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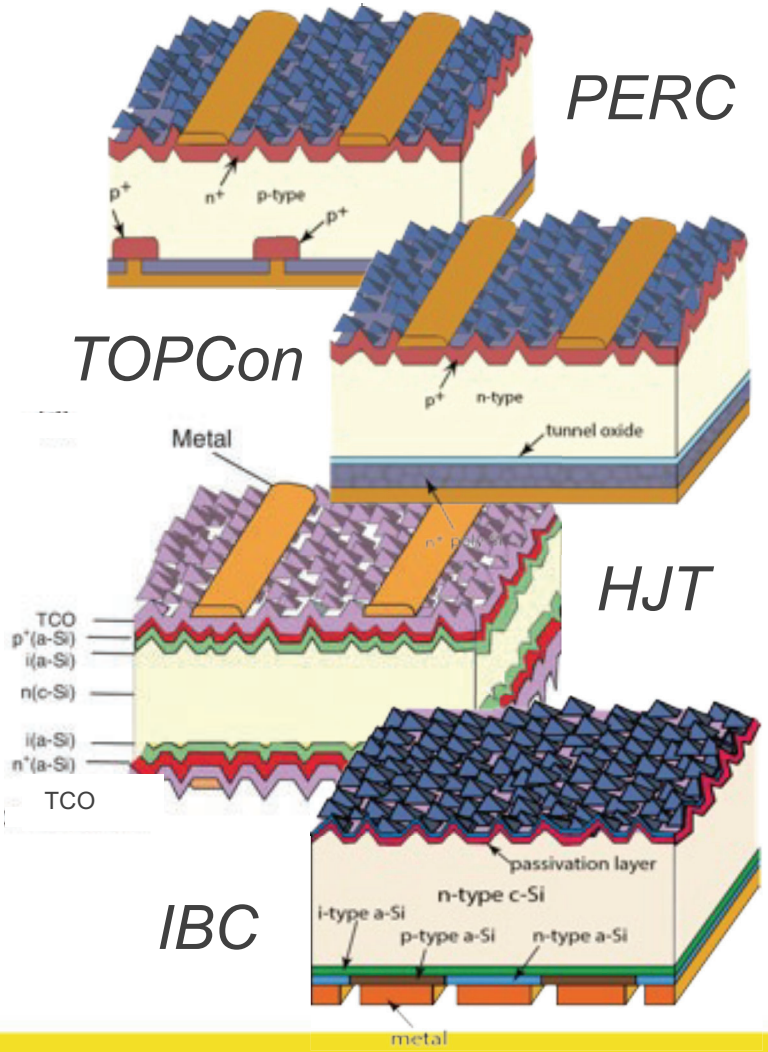
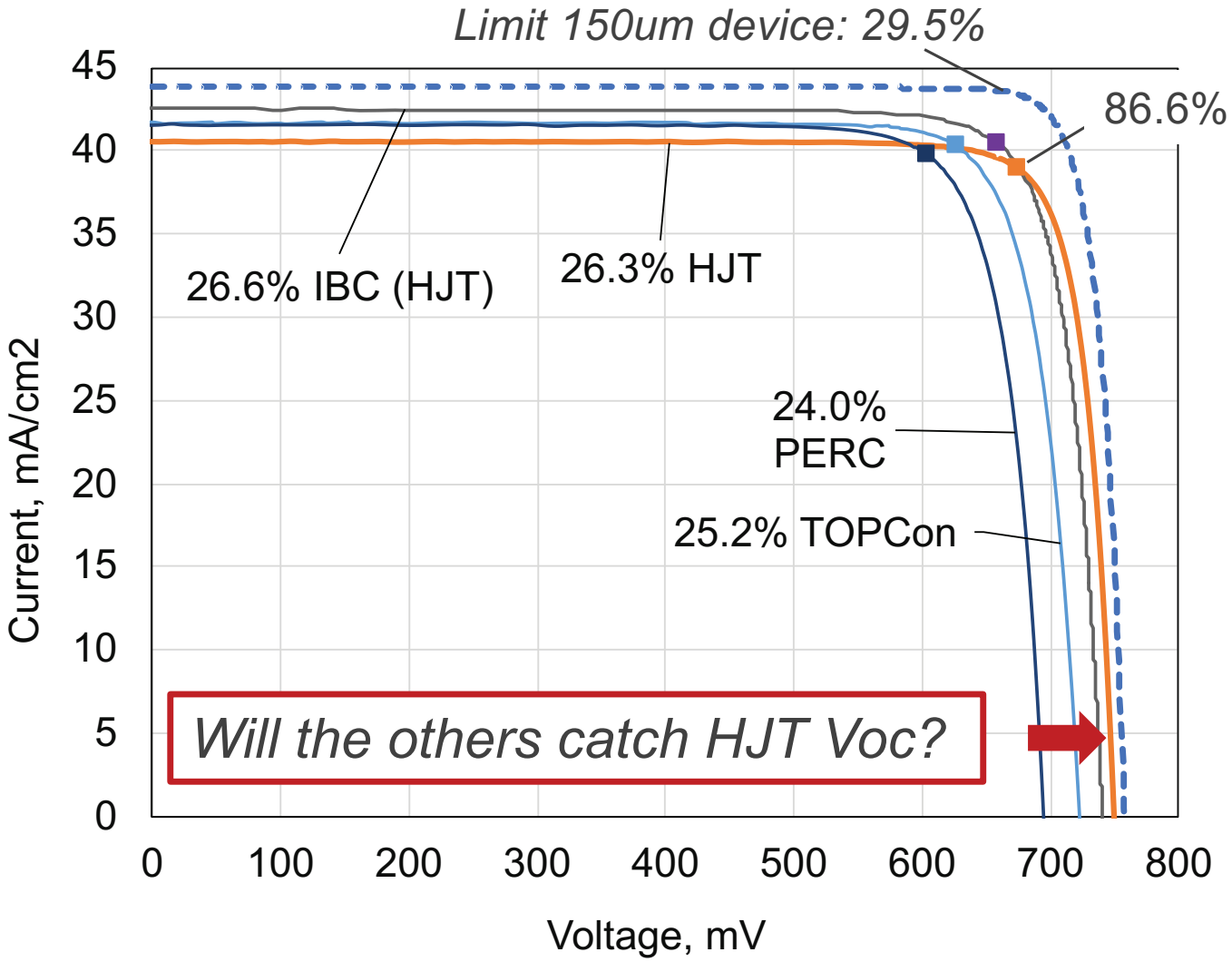
ARENA | Australian Government | Australian Renewable Energy Agency | ACAP

Si heterojunctions: How close can HJTs get to 29% cell efficiency?

Martin Green, UNSW Sydney

The contenders





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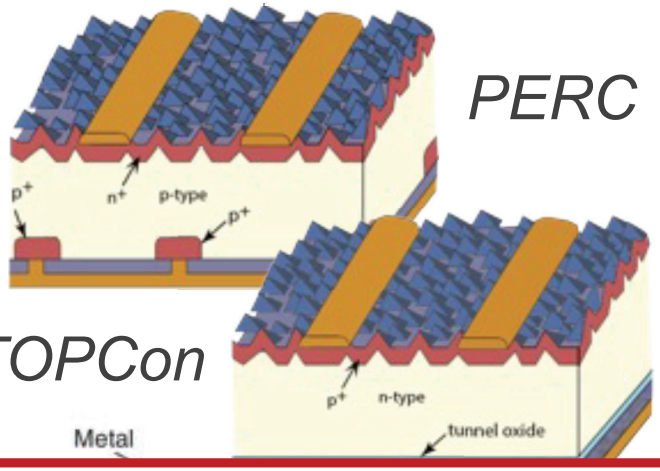
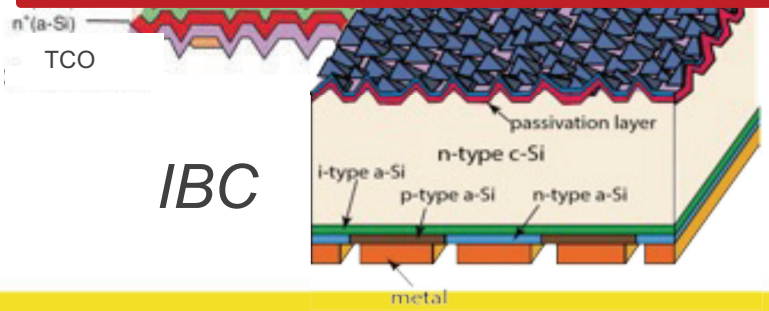
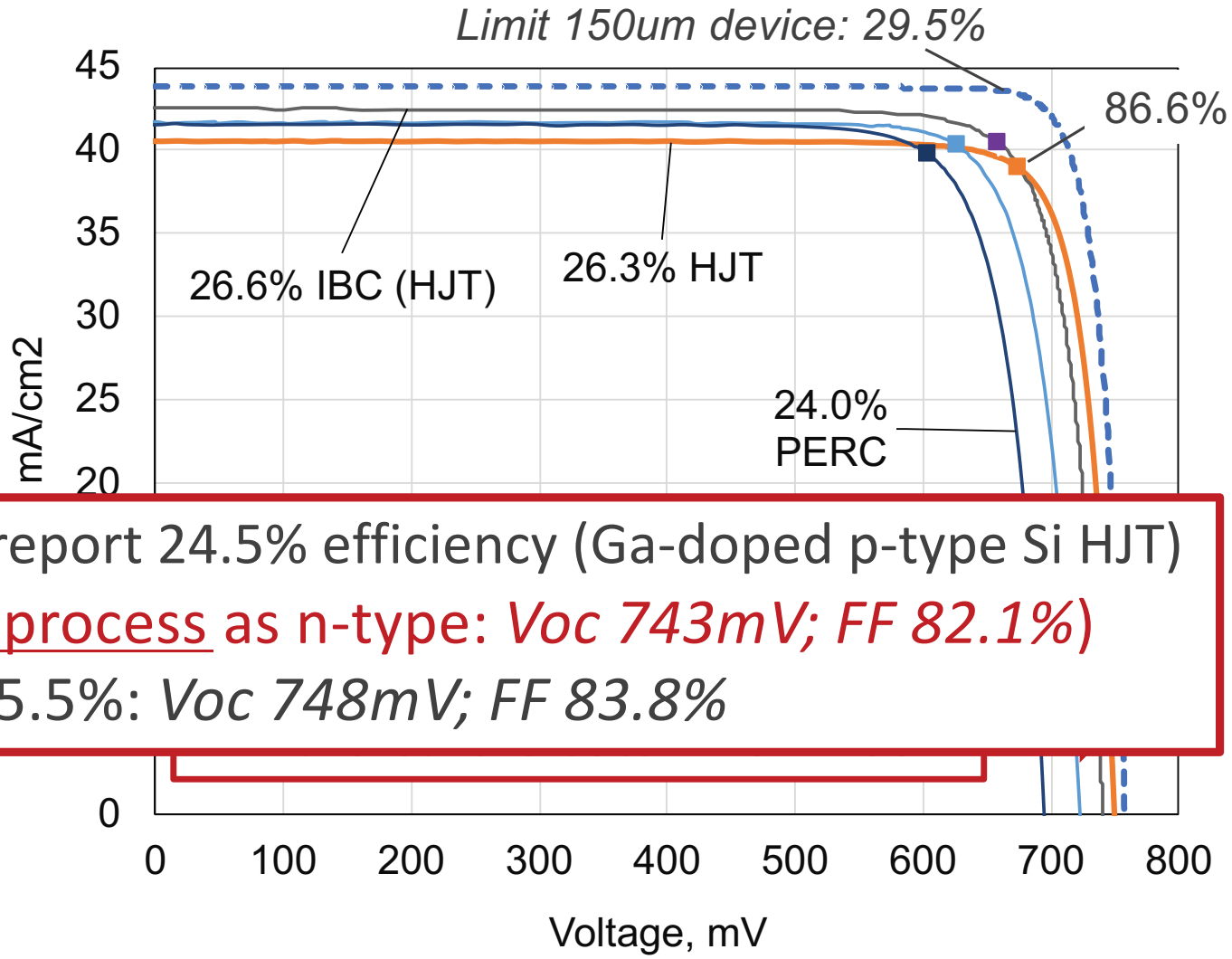




