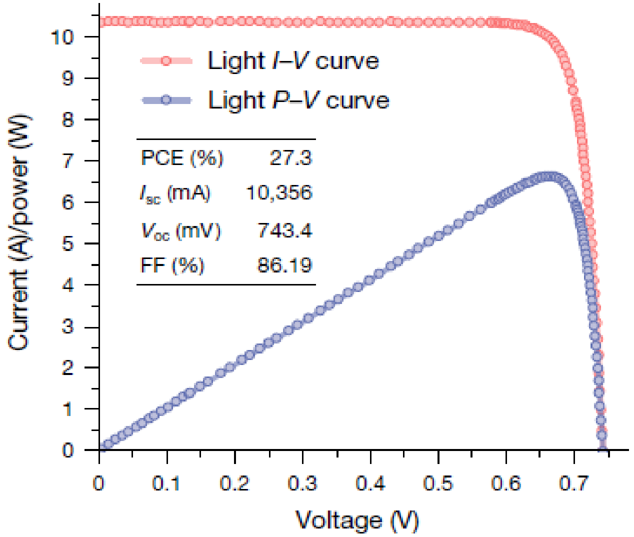


- **Core Activation Tech**: Laser activation enables supersaturated boron doping for bipolar p++/n+ poly-Si, mitigating the typical SiO_2 damage of furnace diffusion
- **High-Precision Doping**: 532nm top-hat laser achieves a boron concentration >5×10^{20} cm^{-3} via melt-regrowth, while strictly preserving the <2 nm SiO_2 layer
- **Mask-Free Patterning**: High alkaline etch selectivity (>1000:1) allows direct formation of the rear interdigitated p/n/gap structure, eliminating the need for masking
- **Superior Passivation**: Excellent metrics (iV_{OC} 722mV, J_0 6.7fA/cm^2) confirm that the critical SiO_2 tunnel layer remains intact throughout the laser process
- **Enhanced Electricals**: The rectangular beam minimizes overlap damage to boost V_{OC}, while high conductivity reduces series resistance R_S by enabling a tighter metallization pitch

Jonathan Linke,, et al,, 24% Efficient TOPCon-based back contacted polyZEBRA solar cells, EPJ Photovoltaics 16, 8 (2025)
Saman Sharbaf Kalaghichi, et al., Laser Activation for Highly Boron-Doped Passivated Contacts, Solar, Volume 3, (2023)

