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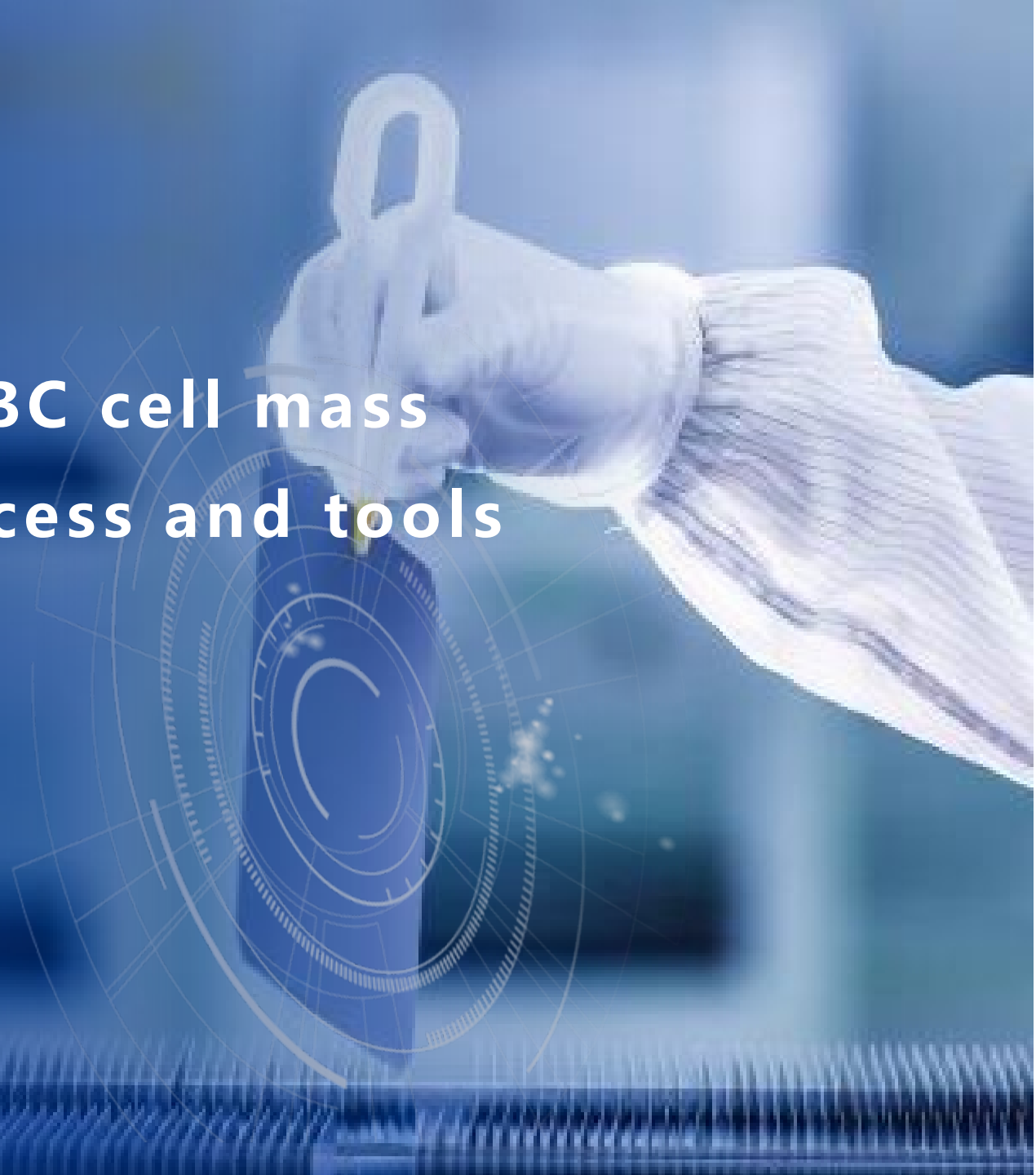
Several key blocks for TBC cell mass production: half cut process and tools

