Australian National University

Progress of IBC Si solar cells

(ACAP PP1.2a)

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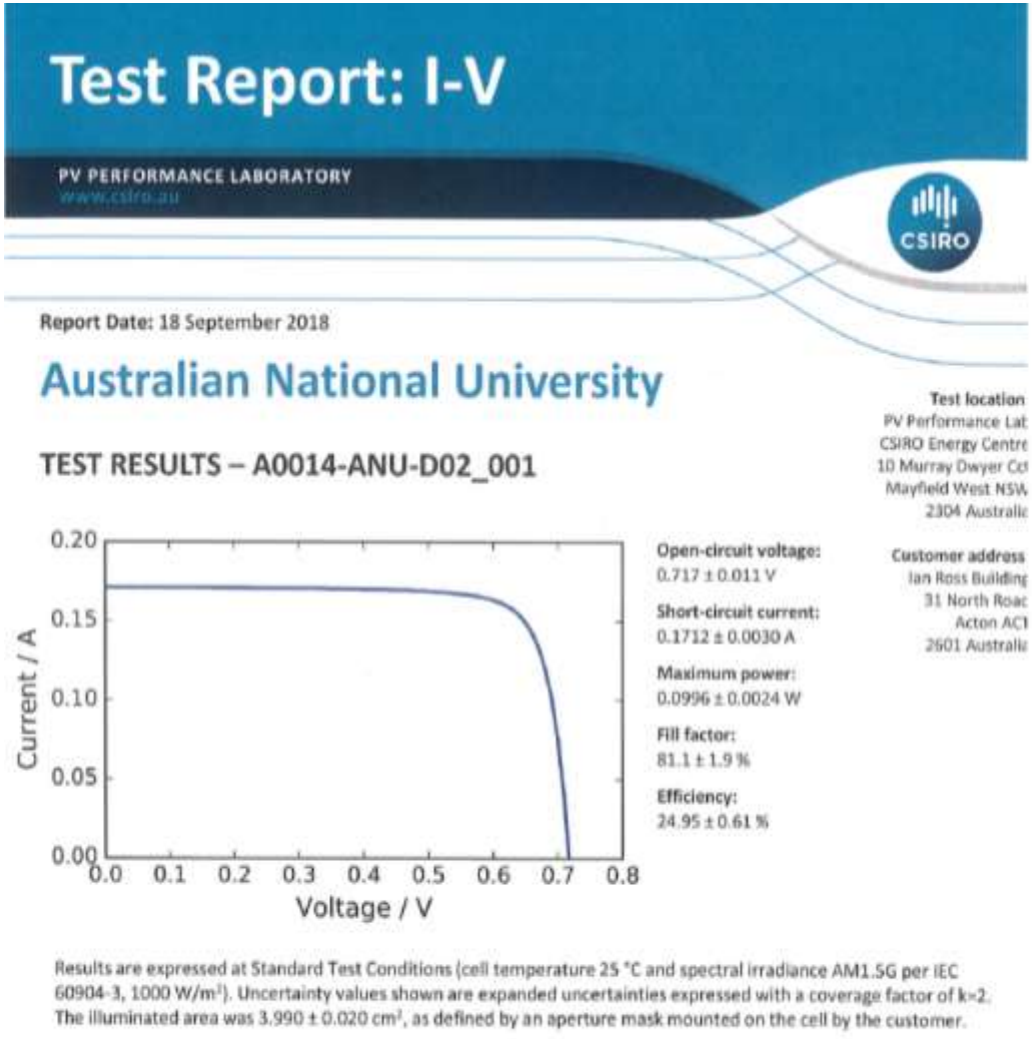
ANU 25% IBC Solar Cell

In 2018, ANU received certification for a **24.95 ± 0.61%** single-junction Si solar cell.

- V_{OC} 717 mV
- J_{SC} 42.9 mA cm^{-2},
- FF 81.1

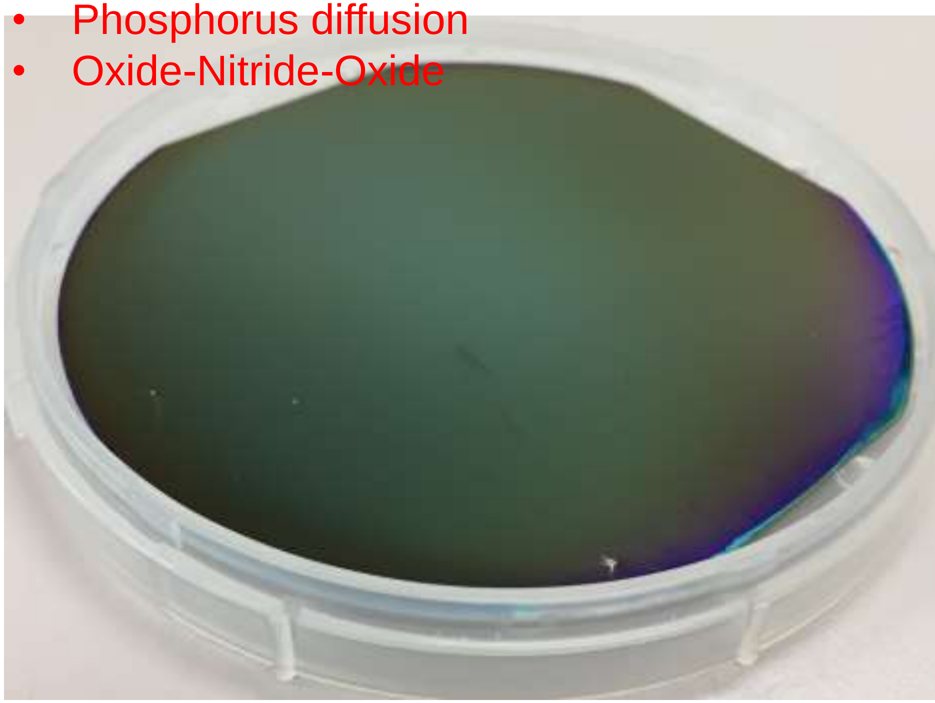
Key features of the cell:

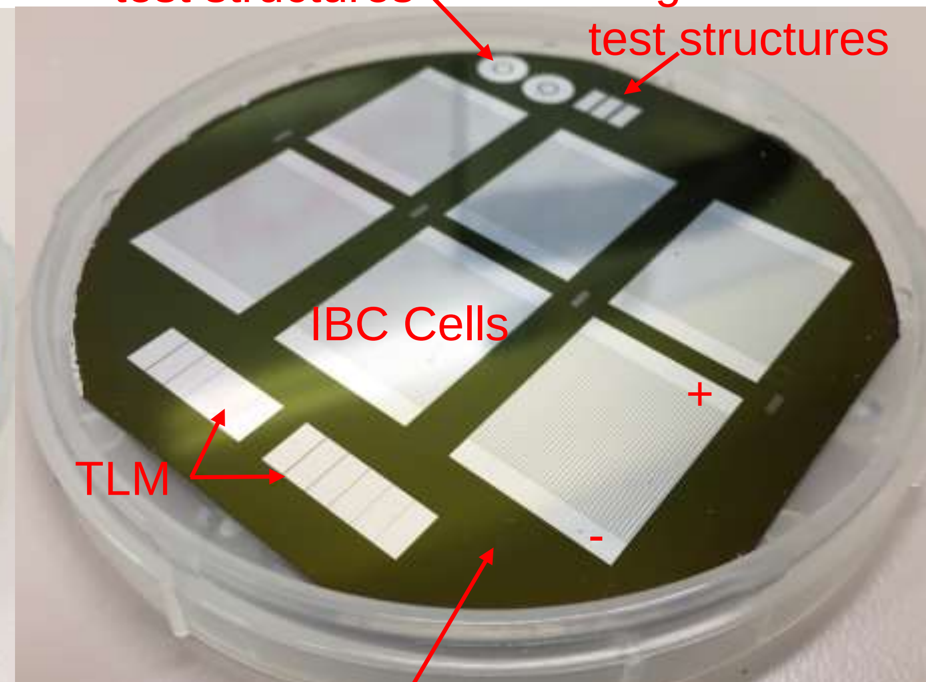
- Oxide-Nitride-Oxide passivation
- High bulk lifetime >50ms
- Excellent light trapping