Laser Patterning for HBC Solar Cells

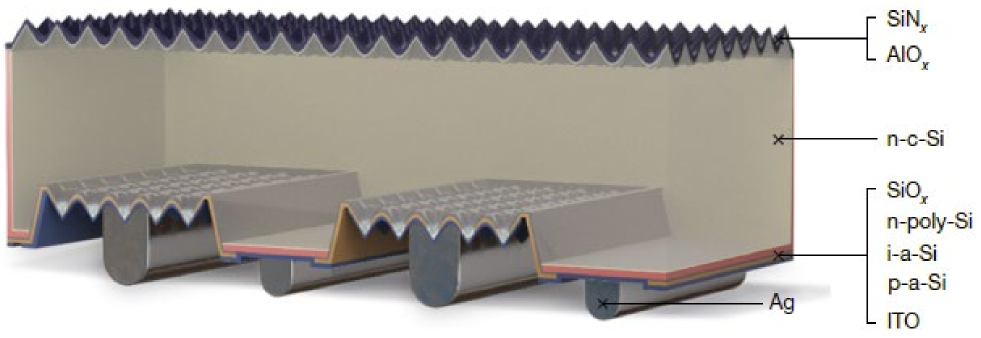


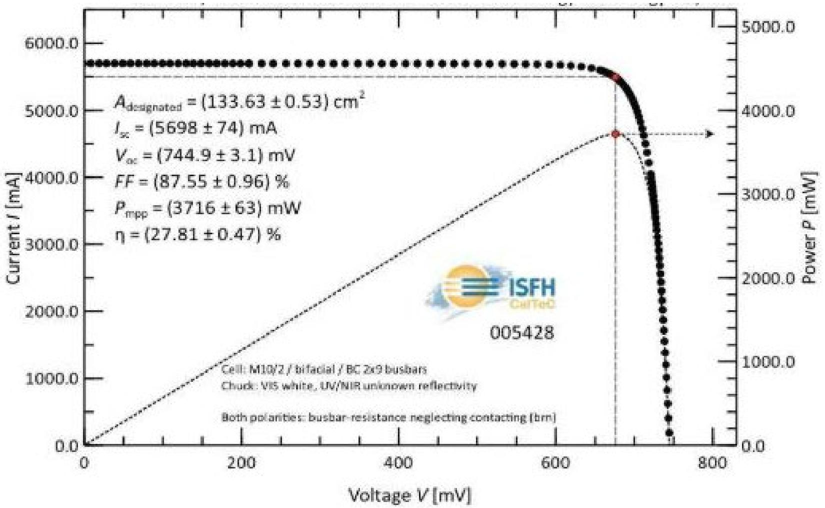


- **Wavelength Control**: Multi-wavelength (532nm and 355nm) picosecond lasers enable selective, layered ablation of rear thin films, supporting 250°C low-temperature metallization
- **Damage Minimization**: The top-hat laser beam ensures uniform energy and controls the thermal effect, minimizing damage to the heat-sensitive a-Si:H passivation interface
- **Precision Structuring**: Laser precisely defines the p/n/gap interdigitated structure (width 200-300μm), which directly determines bifaciality and efficiency limits
- **Selective Contacting**: Forming only local electrical contact during P-layer removal maximizes protection of the underlying N-contact's passivation, thus maintaining high V_{OC}
- **High Throughput**: Simplified process flow reduces effective processing time to approximately one-third of TOPCon, significantly boosting industrial manufacturing efficiency

Hua Wu et al., Silicon heterojunction back-contact solar cells by laser patterning[J], Nature (2025)

Laser Induced Crystallization for HTBC Solar Cells





- **Hybrid Structure Definition**: Laser patterning precisely patterns the rear side, defining and isolating the n-HJT (Heterojunction) and p-TOPCon contacts to form the BC interdigitated structure
- **Ultra-Low Resistance**: Laser activation of the p-poly Si layer creates a TOPCon tunnel contact with supersaturated boron doping, ensuring extremely low contact resistance
- **Interface Protection**: Precise laser energy control achieves supersaturated activation while maximally preserving the critical SiO_2 tunnel layer
- **Fill Factor Boost**: Laser-Induced Crystallization resolves the conflict between thick i-a-Si leakage protection and high contact resistance, reducing p-type contact resistivity by an order of magnitude and raising the FF to 87.55%
- **Record Efficiency**: Laser technology is the key to fusing the high V_{OC} (HJT) and high FF (TOPCon) hybrid structure, enabling HTBC cell efficiency to reach a record 27.81%

Genshun Wang et al., Silicon solar cells with hybrid back contacts[J], Nature (2025)

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About Us

DR Laser Technology Co., Ltd.

- Established in 2008, focused on integrated laser solutions for PV, advanced semiconductor packaging, and new displays
- Strategic Global Footprint: HQ in Wuhan (China Optics Valley), R&D/mfg base in Wuxi, and overseas R&D Centers in Yavne & Singapore
- Pioneering the Future: Leading the Global Transformation of High-Efficiency Cell Technology

Headquarter	R&D / Mfg Base	Global R&D	Asia R&D
Wuhan, China	Wuxi, China	Yavne, Israel	Singapore


Leading the Way in PV Laser Technology

17

17 Years of global leadership in PV laser processing equipment

80%

80%+ global share in high-efficiency cell laser processing equipment

20

Trusted by all top 20 global PV cell manufacturers

3

Driving industry change with n-type c-Si technology deployment

Powered by laser innovation, DR LASER continues to spearhead the worldwide transformation of high-efficiency solar cell process technology

Serving All Customers Globally

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Thanks!