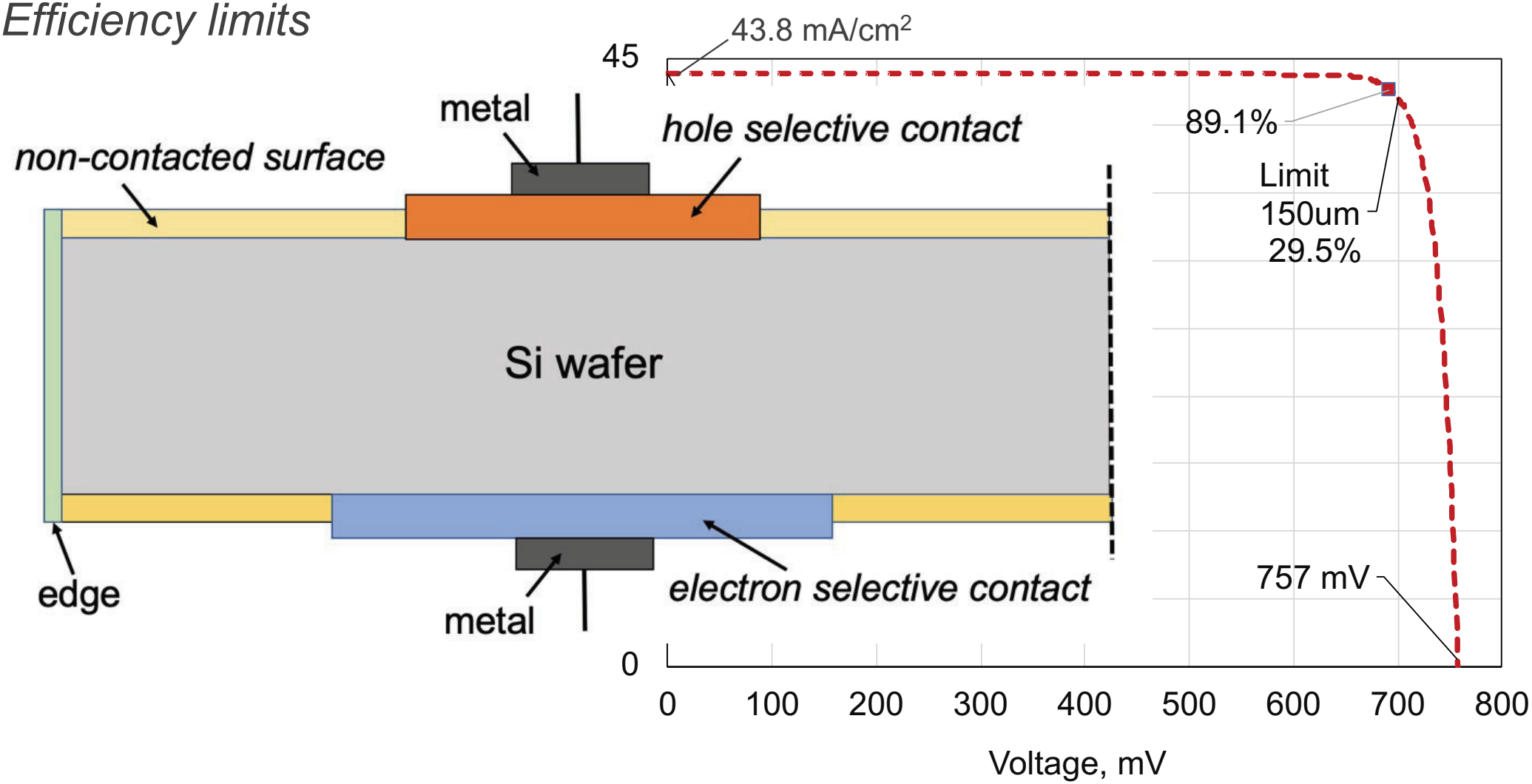


Mar29,2022: EGP/INES-CEA report 24.5% efficiency (Ga-doped p-type Si HJT)

(same manufacturing process as n-type: *Voc 743mV; FF 82.1%*)

LONGi reports 25.5%: *Voc 748mV; FF 83.8%*

Efficiency limits



Green, IEEE ED-31, 684, 1984; Tiedje et al., ibid., 711.

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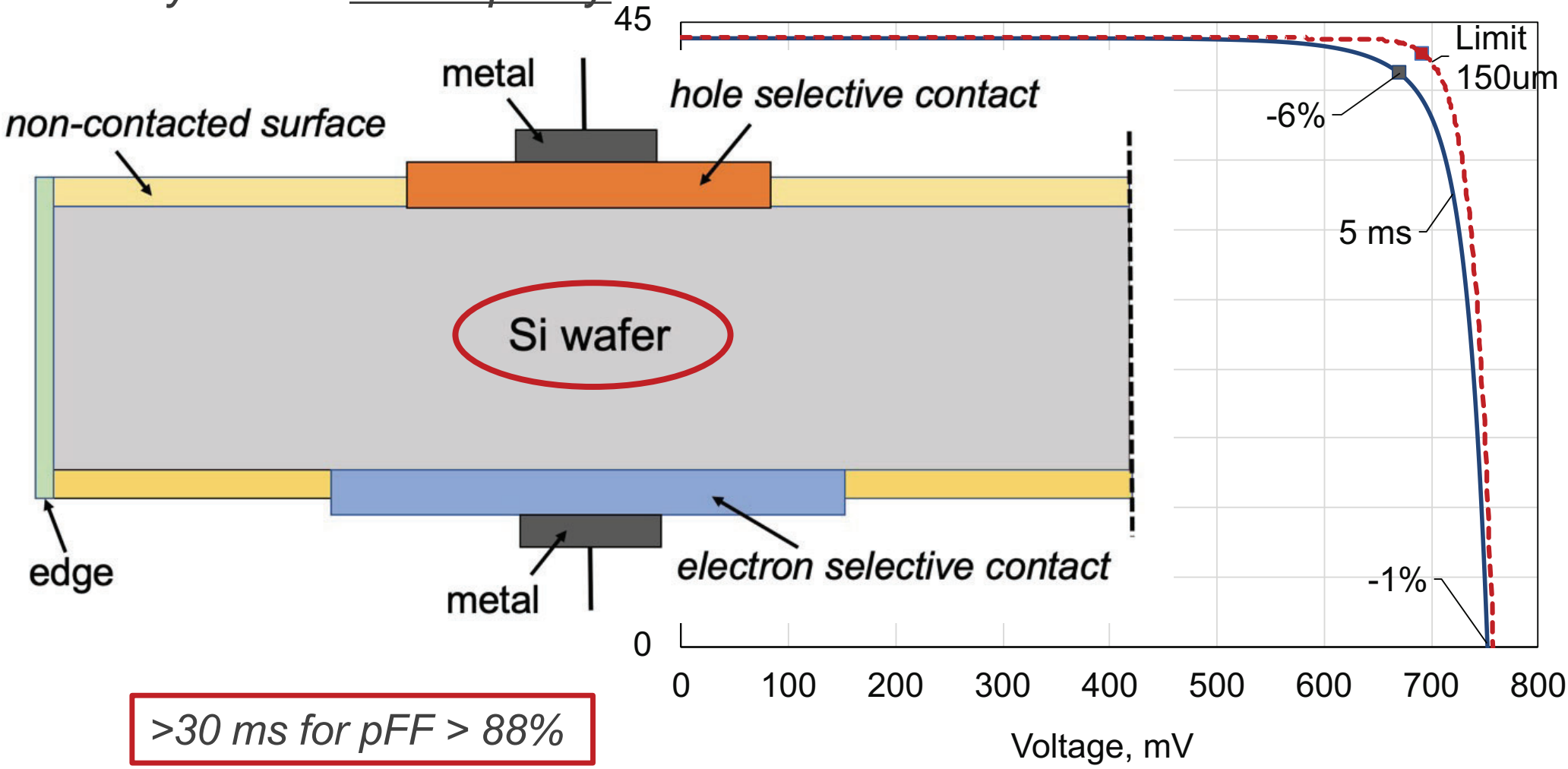
Efficiency limits –wafer quality?



>30 ms for pFF > 88%

Green, IEEE ED-31, 684, 1984; Tiedje et al., ibid., 711.

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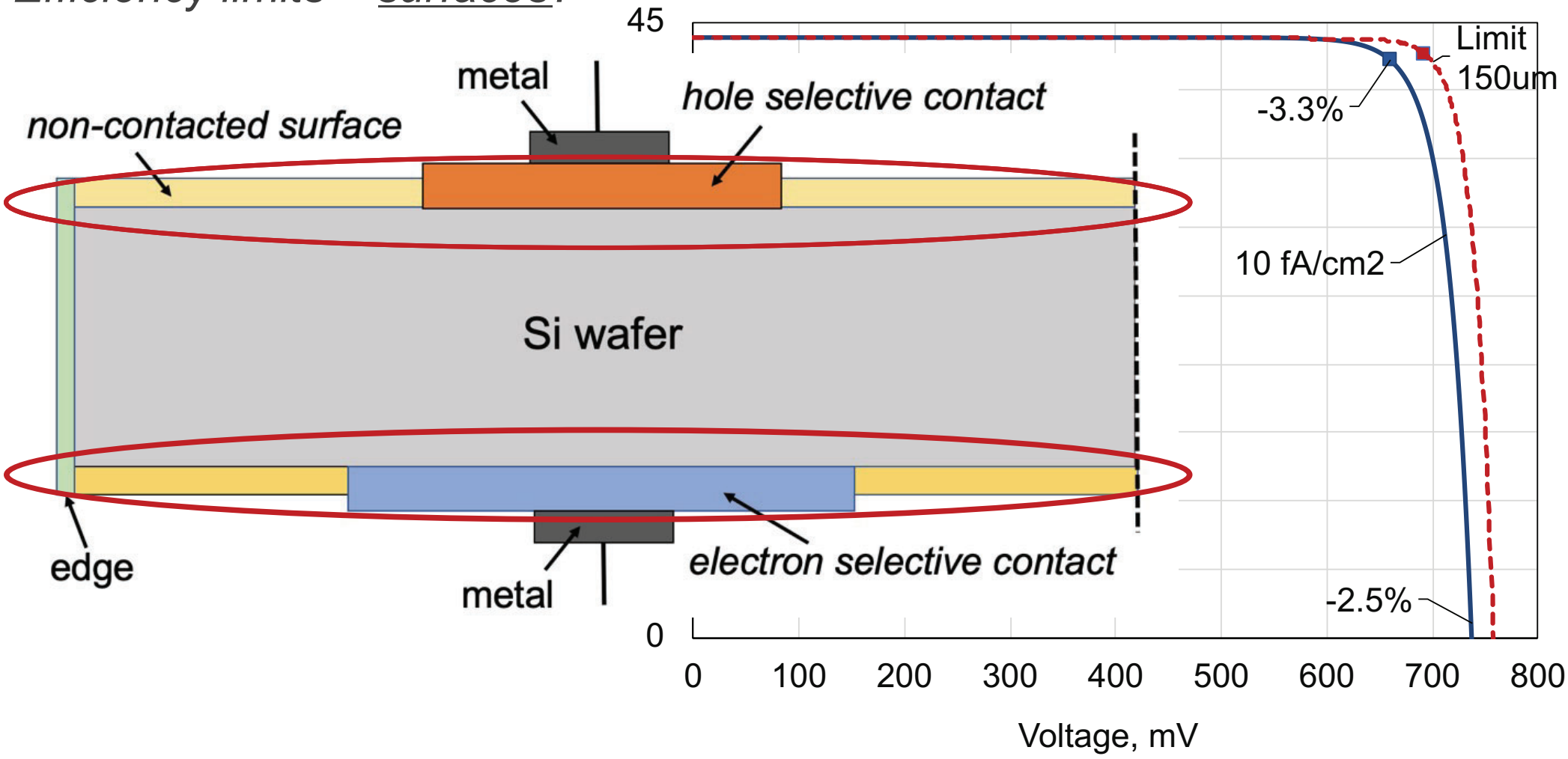
Efficiency limits – surfaces?