Xiajie Meng

2024.12.04



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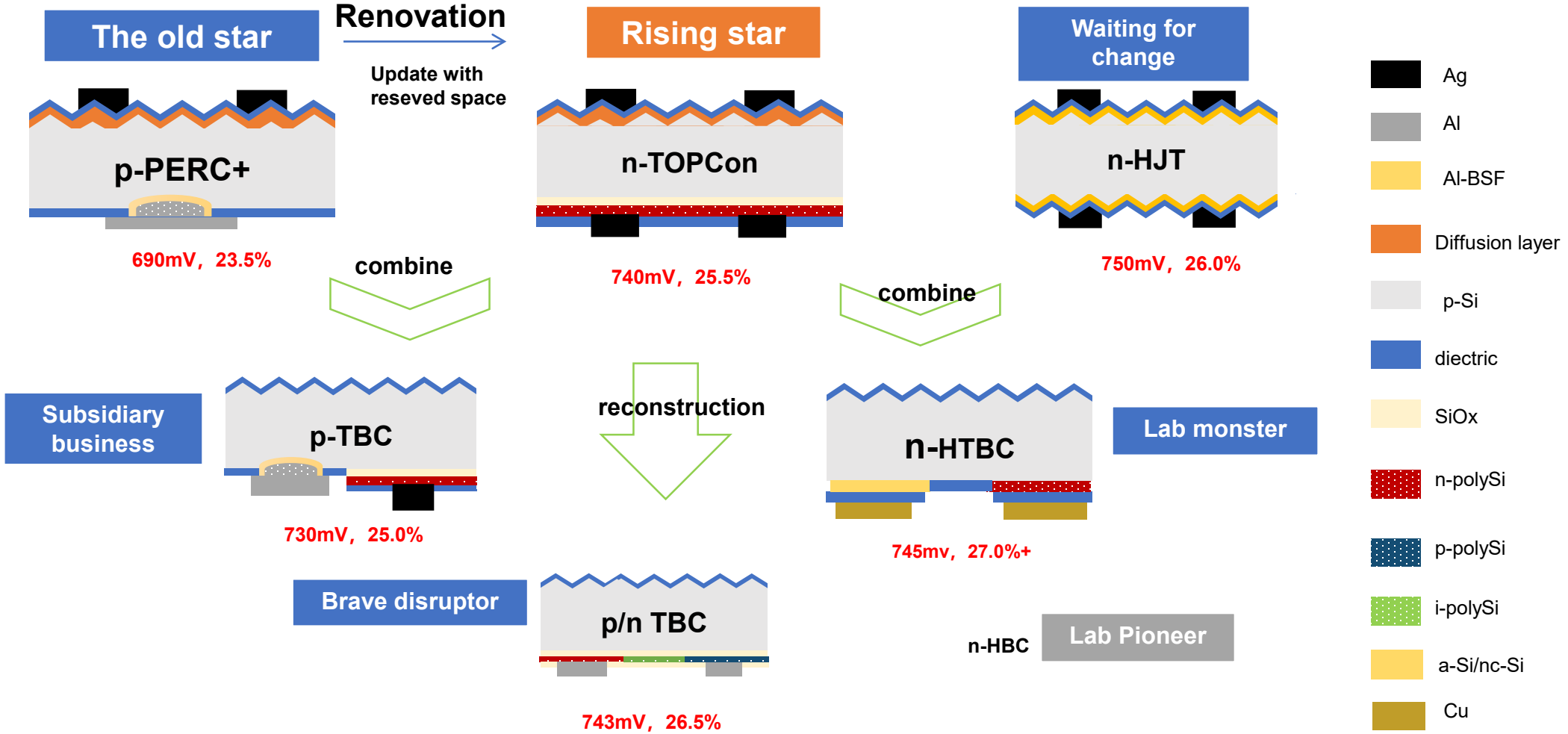
TOPCon became mainstream in 2024