ANU 25% IBC Solar Cell

Front surface:
- Textured
- Phosphorus diffusion
- Oxide-Nitride-Oxide



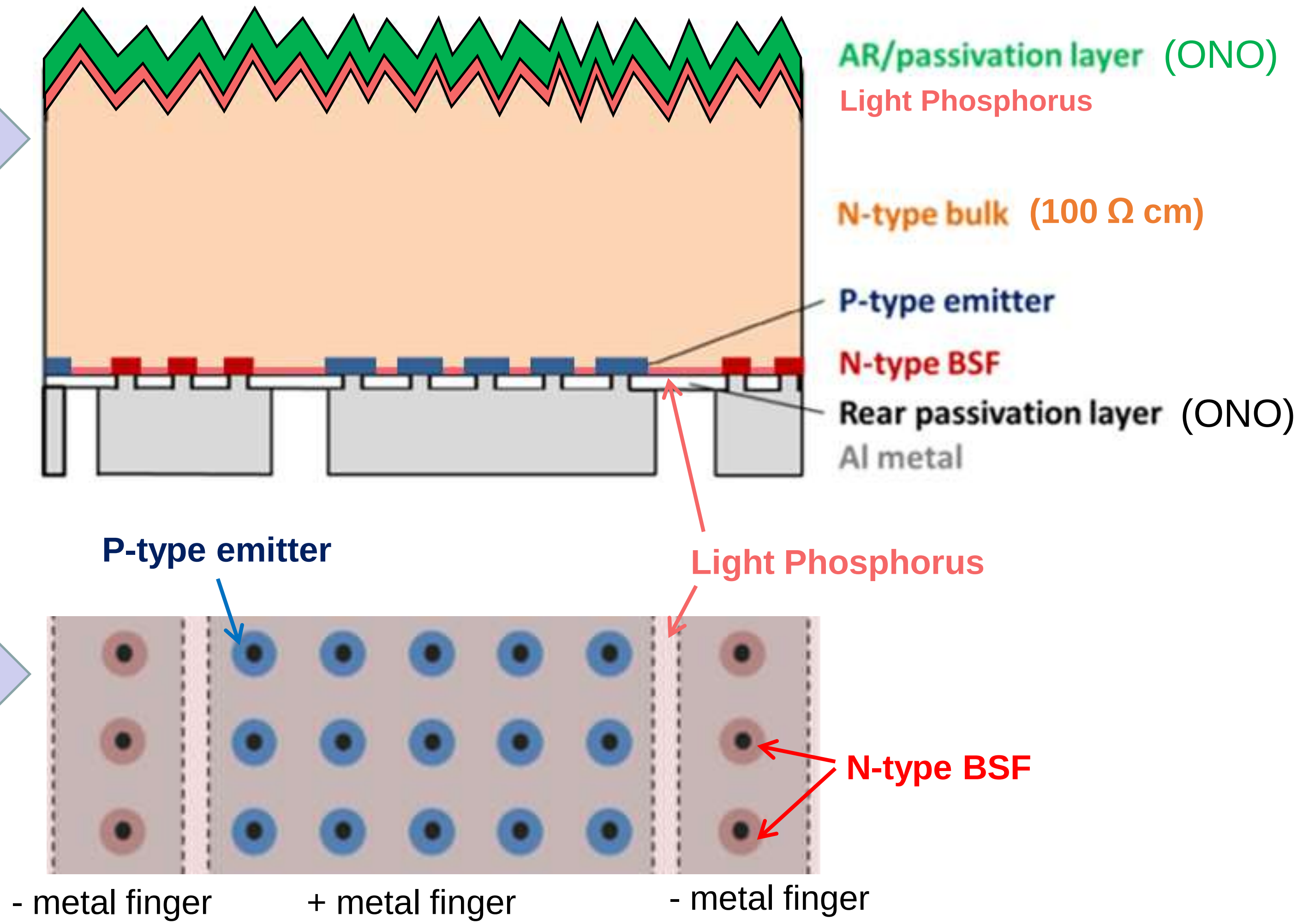


Rear surface:
- Non-textured
- Phosphorus diffusion
- Oxide-Nitride-Oxide

ANU 25% IBC Solar Cell

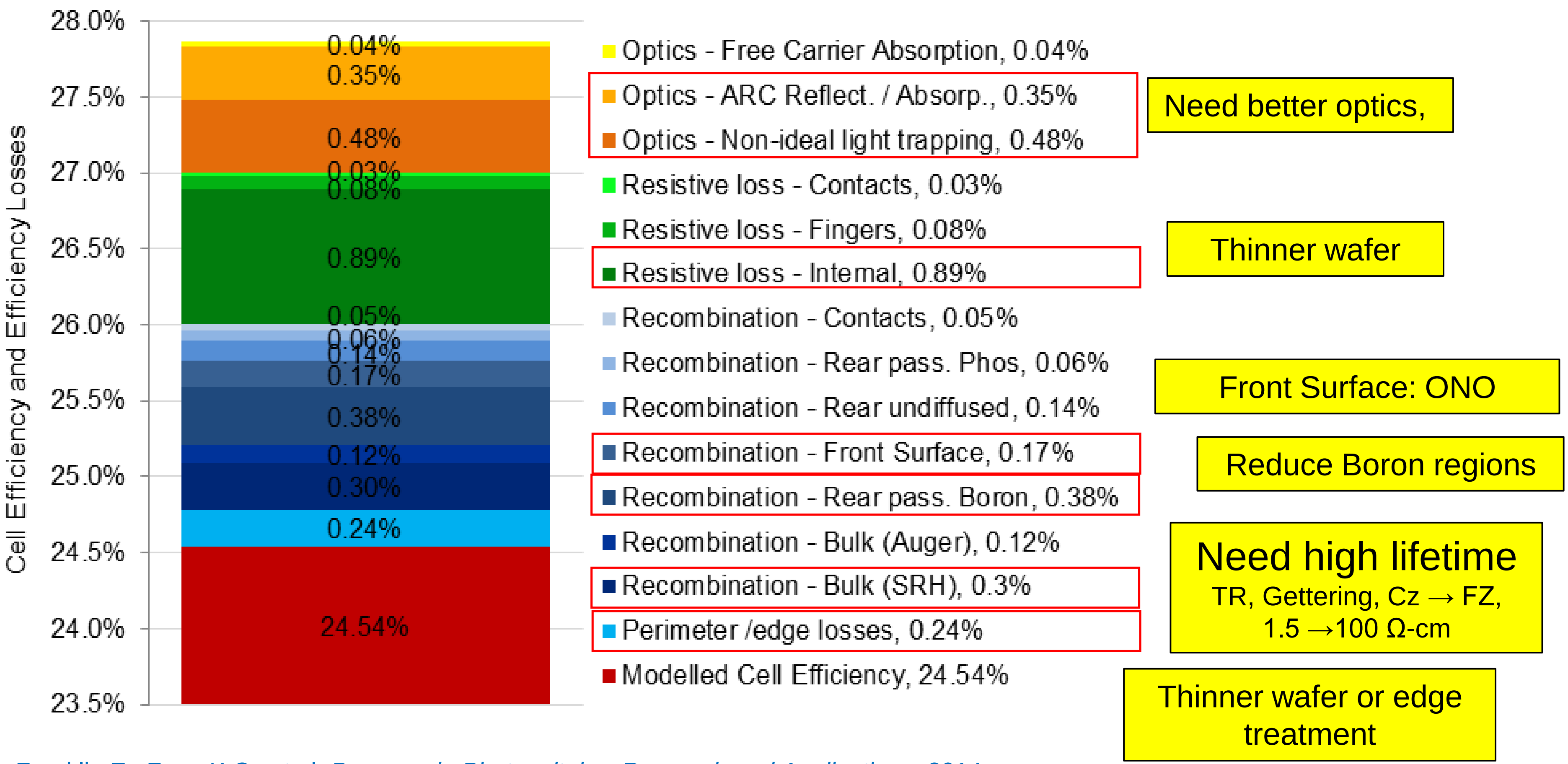
Cross section

Bottom-up View



Key design improvements

Loss analysis of (2014) 24.4% IBC cell:

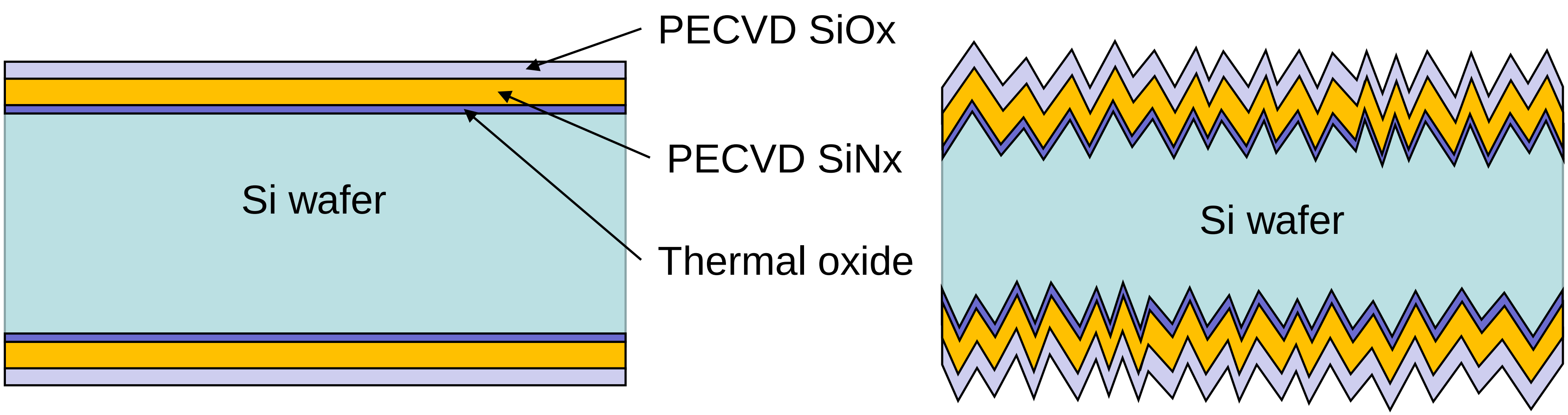


Franklin E., Fong K.C., et al, *Progress in Photovoltaics: Research and Applications,* 2014

Oxide-Nitride-Oxide

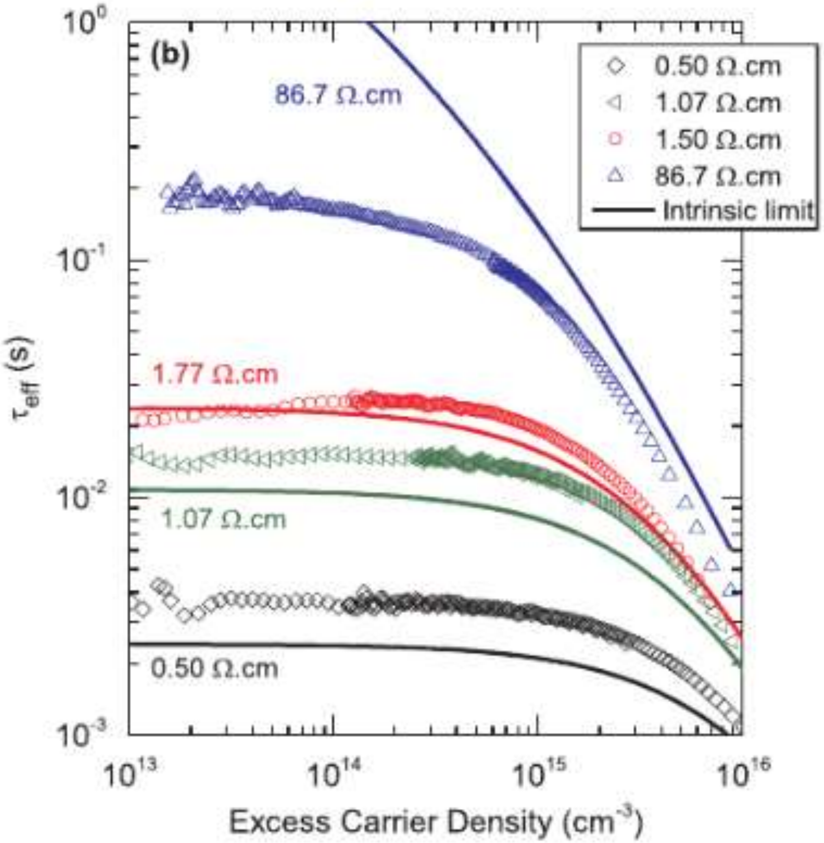
Origin:
The idea of ONO passivation is derived from SONOS memory cells, which has properties of being chargeable with good charge retention capacity.