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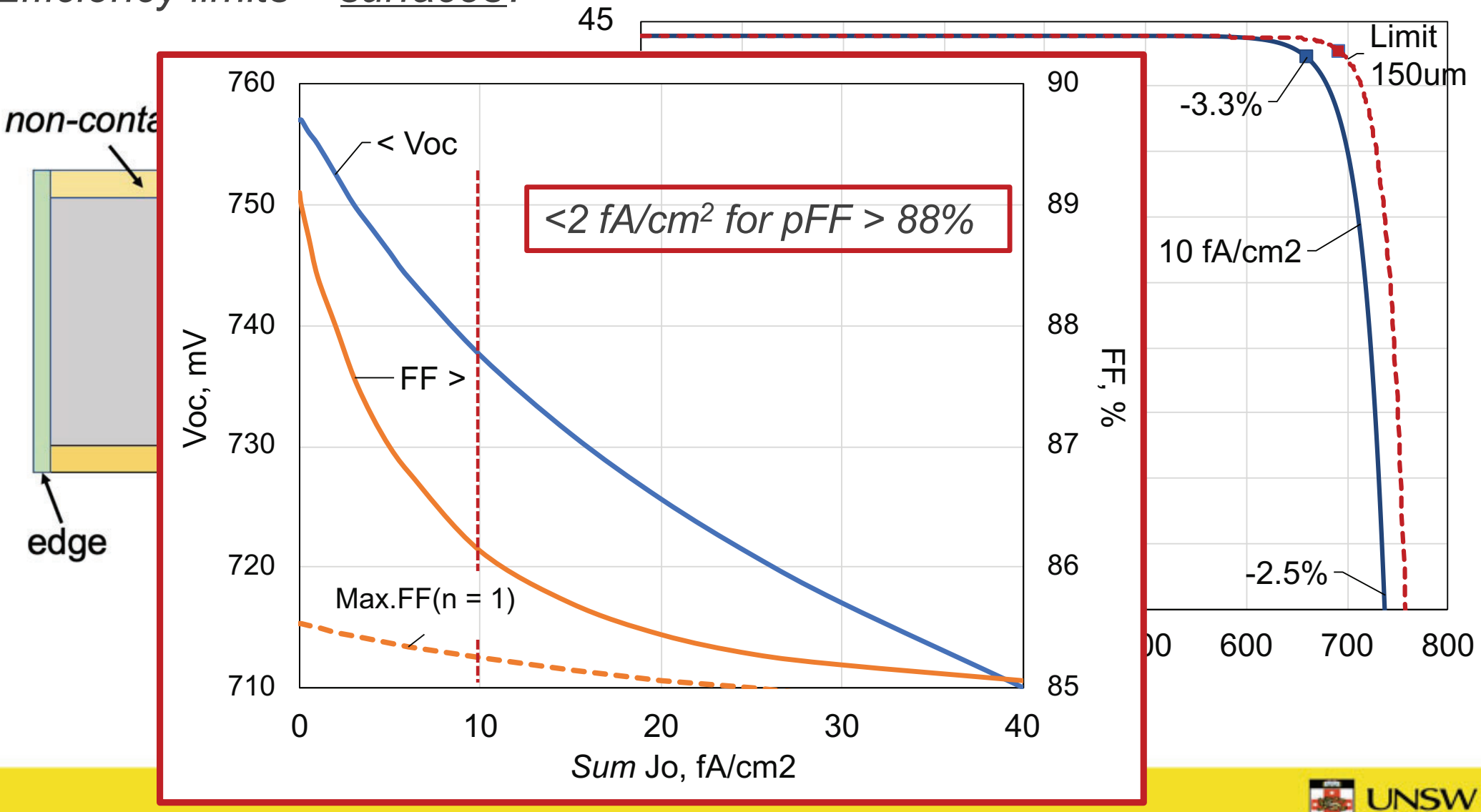
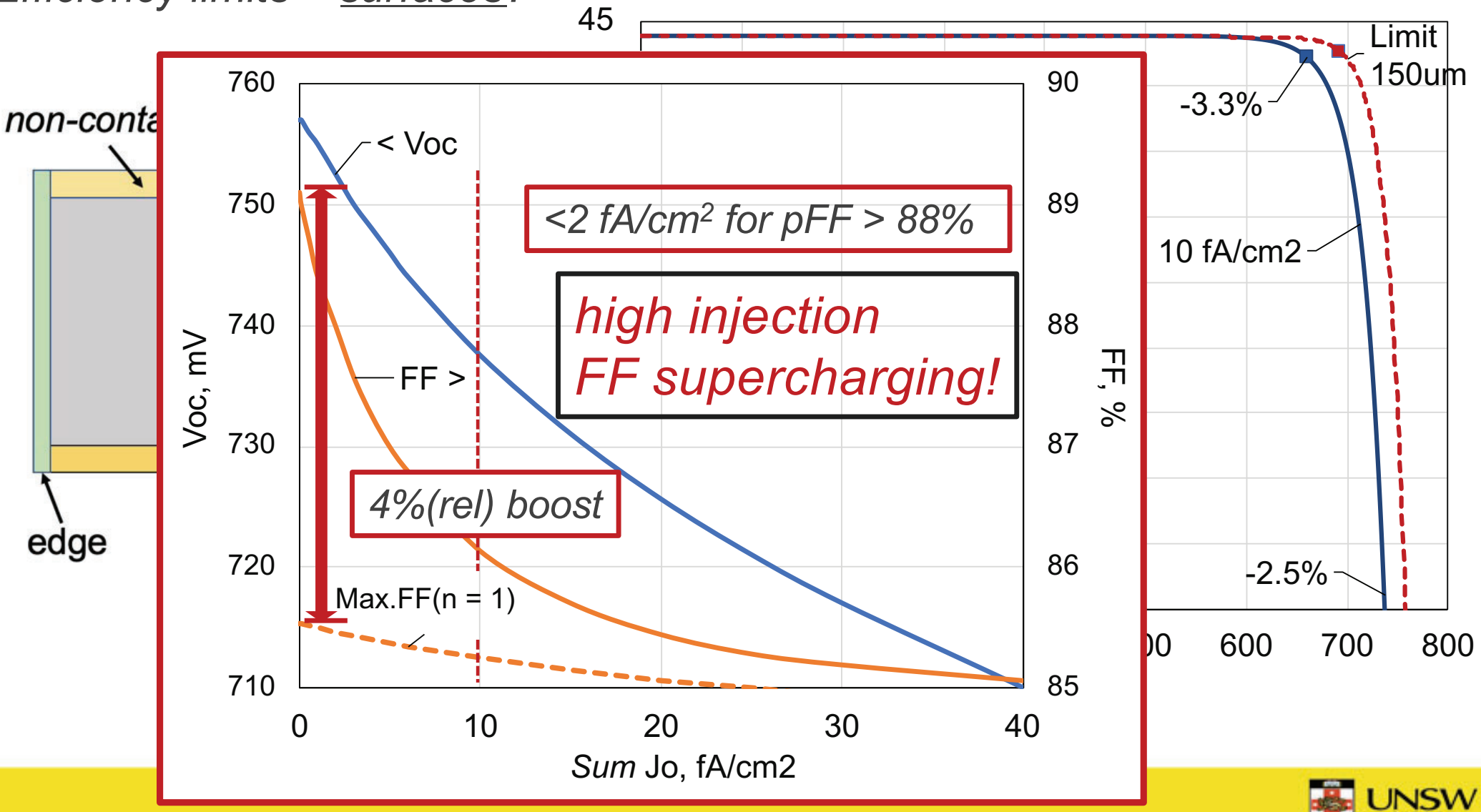
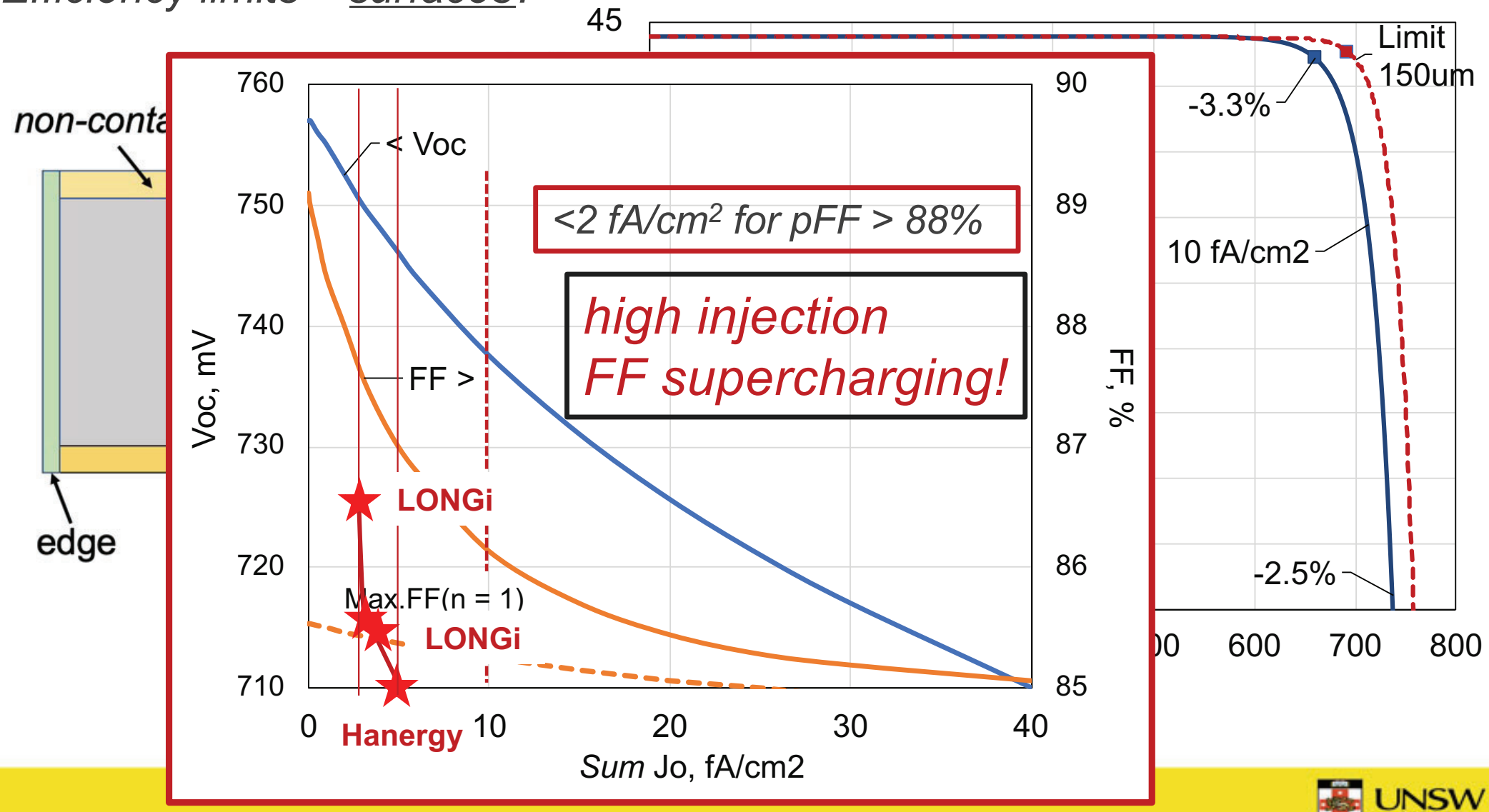
Efficiency limits – surfaces?