Efficiency pradox, struggle for BC future

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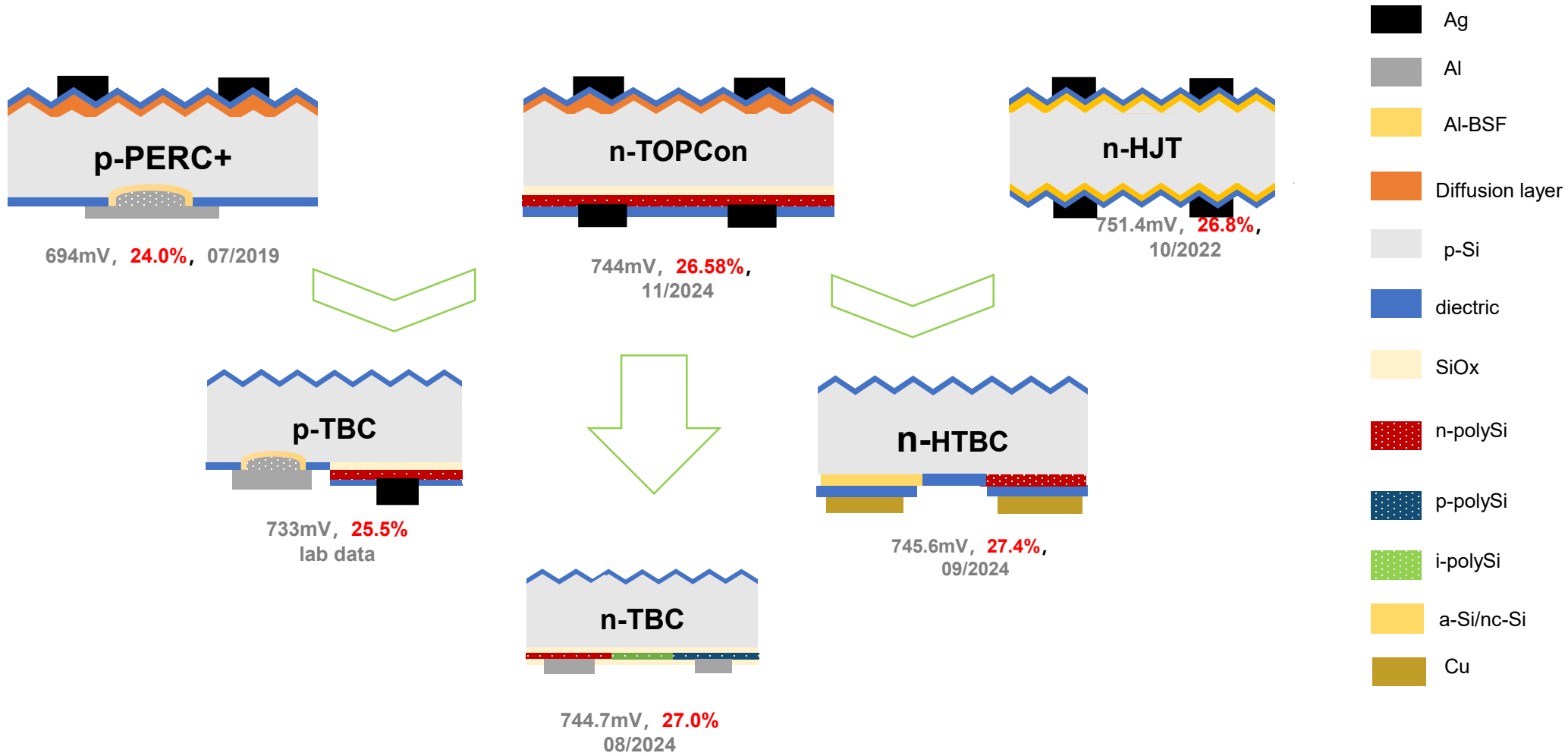
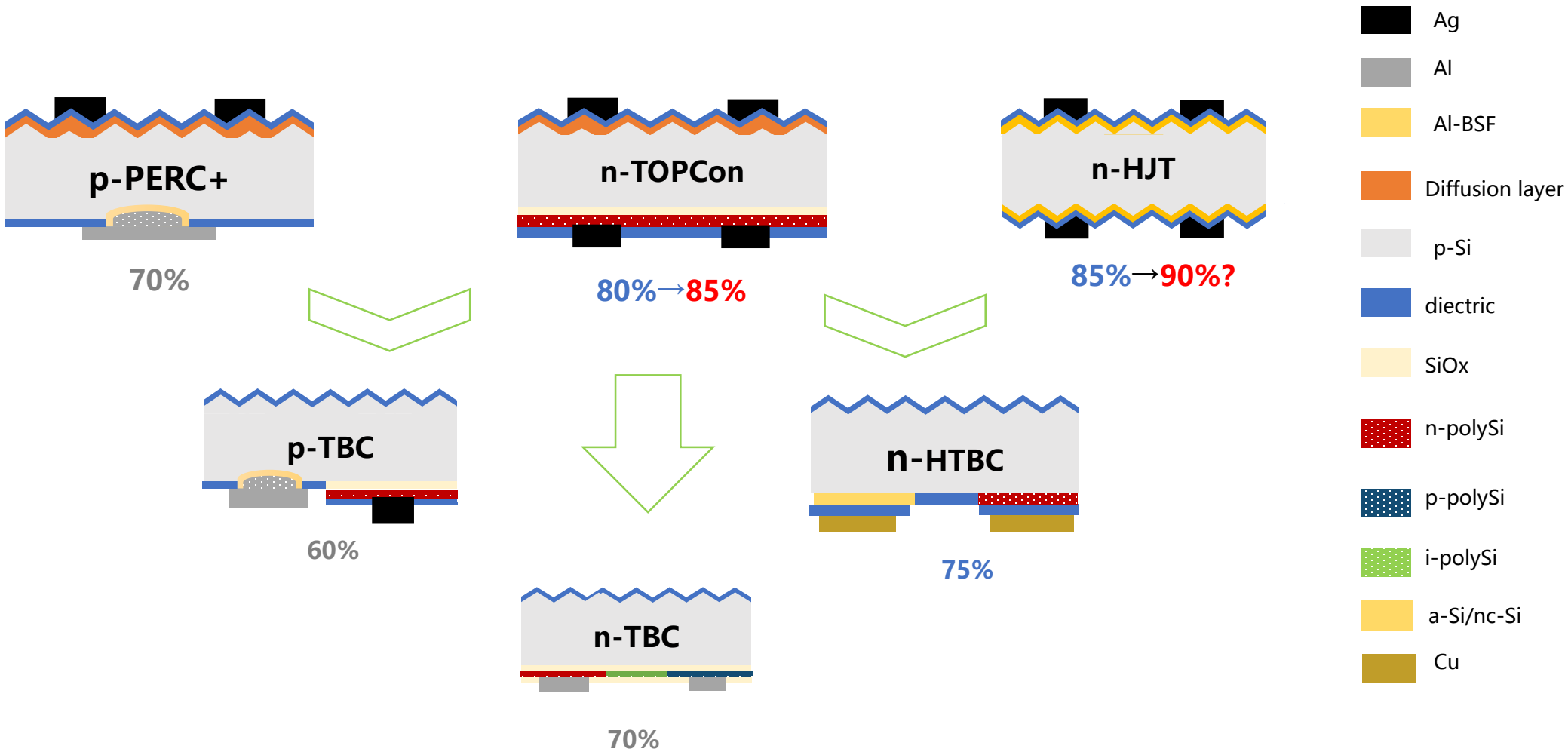
Solar Cell Efficiency Tables (Version 65) 21/10/2024



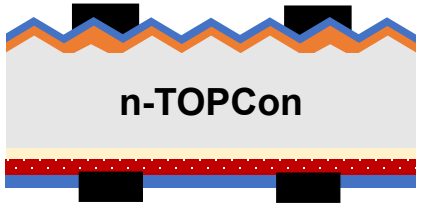
Block 1, bifaciality

Customer doesnt pay for bifaciality, but utility choose the higher and the more relialbe



Block 2，deligent rising star

TOPCon inline innovation is moving fast



25.5%
80% 2024

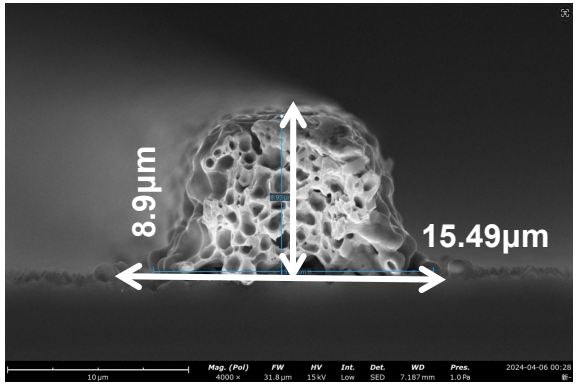
The rising star will get another 0.4% EFF next year.

Inline inovation based on screen shift or single tool integration are easy to be applied.

TOPCon will get traordinary bifaciality for utility market.