It turns out, that an ONO performs excellently as a passivation layer, and surface charges can be tuned from +ve to –ve.



Oxide-Nitride-Oxide

O-N-O on undiffused Si

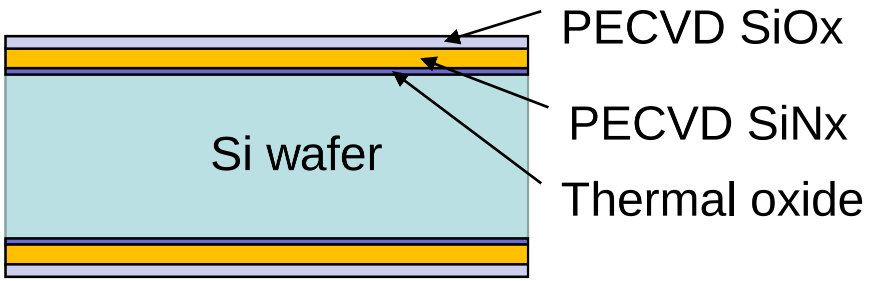


Planar:

- < 0 fAcm^{-2}, exceeding (Richter) Auger lifetime limits.

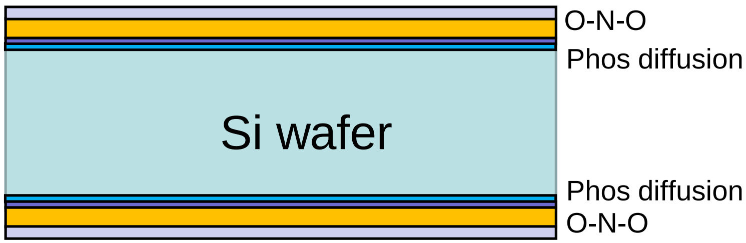
Random Textured:

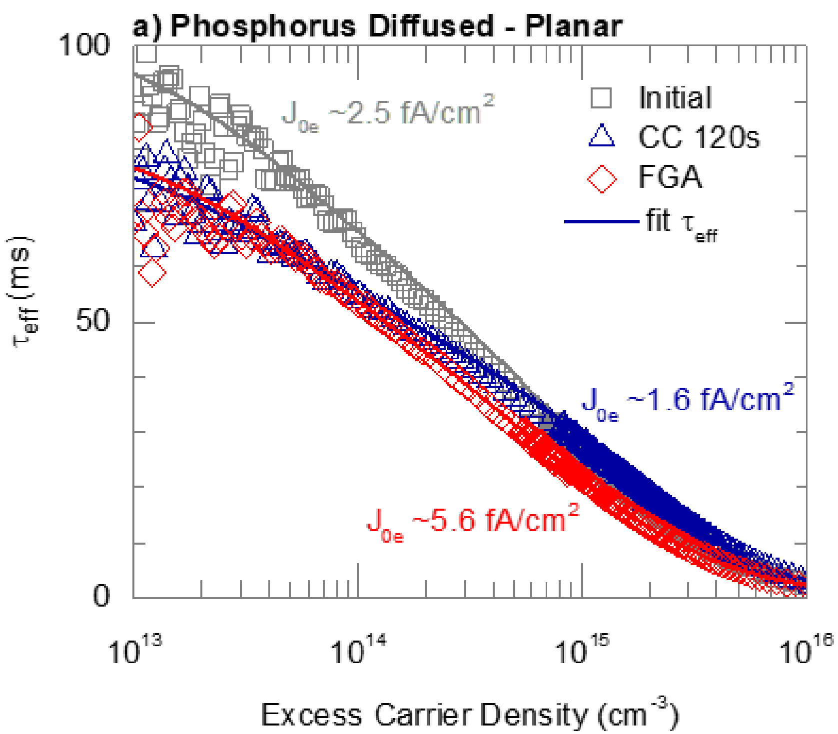
- ~ 1-5 fAcm^{-2}

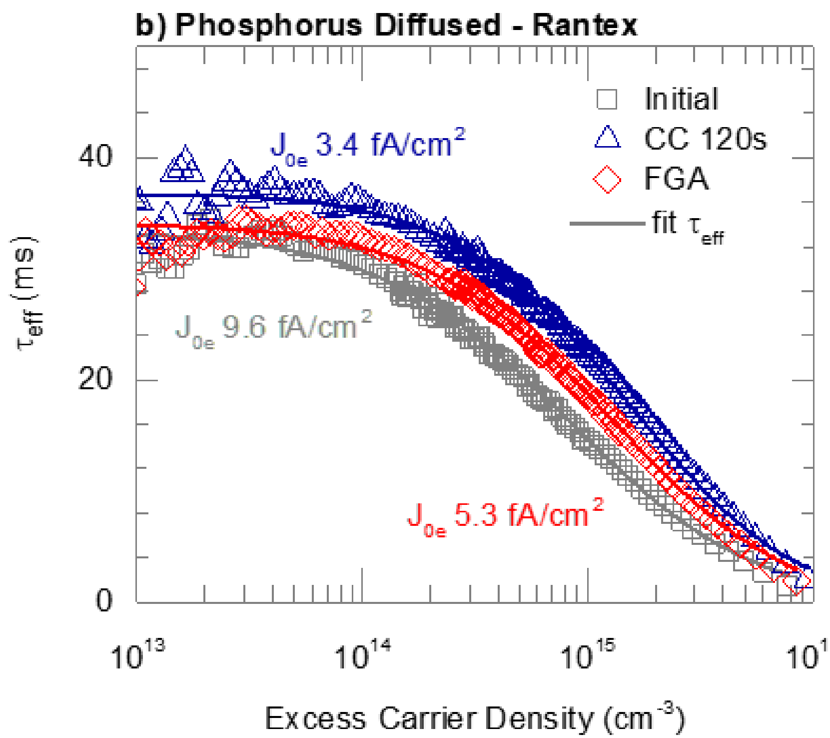


T.C. Kho, K.C. Fong, et al., "Exceptional silicon surface passivation by an ONO dielectric stack", Solar Energy Materials and Solar Cells, 2018.