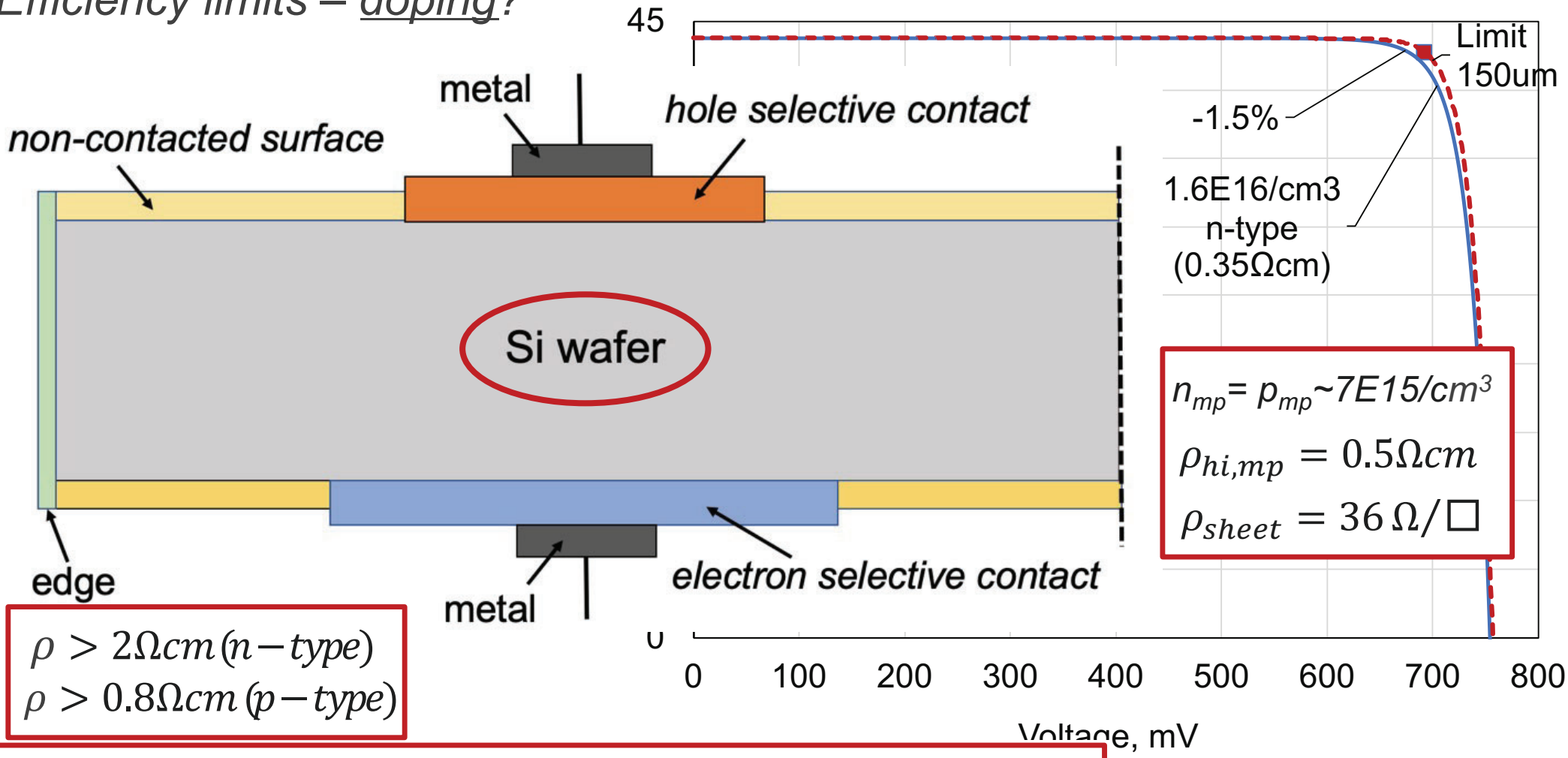
Efficiency limits – surfaces?



Efficiency limits – surfaces?



Efficiency limits – doping?



$\rho > 2\Omega cm\,(n-type)$
$\rho > 0.8\Omega cm\,(p-type)$

$\rho_{opt} = 4\Omega cm\,(p-type); 2-13\Omega cm$ *better than intrinsic*

Green, IEEE ED-31, 684, 1984; Tiedje et al., ibid., 711 (intrinsic Si!); Green & Fell, to be published.

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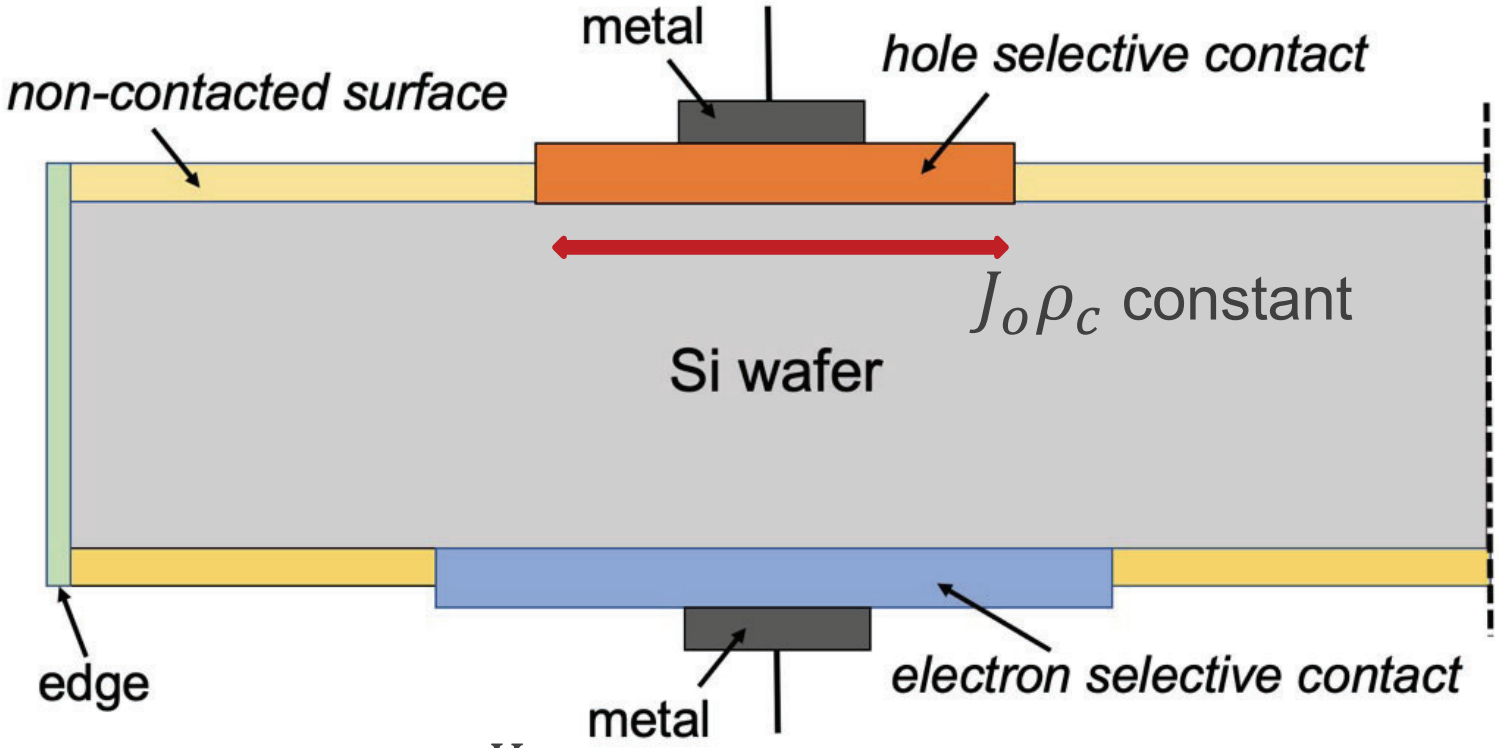
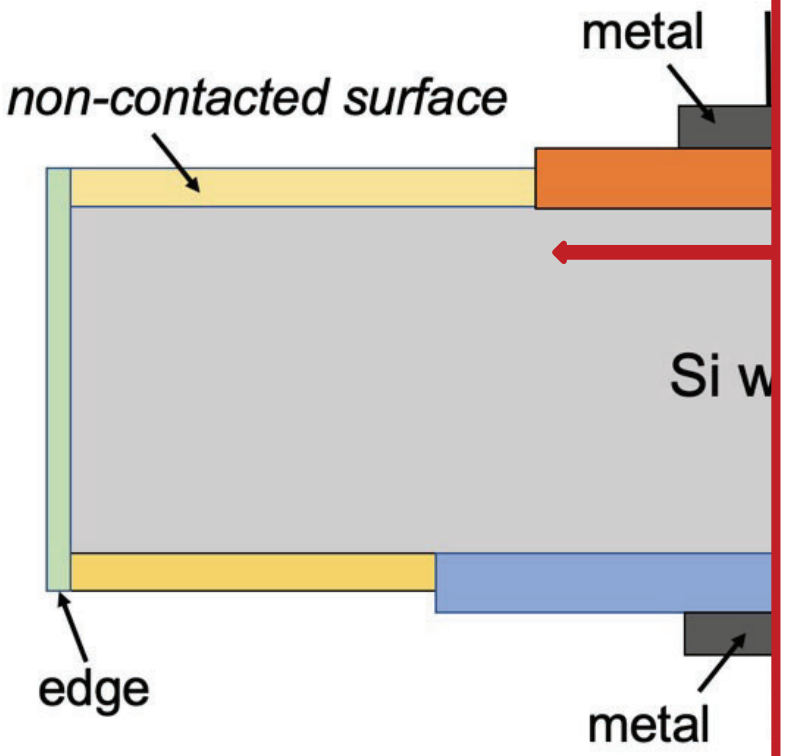
Contact selectivity S_{10}



$$S_{10} = \log[\frac{V_{th}}{J_o\rho_c}]$$

$$(= \log[\frac{minority\ carrier\ incremental\ R}{majority\ carrier\ incremental\ R}]|_{V=0})$$

Contact selectivity S_{10}



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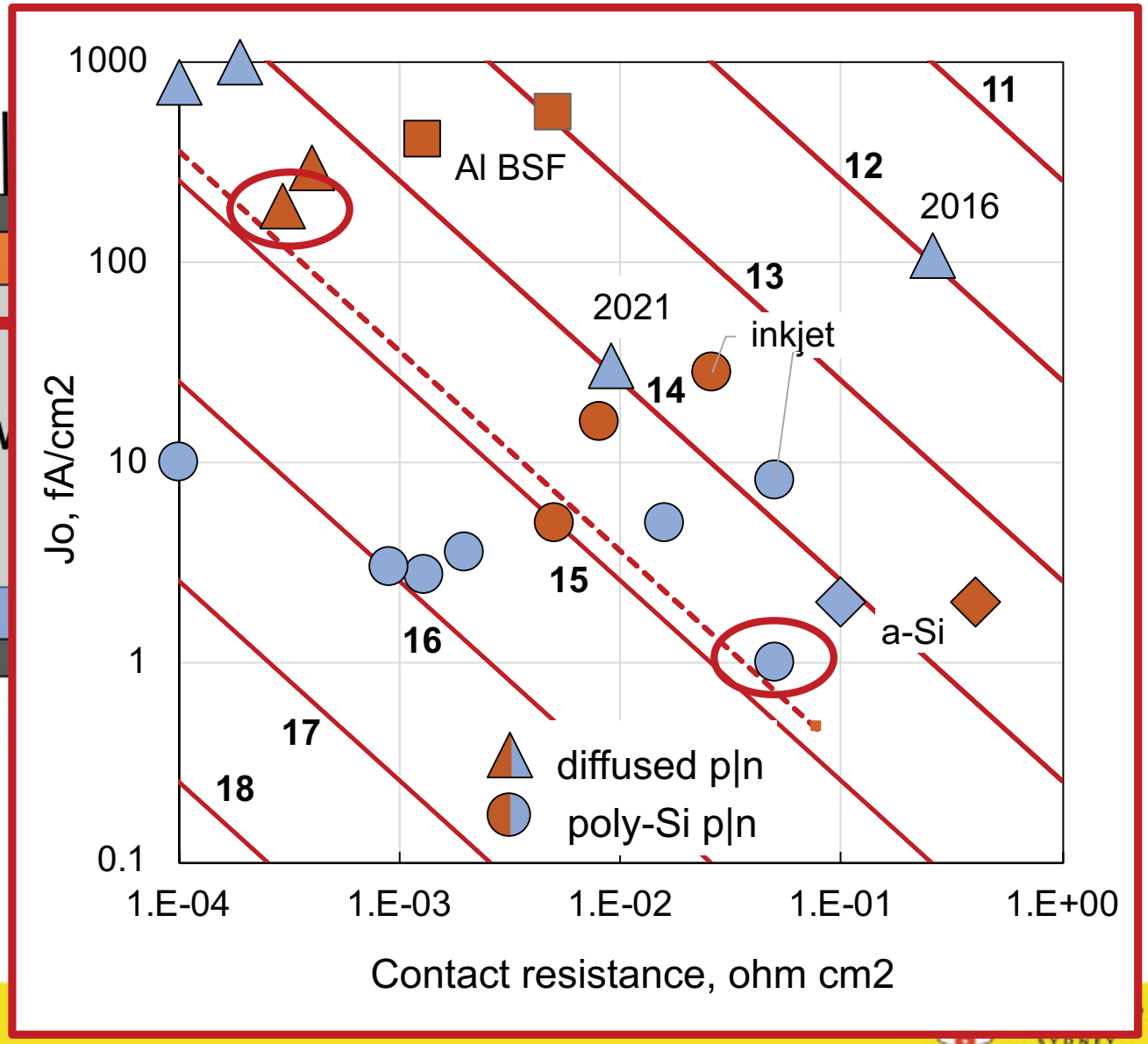