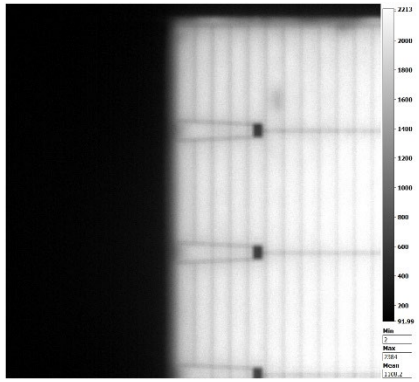
Stencil printing

- 0.15% EFF gain
- silver saving as low as to **8 mg/w**



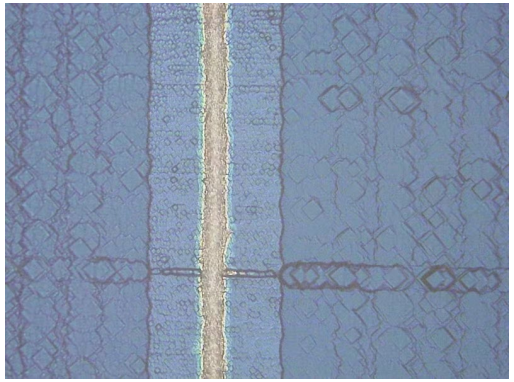
Edge passivation

- Pickup 0.15% EFF laser cleavege loss
- Easy **inline integration**



Rear Polyfinger

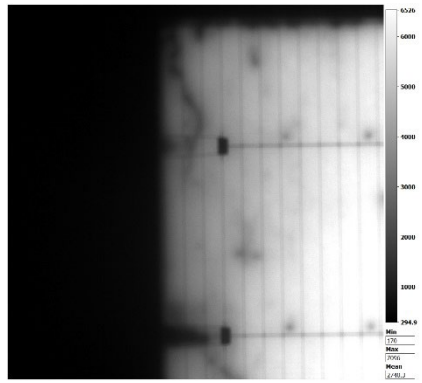
- 0.15% EFF gain
- **85% bifaciality** for utility market



Block 3，EFF of half cut loss

TBC/HTBC mass production from half cut raw wafar

- **PERC Shingle，HJT and n-TBC** laser cut loss are TOP 3.
- **0.35% EFF half cut loss** for n-TBC is equal to **7W** for module at 2278x1134 mm size.
- HJT process in industry is already half cut.
- TBC cells are difficult to stack together for edge passivation.



Edge recombination because of laser thermal half cut

PL pic, HJT 1sun

Cell	Type	Class Bin	Cut loss					
			ΔEff (%)	J_{sc} (mA/cm2)	ΔV_{oc} (mV)	ΔFF (%)	ΔPFF (%)	ΔJ_{02} (nA/cm2)
HJT	156	25.0%	**-0.58** TOP①	-0.03	-2.06	-1.68	-1.78	2.63
PERC	182	23.0%	**-0.17**	-0.08	-0.62	-0.37	-0.33	1.14
	210-**Shingle** 6 cut	22.8%	**-0.47** TOP②	0.01	-0.62	-1.61	/	/
TOPCon	182	24.6%	**-0.21**	0.00	-0.42	-0.67	-0.56	1.53
p-TBC	182	25.0%	**-0.20**	-0.22	-0.42	-0.20	-0.22	0.26
n-TBC	182	26.7%	**-0.35** TOP③	-0.10	-1.18	-0.77	-0.68	0.80