Phos diffused ONO

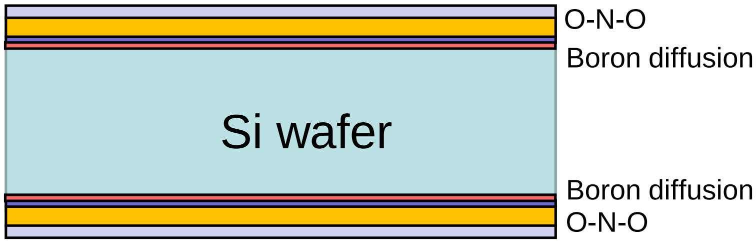


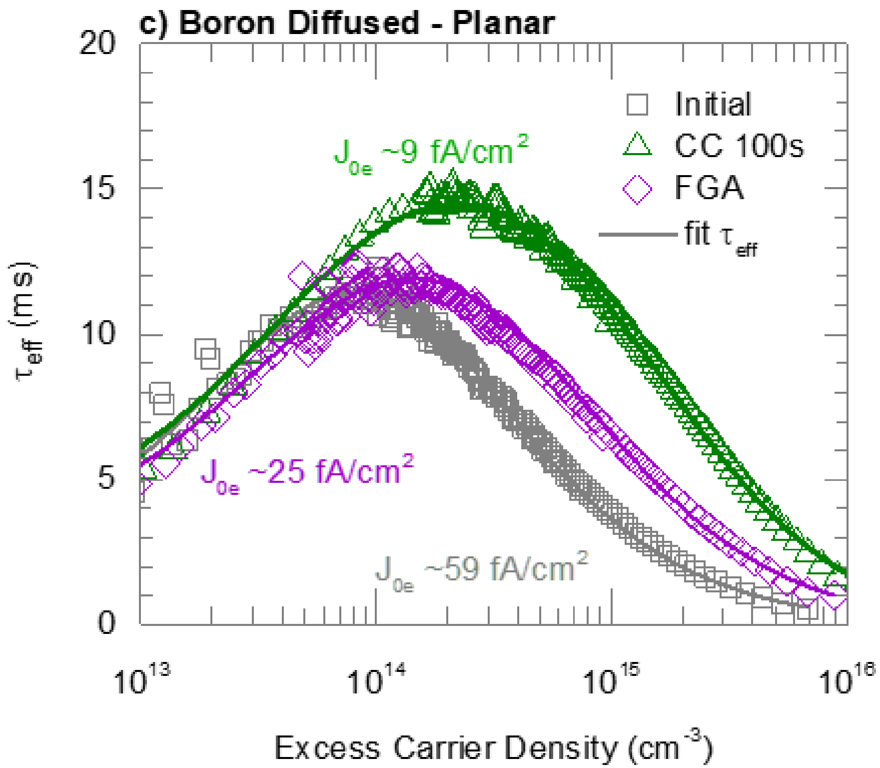




T.C Kho, PhD thesis , in preparation. (est. 2019)

Boron diffused- ONO





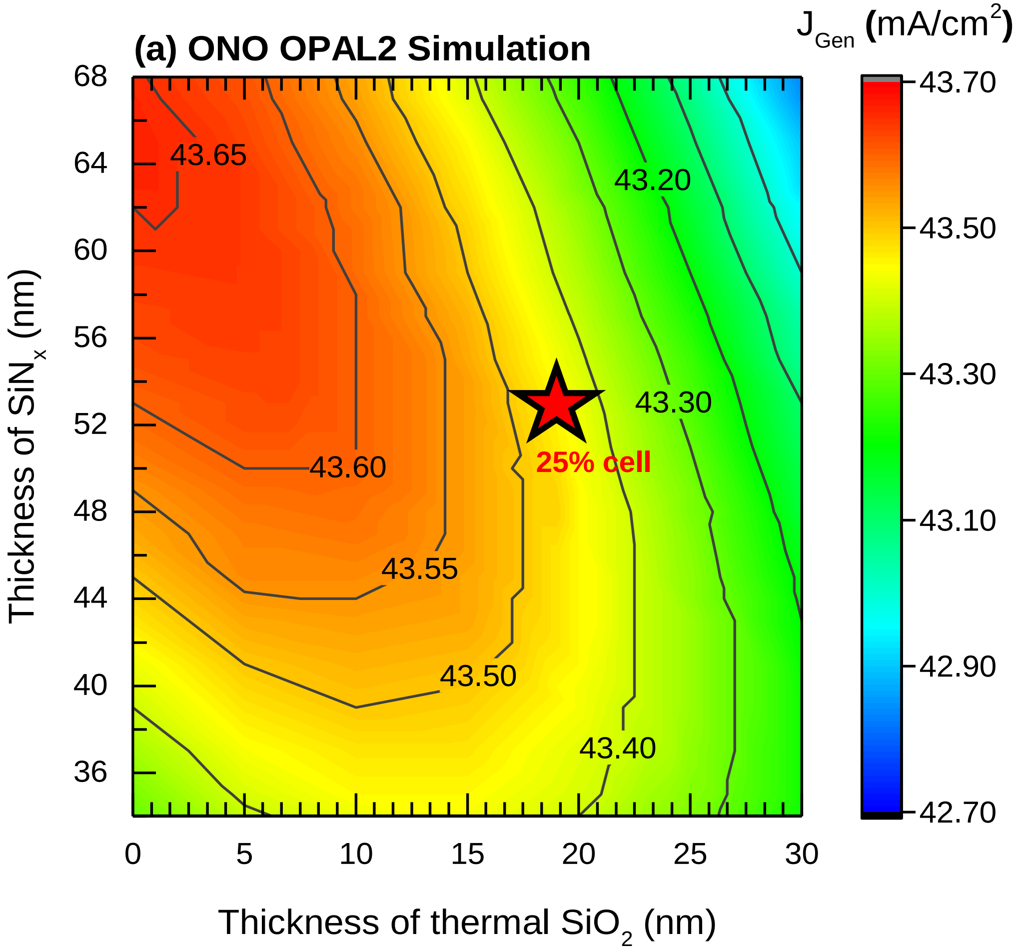
- Uncharged 25 fAcm^{-2}
- Negatively charged J_0 at 9 fAcm^{-2}

T.C Kho, PhD thesis , in preparation. (est. 2019)

Optics of ONO

Optimal Optics is achieved when SiO2 is thinnest.