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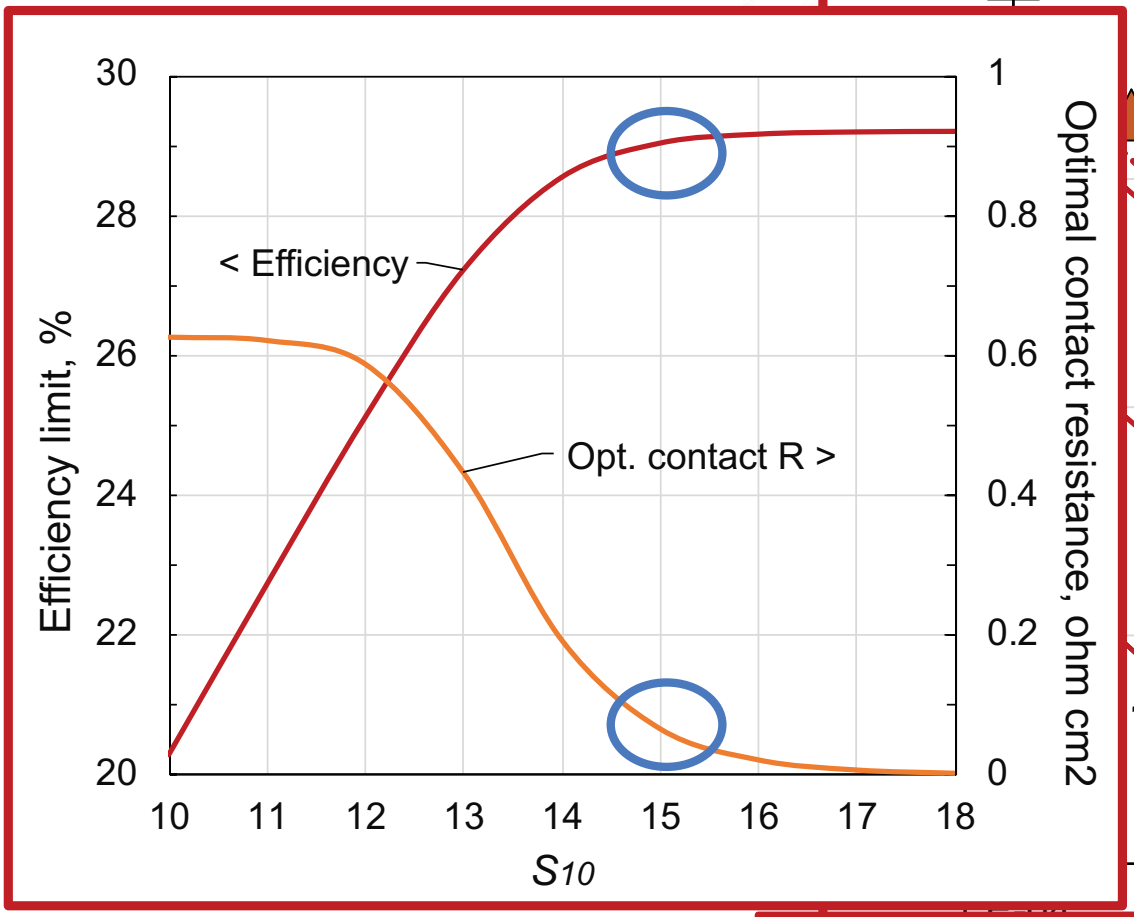

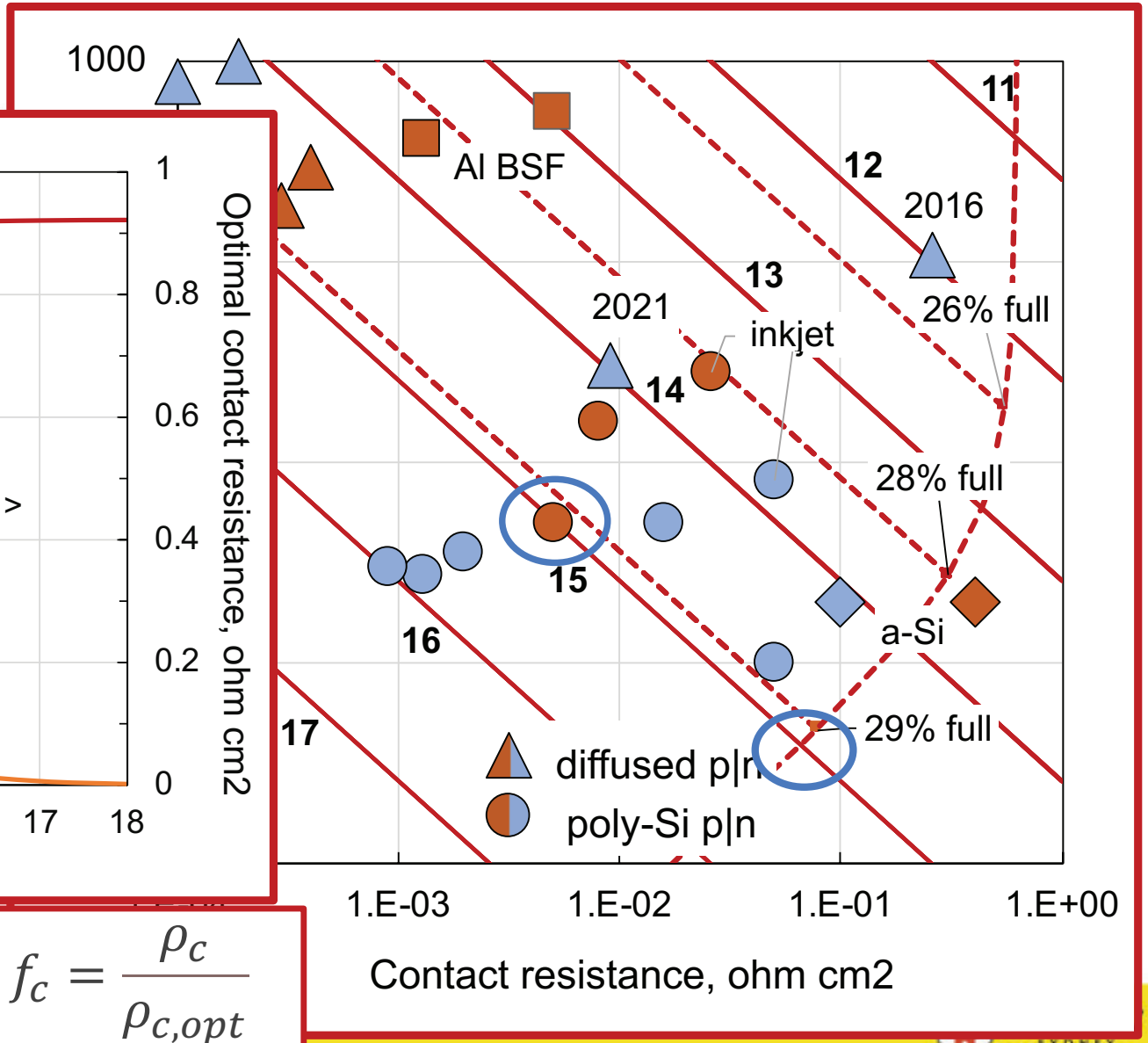

$$f_c = \frac{\rho_c}{\rho_{c,opt}}$$

Brendel et al., 32nd EUPVSEC, 2016

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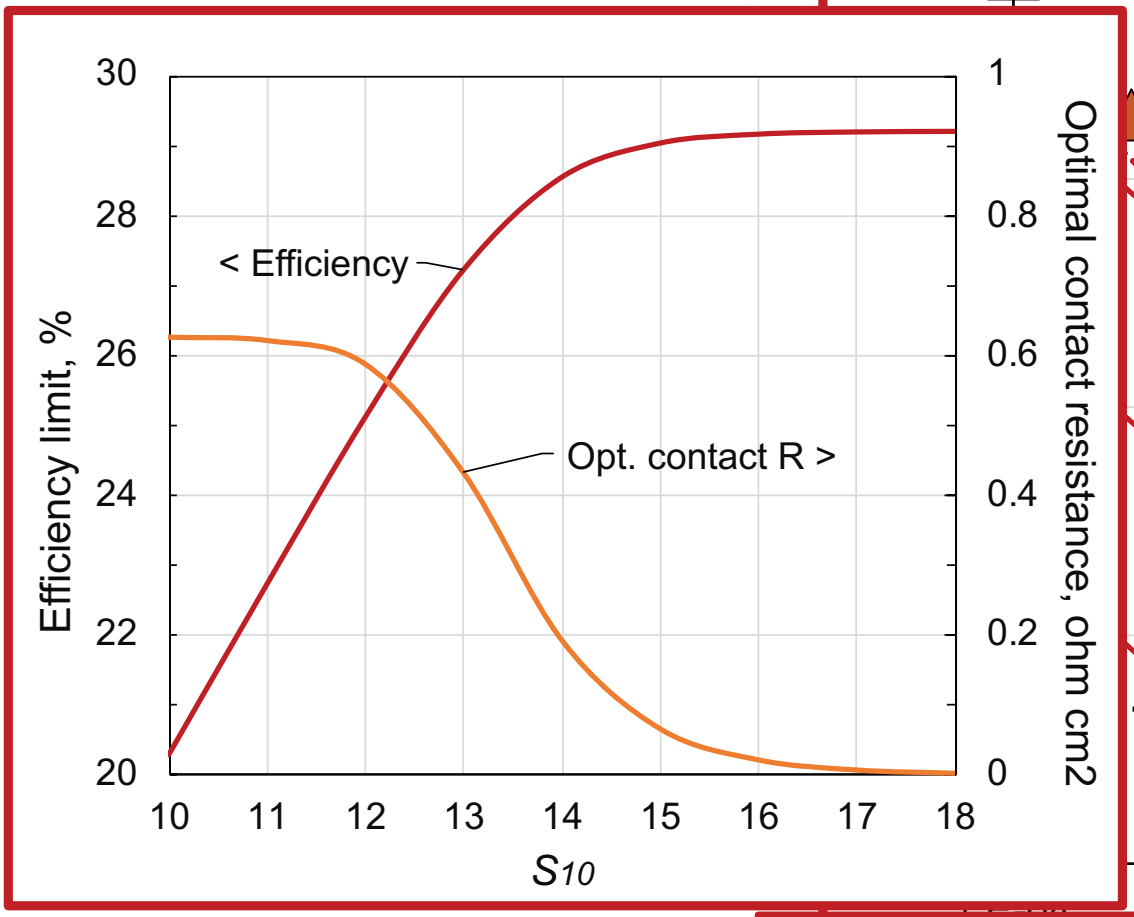