Solution trial，half cut TBC mass production

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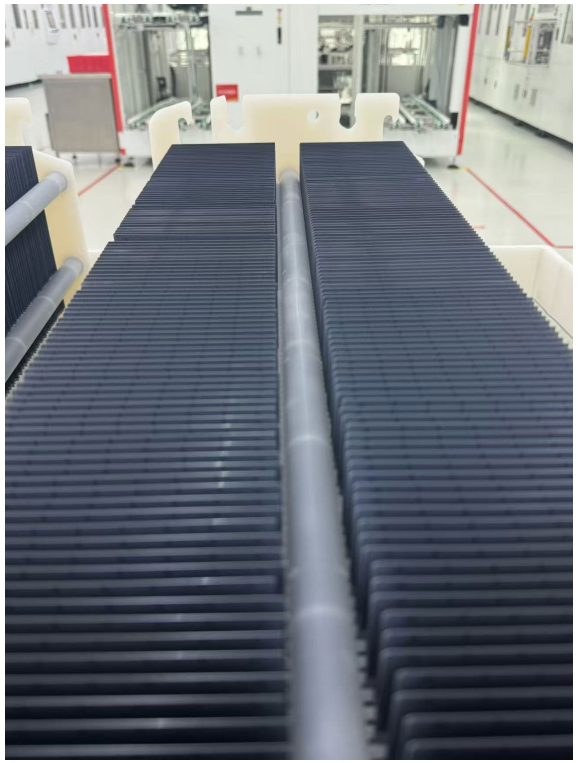
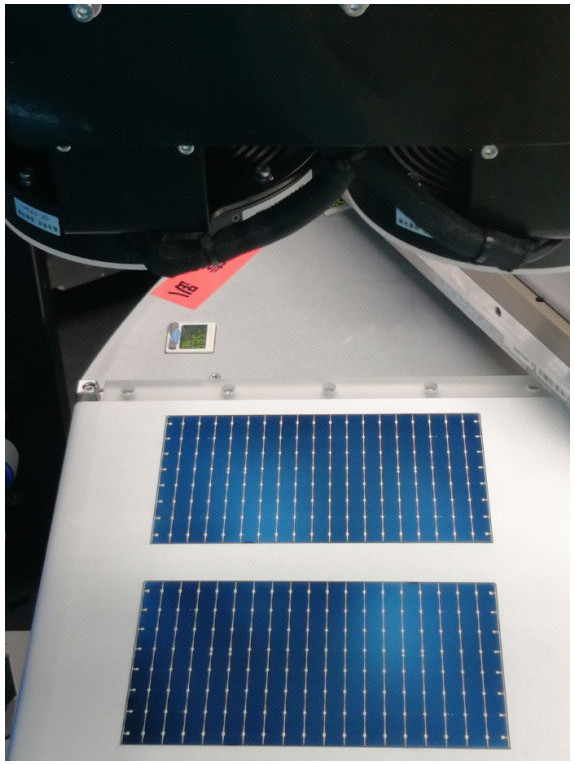
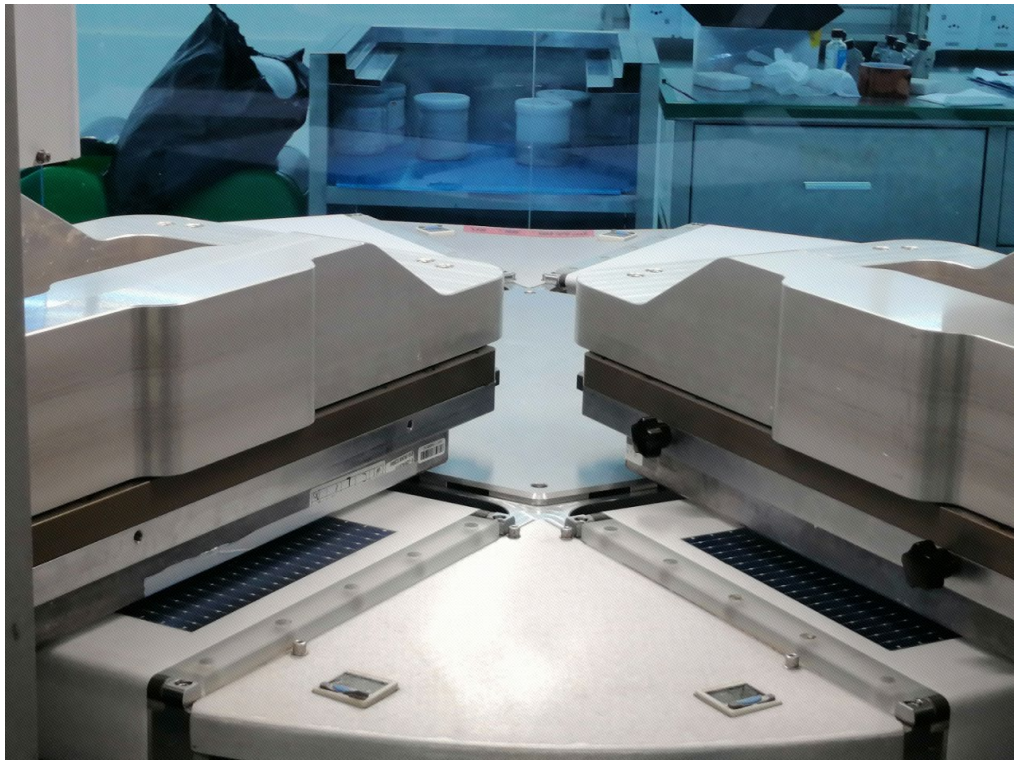
Automation Carrier
Two rows in one