- Trade-off between optics & passivation



T.C Kho, PhD thesis , in preparation. (est. 2019)

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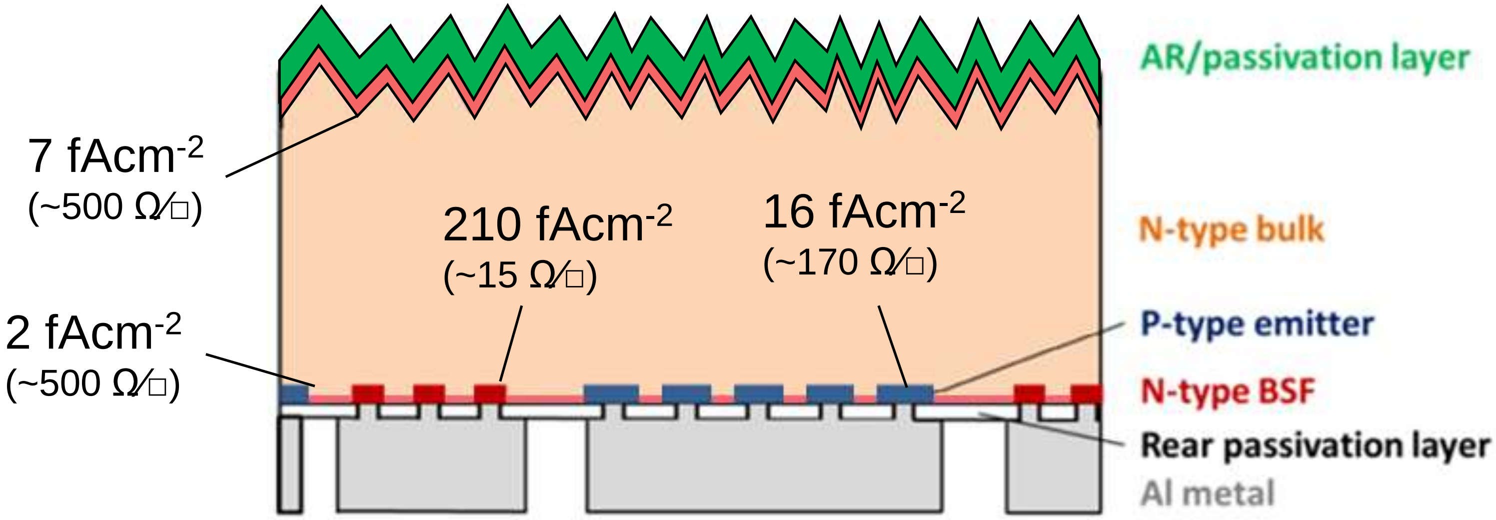
Application of ONO to IBC cells



Area Weighted J_0 indicates the surfaces and contacts contribute approximately 16 fAcm^{-2} to the entire cell.

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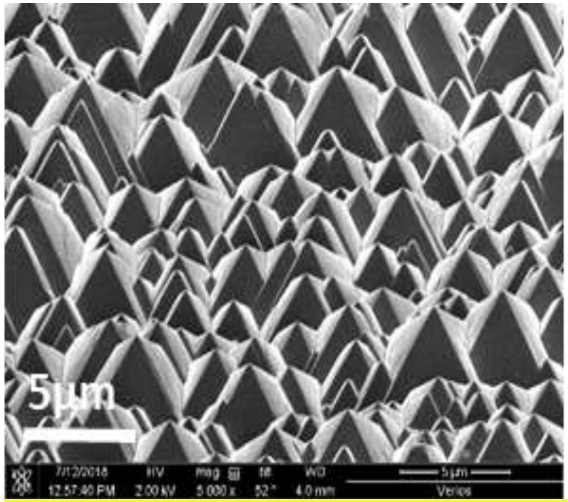
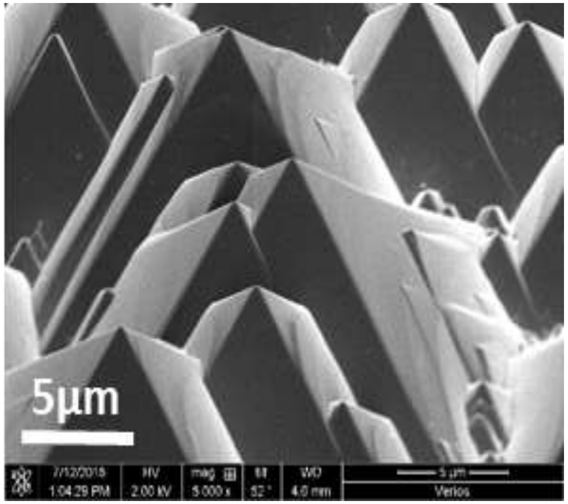
Improvement to Texturing

- ANU adopted the use of monoTEX additive for the formation of random pyramid structures.
  - **Physical :** Uniform, repeatable, smaller pyramids (~3um), consumes less silicon (~10um)
  - **Electrical :** Slightly higher bulk lifetimes achieved in controlled test versus TMAH-IPA texturing.



TMAH + MonoTEX
(presented improvement)