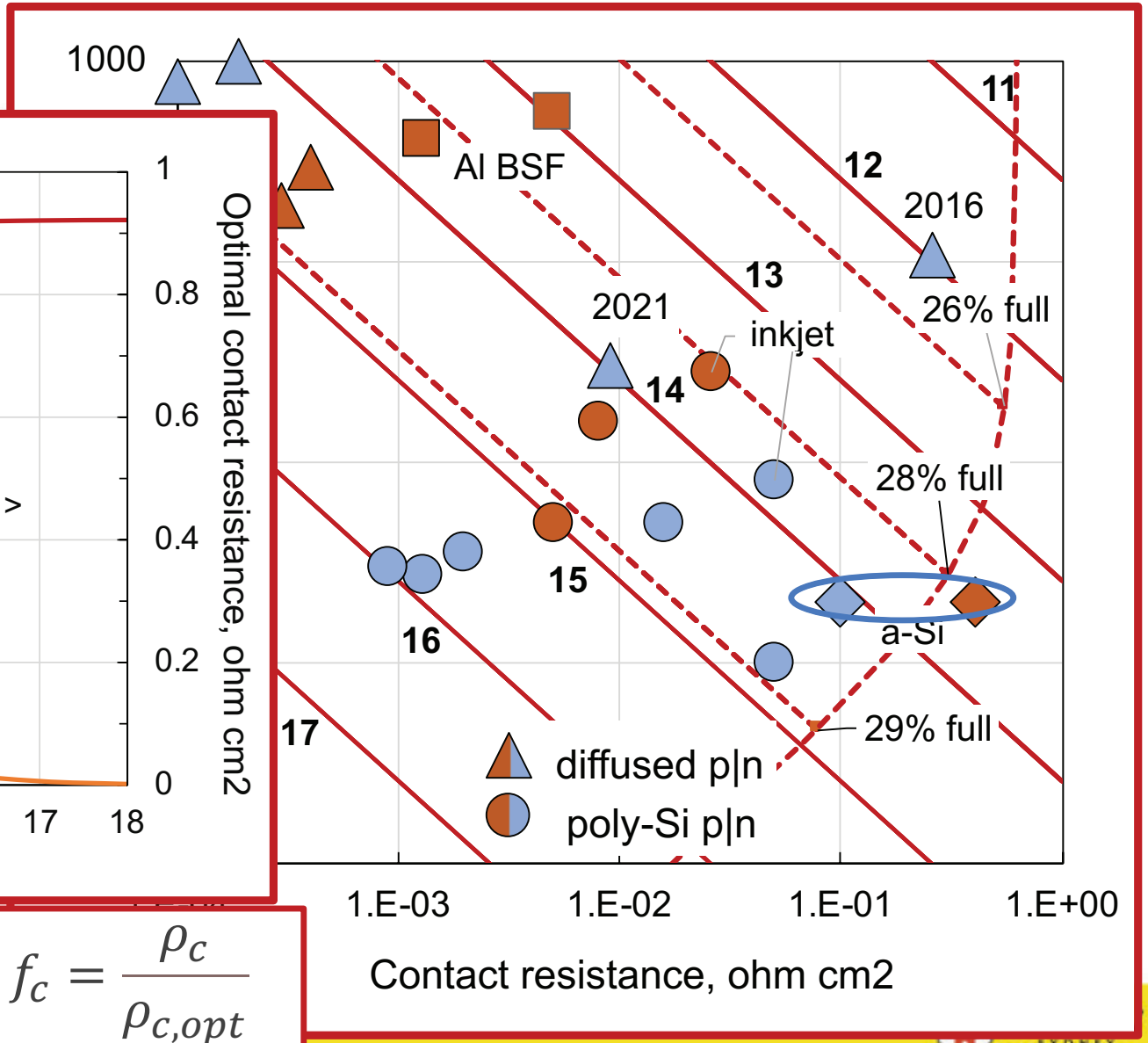

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Brendel et al., 32nd EUPVSEC, 2016

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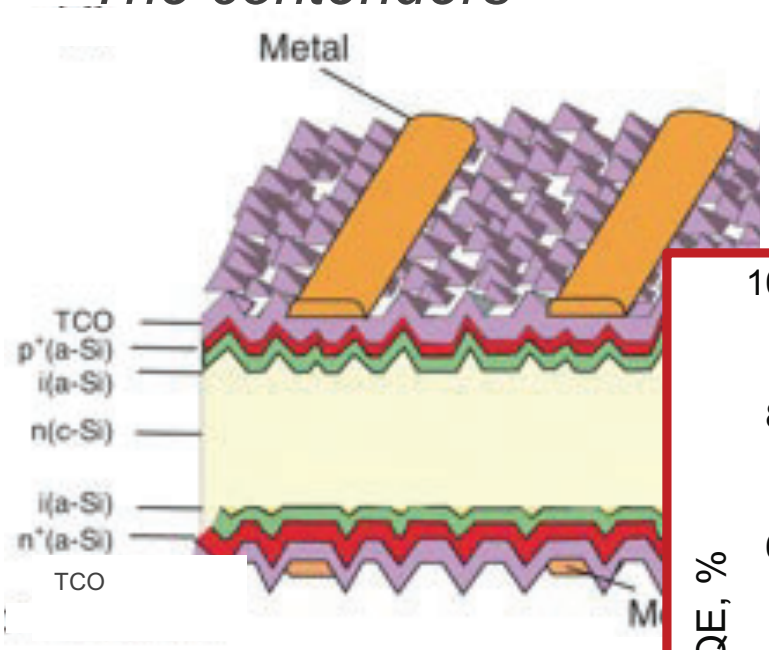
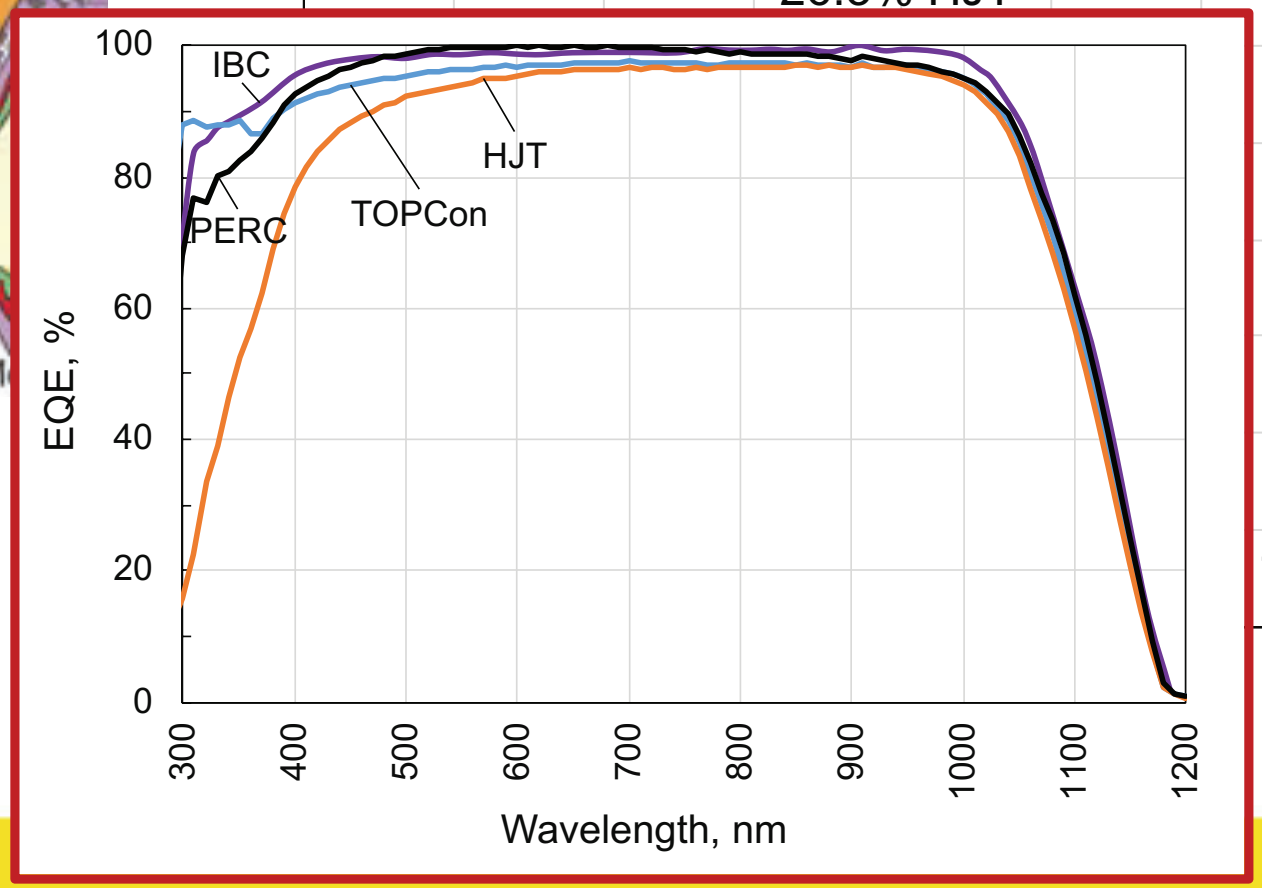


HJT



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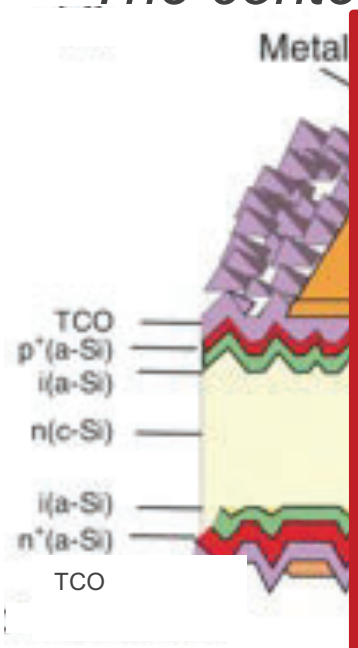
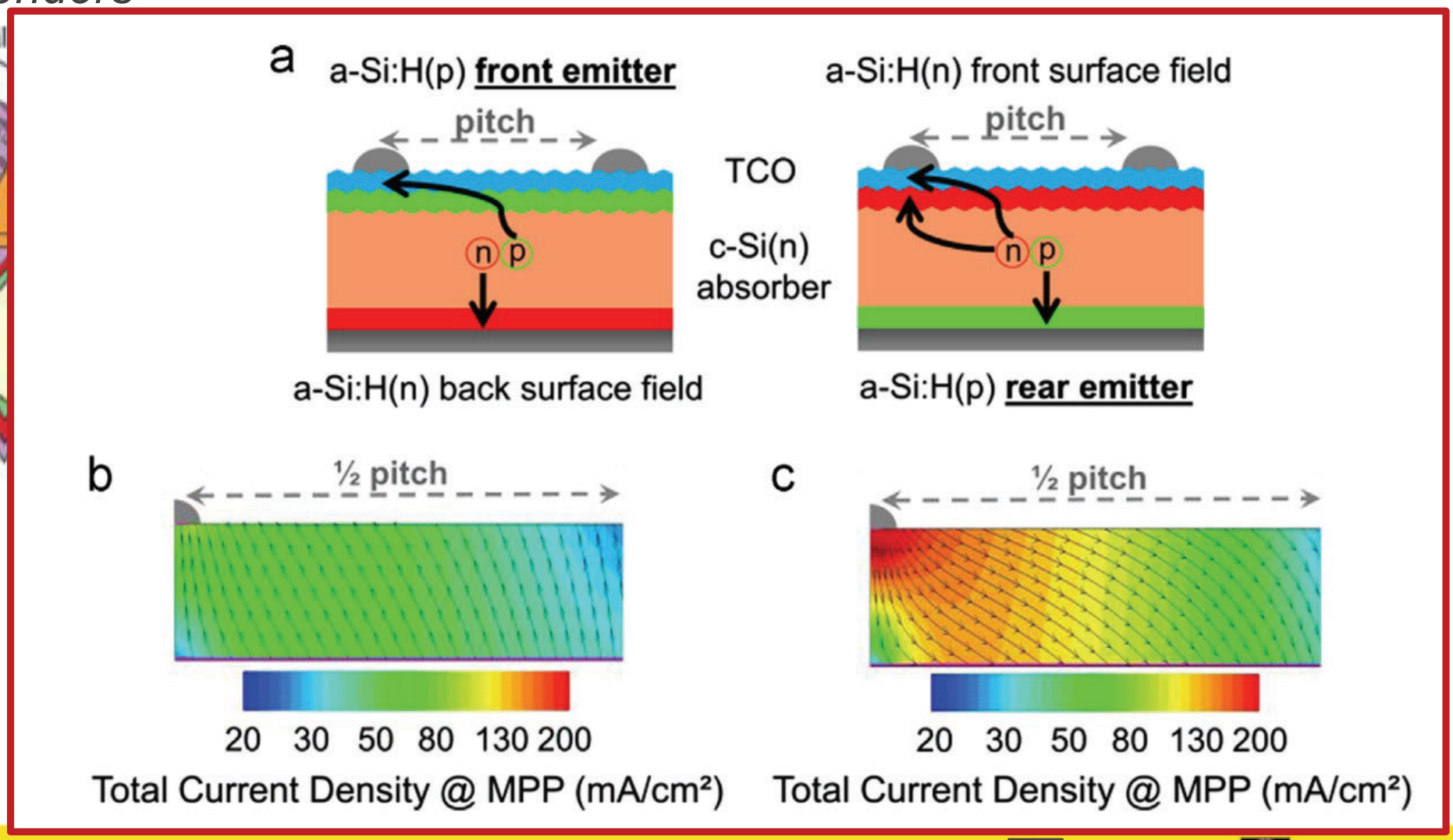
The contenders