One camera for two cell alignment



Hexagon half cut cell printer

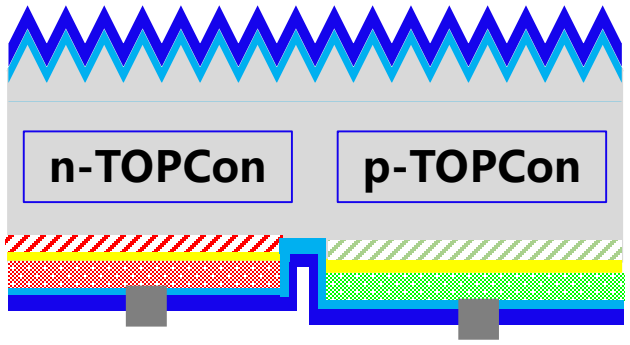


Block 4，Simplified TBC based on boron diffusion

Simplified boron diffsion juction is hard to form good contact

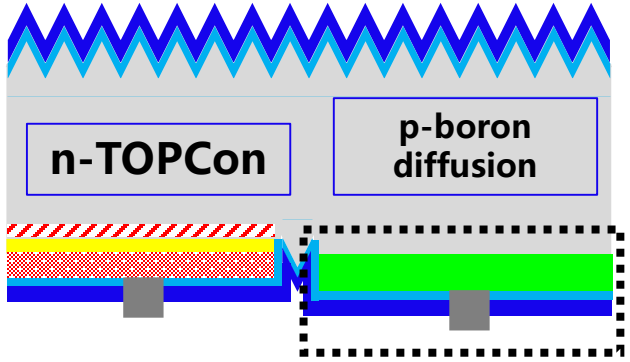
n-TBC

boron doped polysilicon Juction

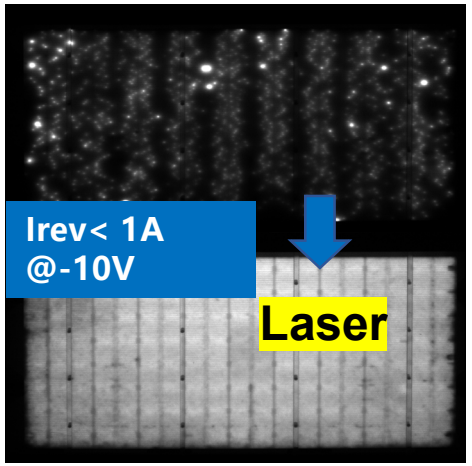


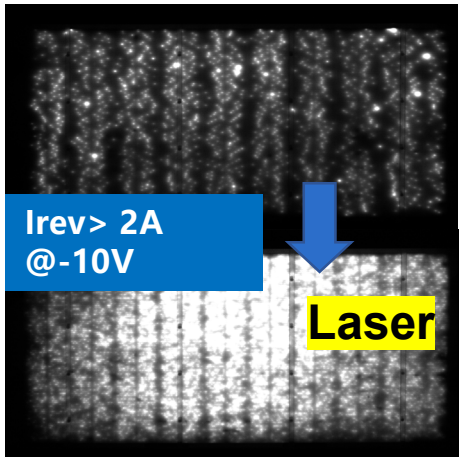
n-TBC

boron diffusion juction



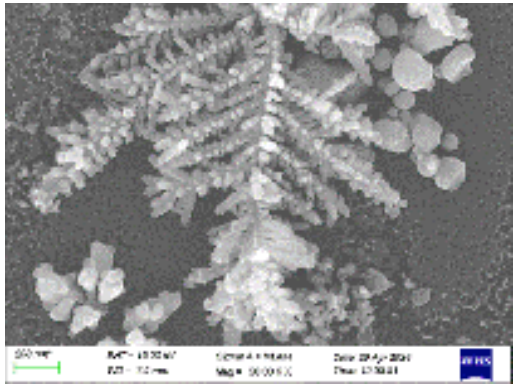
It is hard to creat enough electrons required for silver redox ibecause of low breakdown voltage





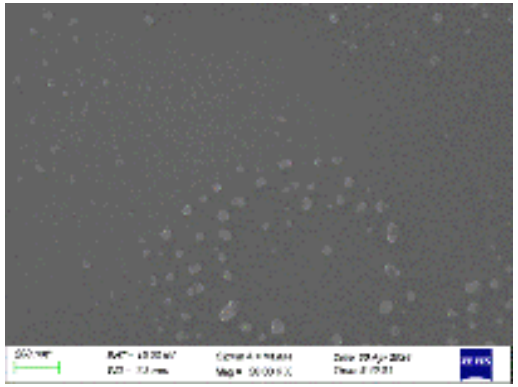
Standard: $\rho_{c,-p}$~ 1mΩ·cm2

Fire→LED furnace hygrogenation



Laser induced Firing: $\rho_{c,p}$~ 10mΩ·cm2

Fire→Laser induced contact formation



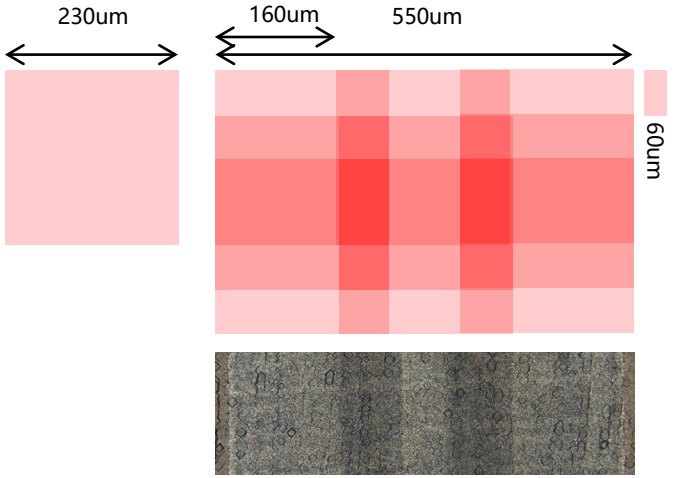
Block 5，Expensive Laser

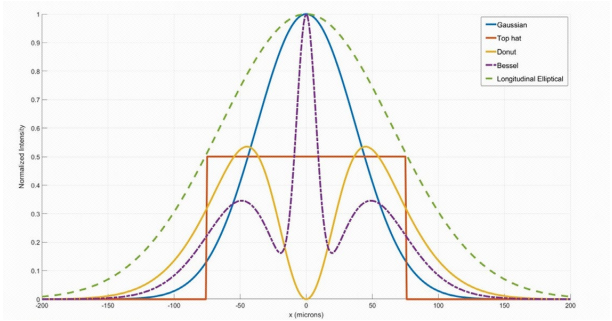
- Pico second laser is required to open PSG or BSG for patterning.
- Ultra fast laser gaussian beam is shaped by DOE.
- Single spot of laser is shaped to “Donut”.
- 50% overlap is applied for complete opening.

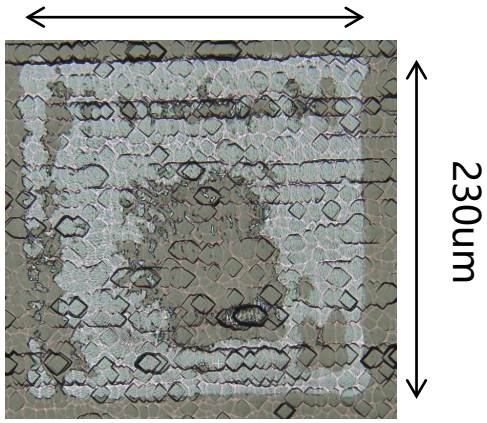
The trouble is TBC requires over 100% area patterning.

Over 100W high power laser is still expensive for solar.

Moreover, the yield is too low for single laser head.