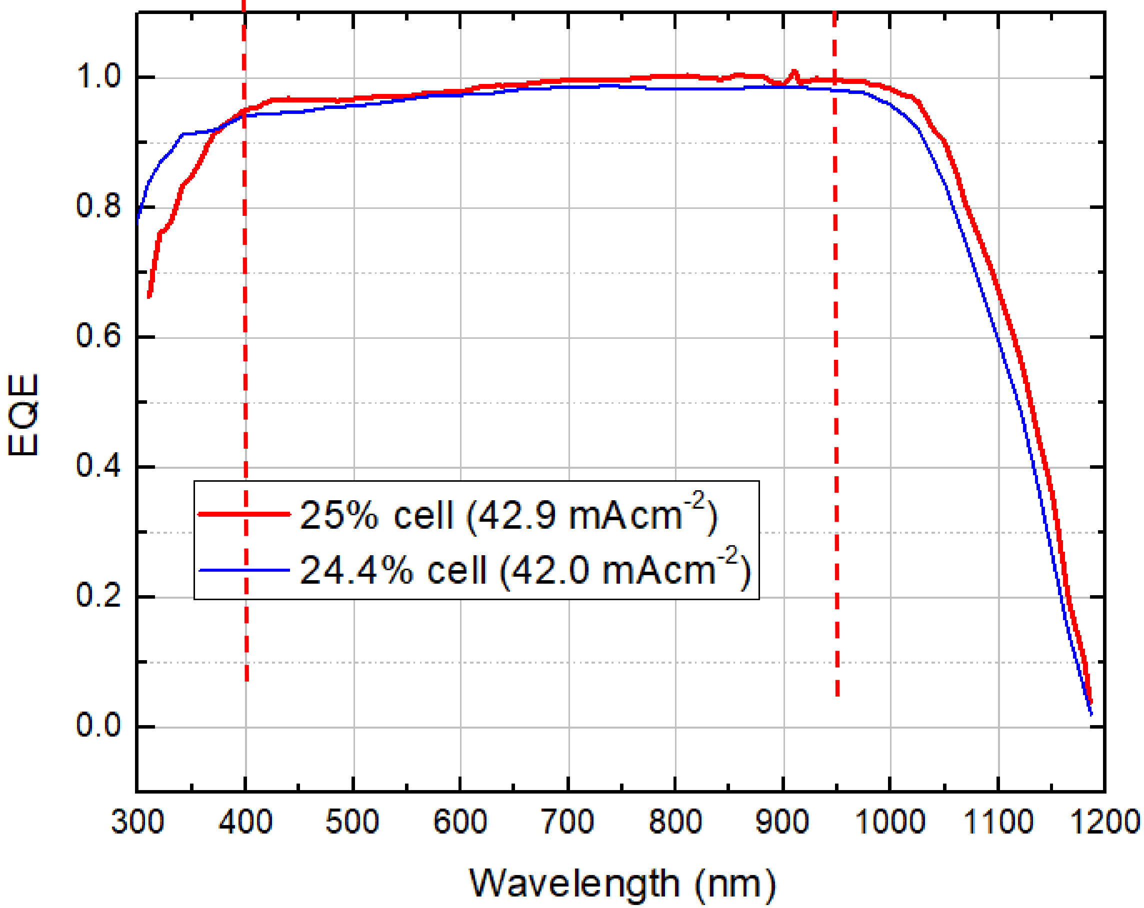


TMAH + IPA

W.S.Liang, K.C. Fong, et al, "TMAH etchant and monoTEX agent induced highly reproducible and non-metal contamination c-Si texturing*", ASPRC 2018*

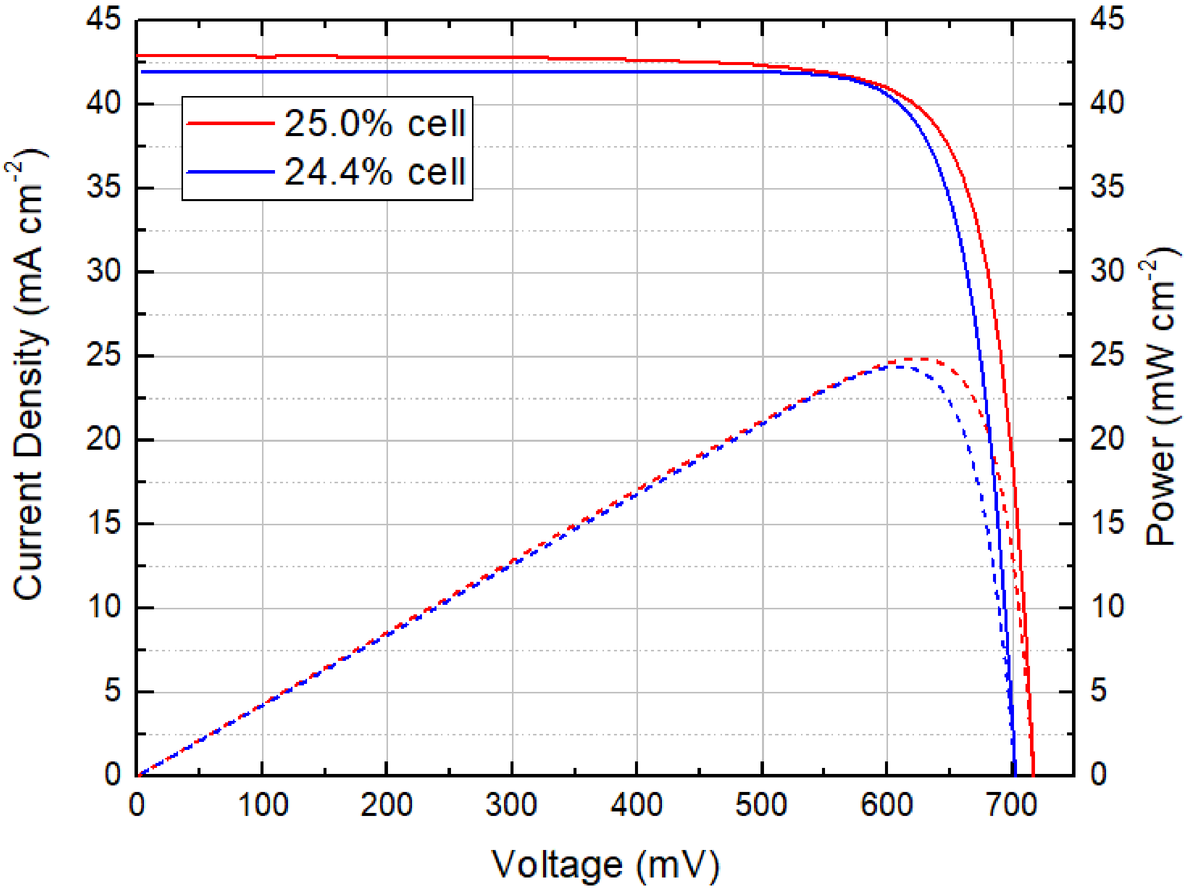
Quantum Efficiency

300-400 nm	400-950 nm	950-1200 nm
-0.04 mA cm^{-2}	+0.4 mA cm^{-2}	+0.5 mA cm^{-2}



IV measurements

- High V_{OC} of 717 mV..
- Bulk lifetime >50ms before metallisation.
- High J_{SC} of 42.9mAcm^{-2}.
- But weak knee, low FF of 81.1.