M. Bivour et al. / Solar Energy Materials & Solar Cells 122 (2014) 120–129

p-type n-type

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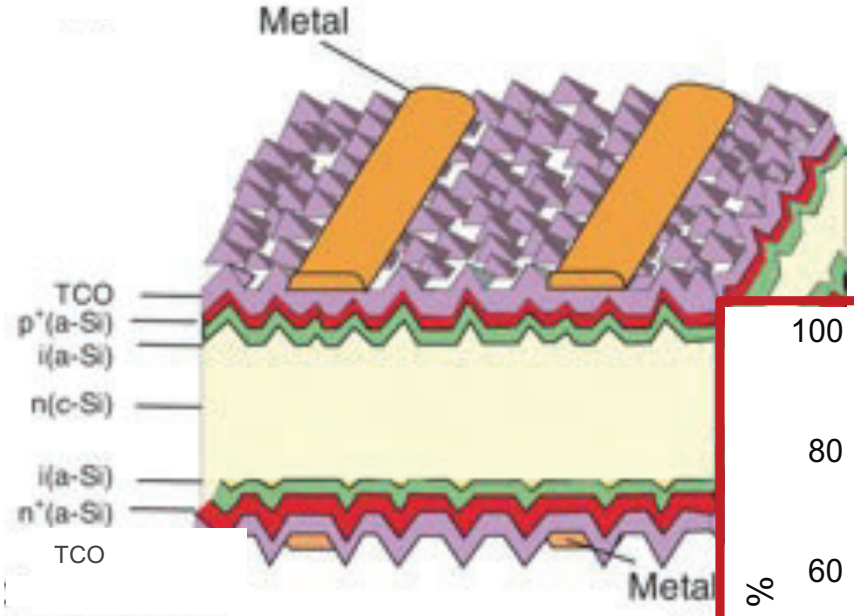
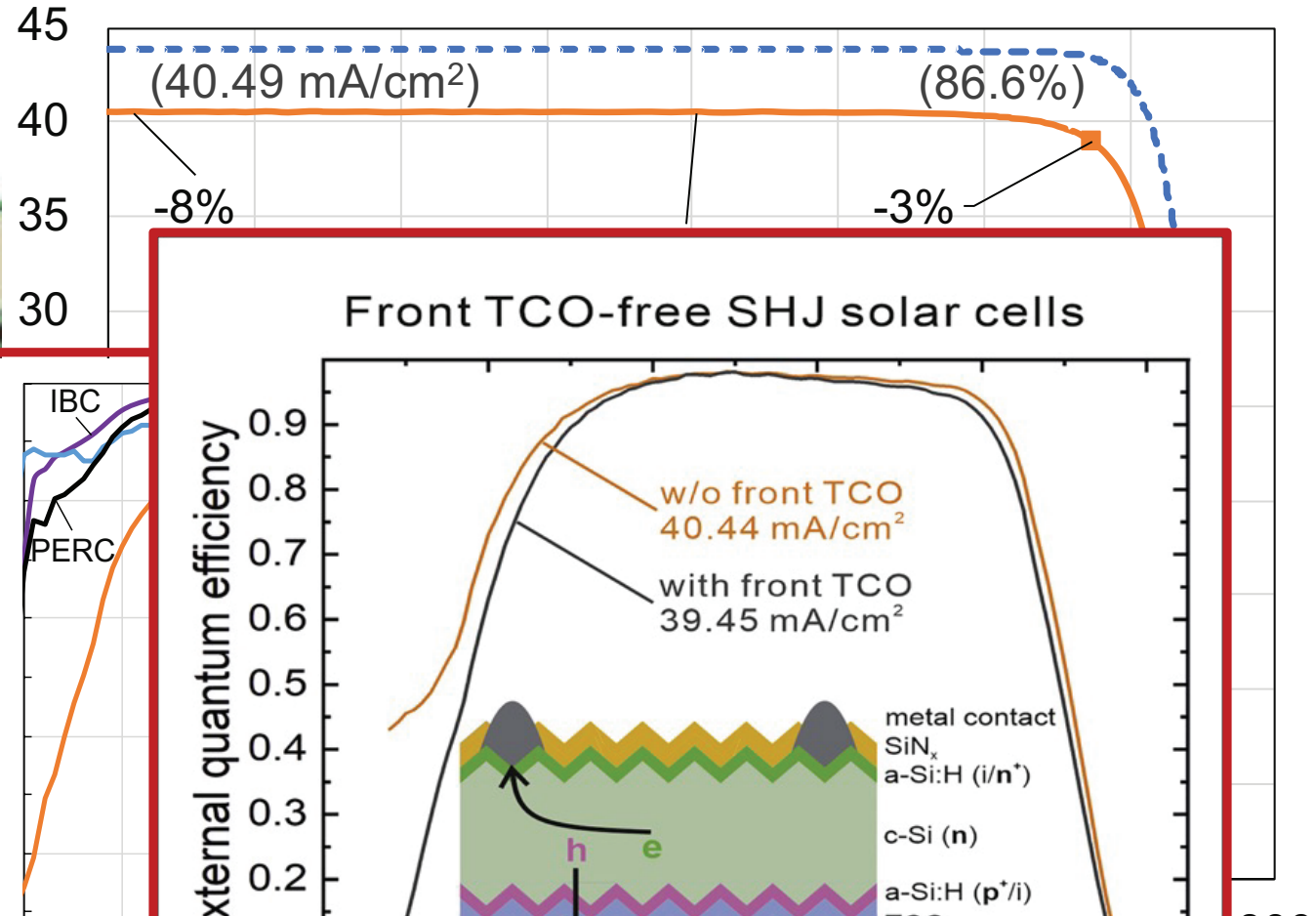
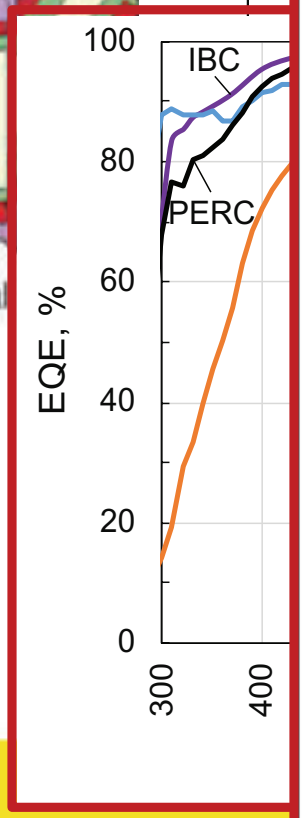
The contenders