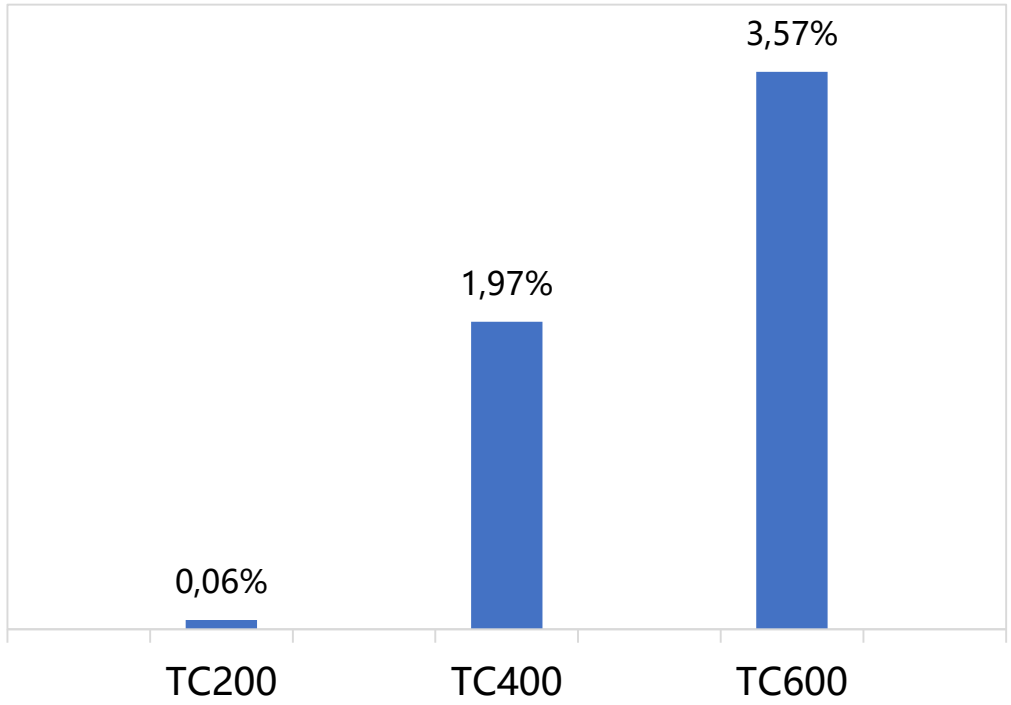
Bakhtari A R, Sezer H K, Canyurt O E, et al. Advanced Engineering Materials, 2024, 26(14): 2302013.

Block 6，thermal cycle

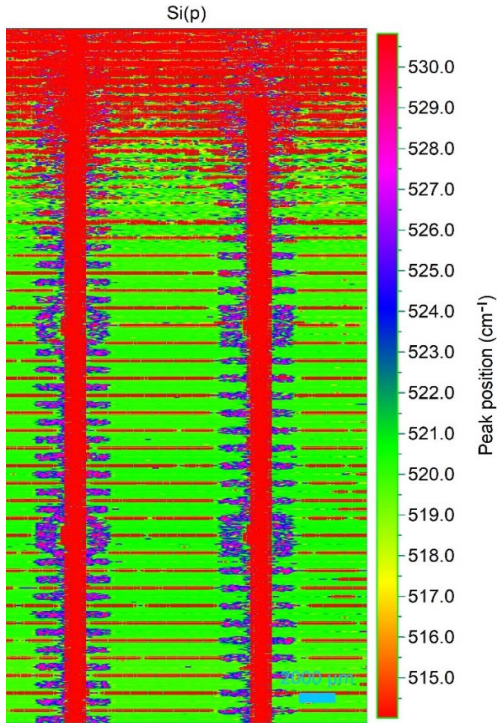
The tension between ribbon and Ag pad of back contact module is located at the cell edge, as shown in the Raman image.

After thermal cycle, delamination grows.

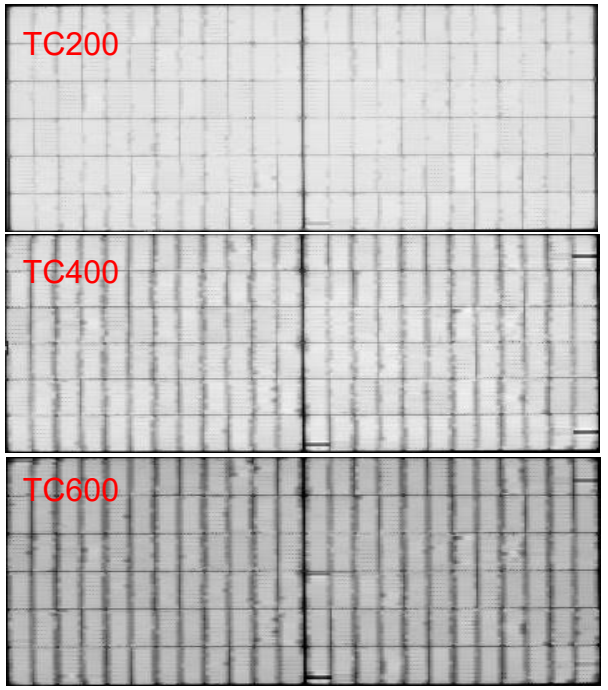
Module efficiecy loss after thermal cycle