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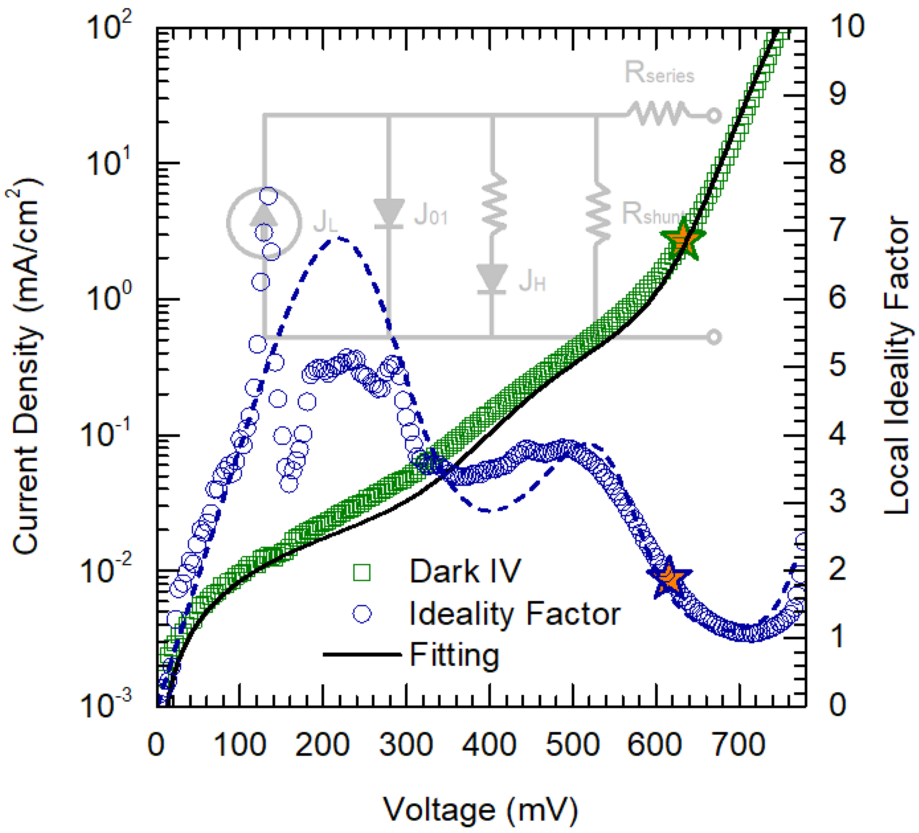
Future Improvements

- Low FF, identifying source of non-ideality
- Application of passivated contacts in combination with ONO



T.C Kho, in preparation for presentation at SiliconPV 2019.

ANU IBC Cell progression

2013: 24.4% (independently confirmed)

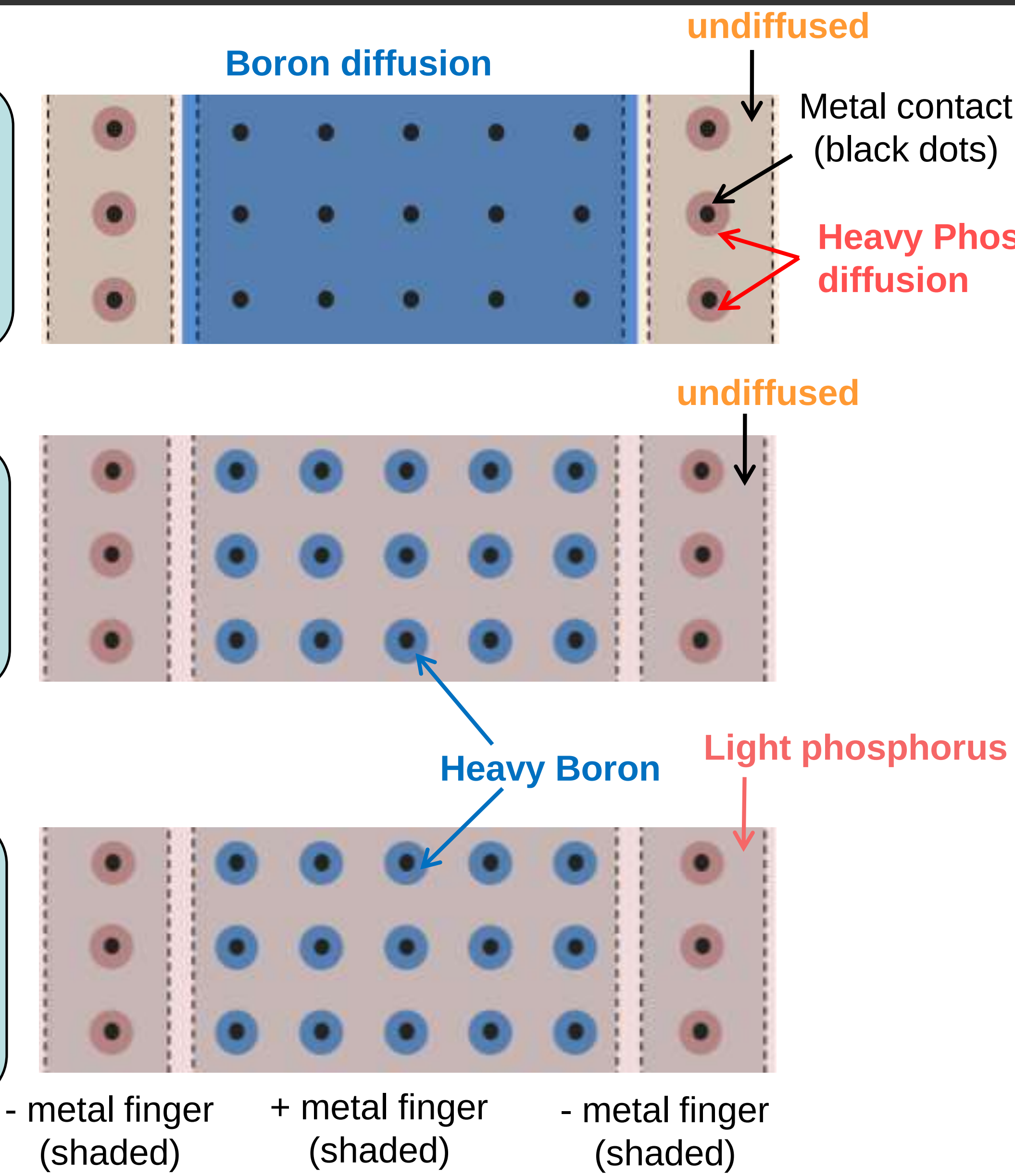
- 703mV, 42.0 $mAcm^{-2}$, FF 82.7%
- 1.5 Ohm-cm n-type
- PECVD SiN/SiO front, LPCVD SiO/SiN rear.

2016: 24.7% (in-house)

- 714mV, 42.0 $mAcm^{-2}$, FF 82.3%
- High resistivity (100 Ohm-cm)
- ONO passivation
- Phosphorus gettering

2018: 25.0% (independently confirmed)

- 717mV, 42.9 $mAcm^{-2}$, FF 81.1%
- Phos + BRL gettering
- Improved texturing (MonoTex)



Conclusion

- 25% efficient IBC cells fabricated at ANU.
- Key features: ONO, TMA-MonoTEX, Bulk lifetime (TR, BRL & Phos gettering.)
- Publications:

  - T. K. Choon, K.C. Fong, *et al.*, *SOLMAT,* 2018.
  - W. S. Liang, K.C. Fong, *et al.*, *ASPVC, 2018*.
  - E. Franklin, K.C. Fong, *et al.*, *PIPV,* 2016.
  - K.C Fong, et,al, JPV, 2016.
  - K.C Fong, et,al, JPV, 2015.
  - A.Fell, K.C. Fong, JPV, 2014
  - K.R. McIntosh, PVSC 2014, … many more…

- Open to collaboration.