Raman image of silicon



Electroluminescence image



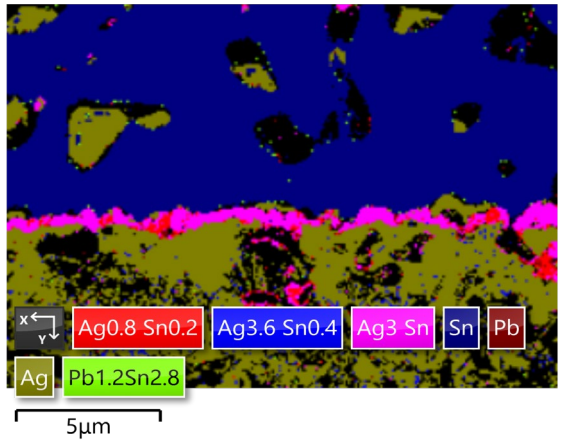
Block 7，Ag consumption in solder joint

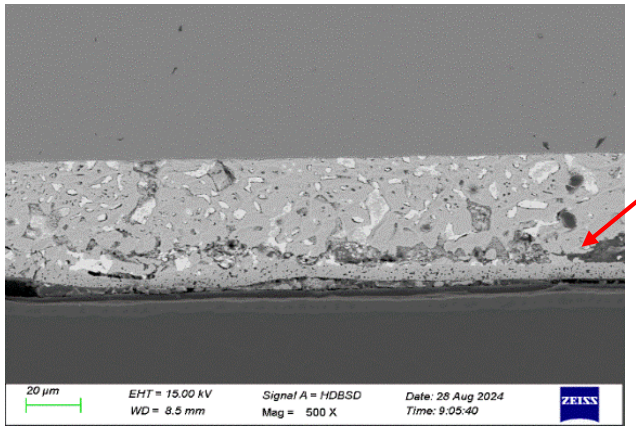
Sn diffusion to Ag attacks solder joint. Delamination is often discovered after damp heat as well.

Zero busbar BC module design is also restricted by edge sold pad area.

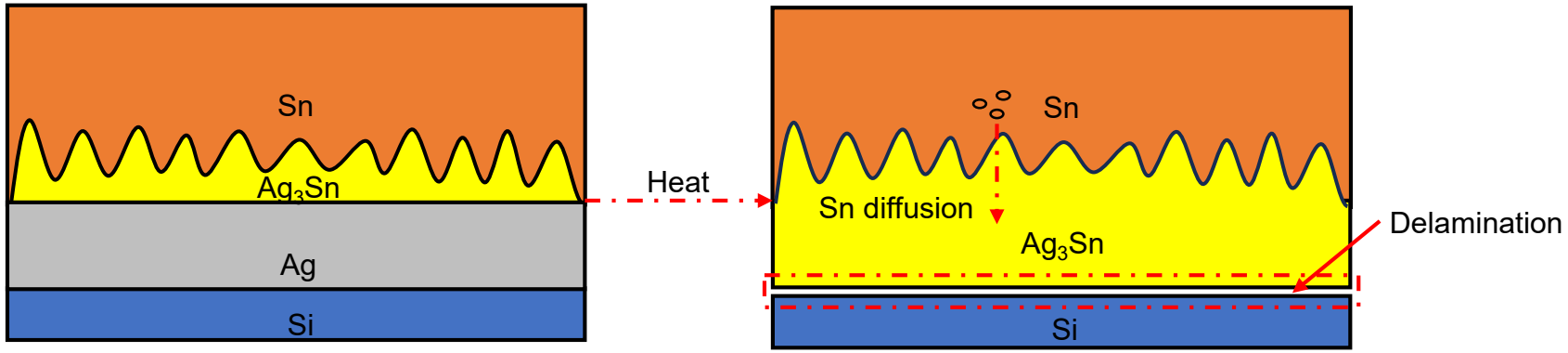
TBC back contact solder joint is over **3mg/W**. nealy 40% of TOPCon Ag paste

Silver cost for BC is nearly 1.5~2 time as TOPCon. Is copper the solution? **Plating or Copper Paste?**





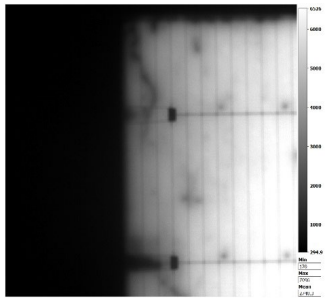
Delamination



Jeon Y J, Kang M S, Shin Y E. . International Journal of Precision Engineering and Manufacturing-Green Technology, 2020, 7: 89-96.

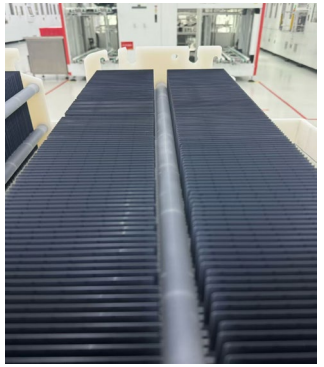
Conclusion

Back contact cell reaches top 3 in solar efficiency table in practical.



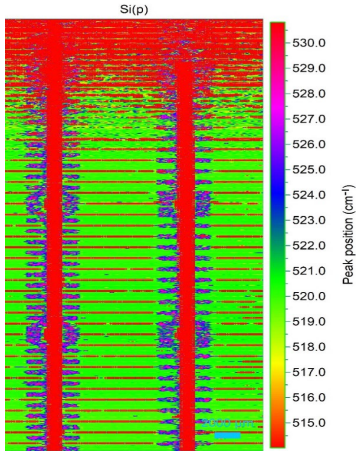
There are still several blocks fot TBC cell mass production:

1. Bifacial limit,
2. Deligent rising star TOPCon in-line upgrade rapidly,
3. EFF of half cut loss,
4. Simplified TBC structure with boron diffusion junction but not easy in experiment trial,
5. Expensive laser and low yield,
6. Thermal cycle induced delamination,
7. Ag consumtion in solder joint.



TBC and HTBC will be one of the future.

Half cut and tools are one possible solution trial for future mass production



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Thanks!