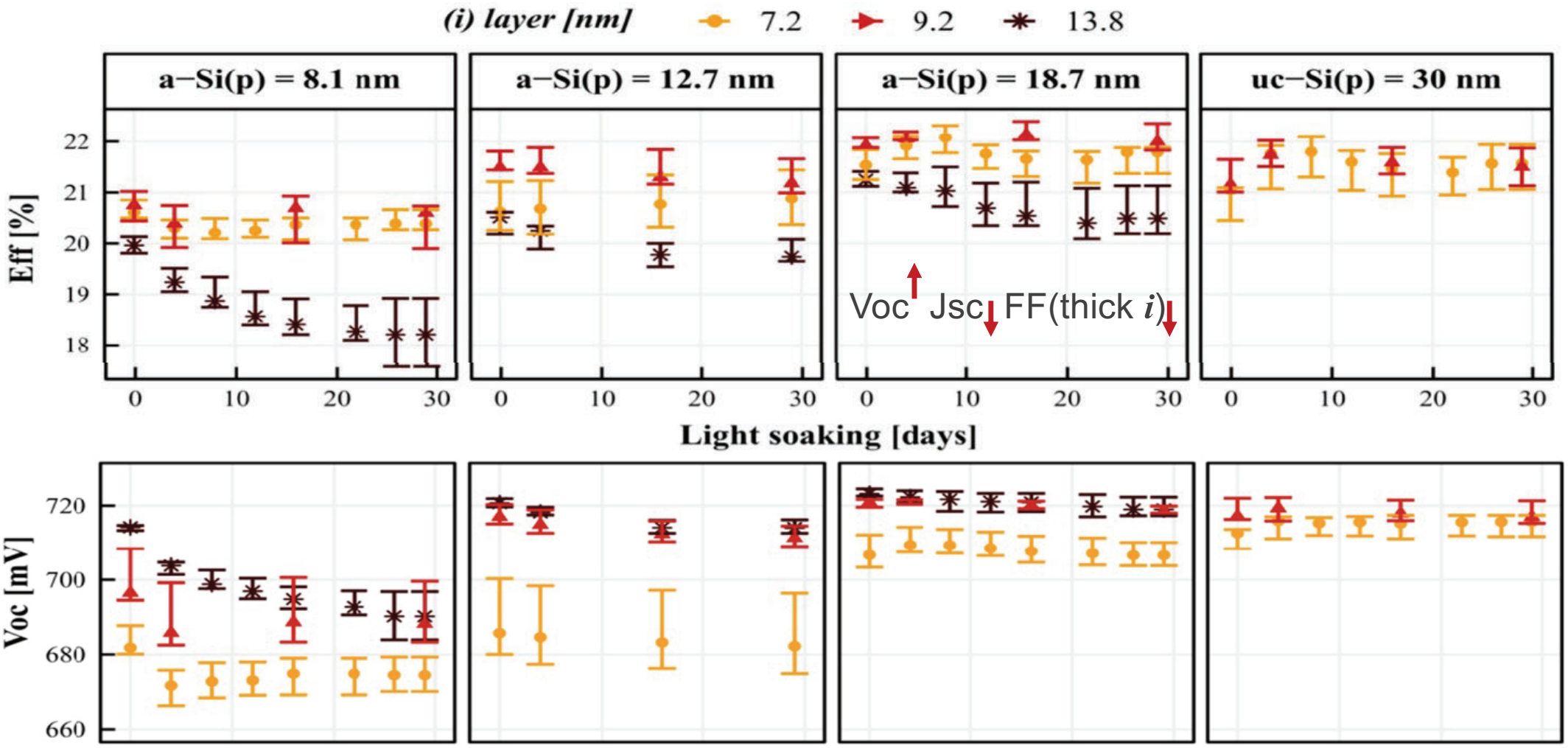
HJT





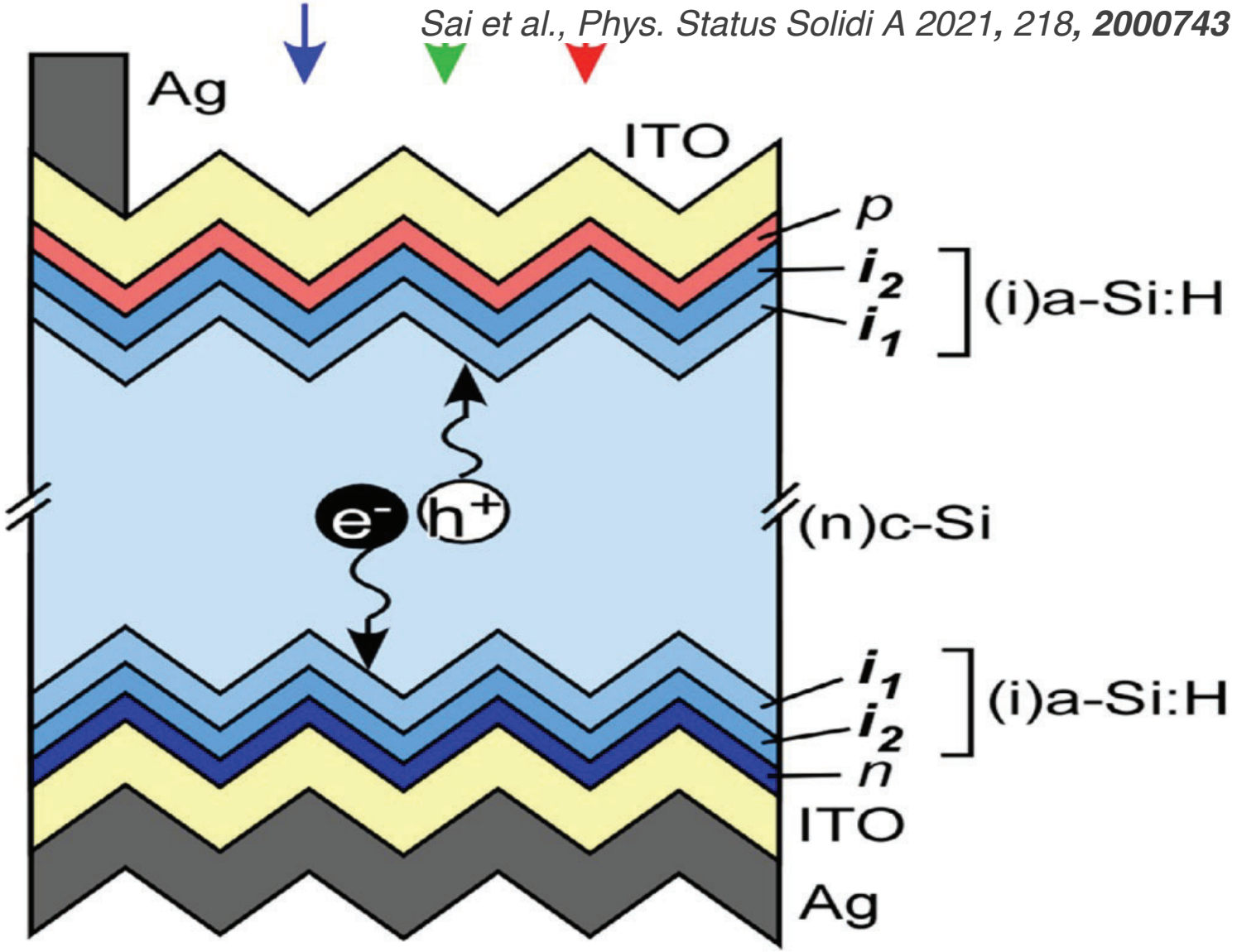
Li et al, Joule 5,16 June 2021, p.1535

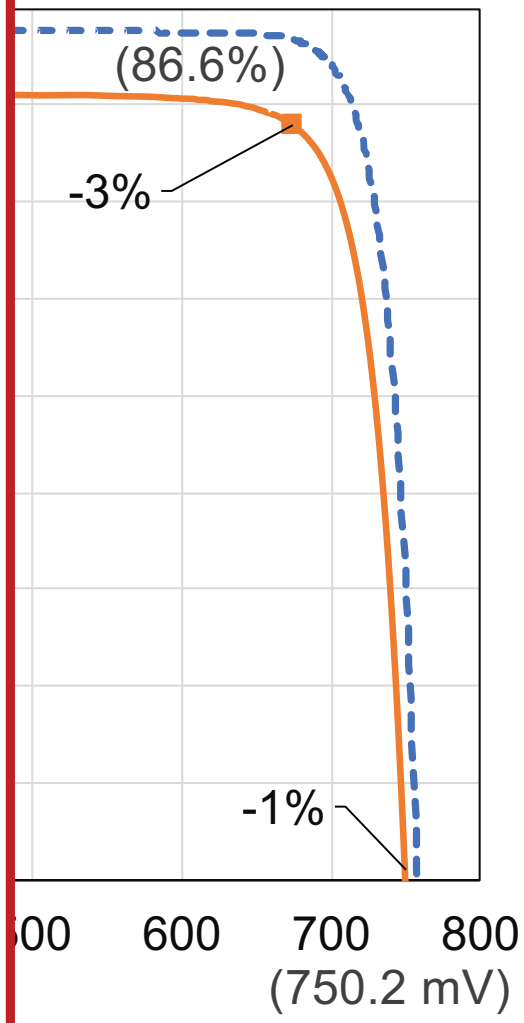
The contenders



Cattin et al. (EPFL et al.), IEEE JOURNAL OF PHOTOVOLTAICS, VOL. 11, 575 , MAY 2021

*Sai et al., Phys. Status Solidi A 2021, 218, **2000743***





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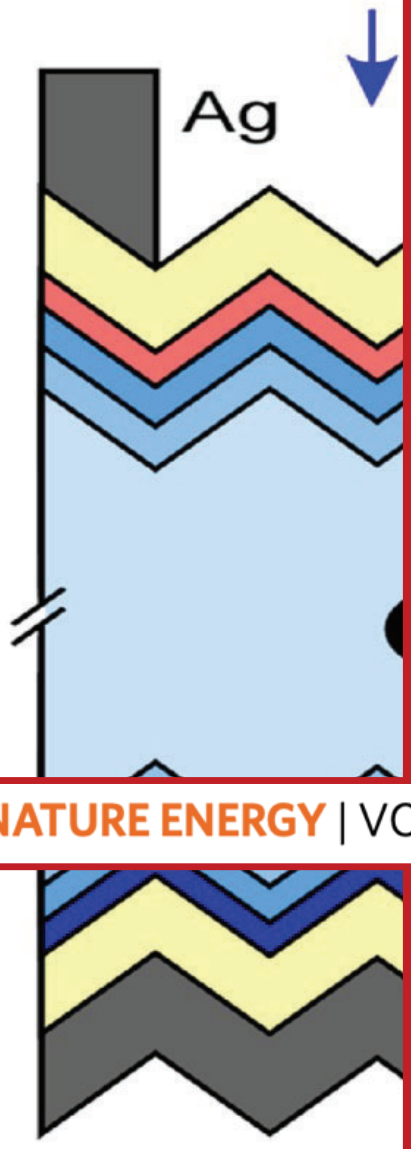

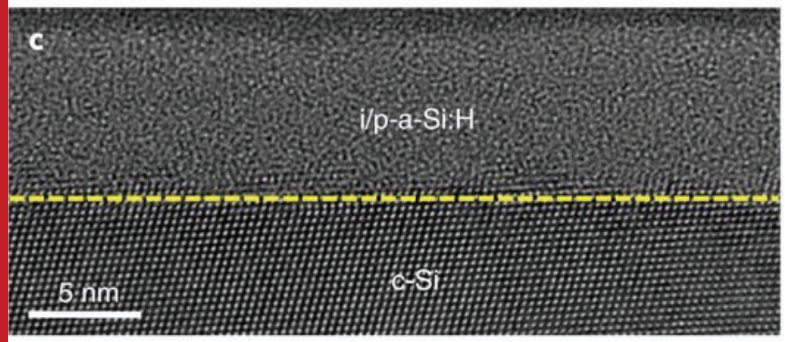

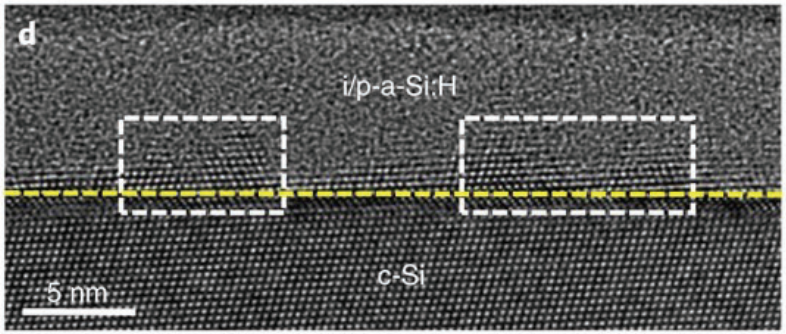

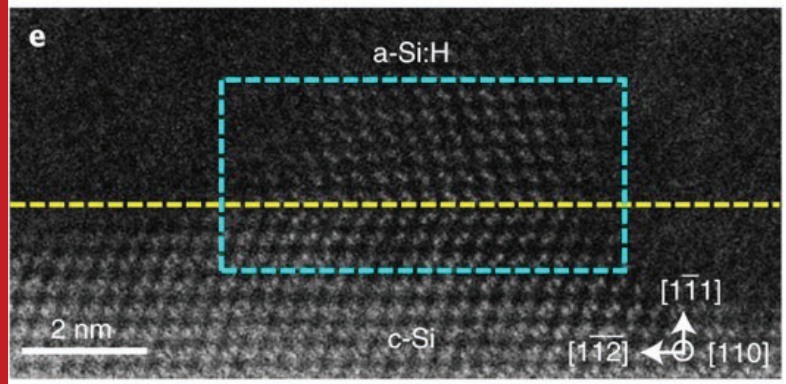

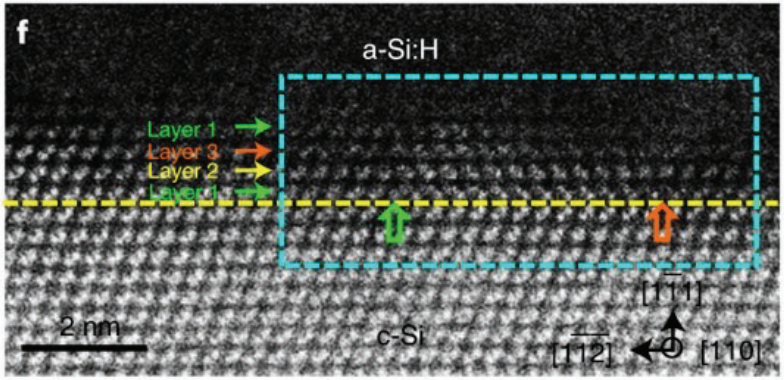

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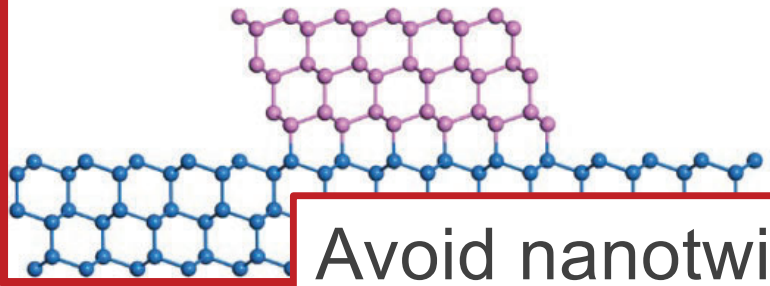
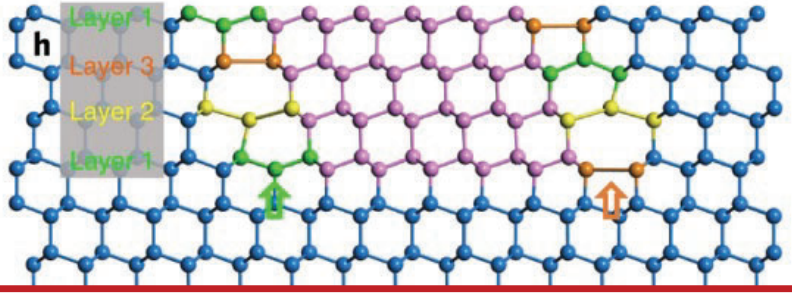
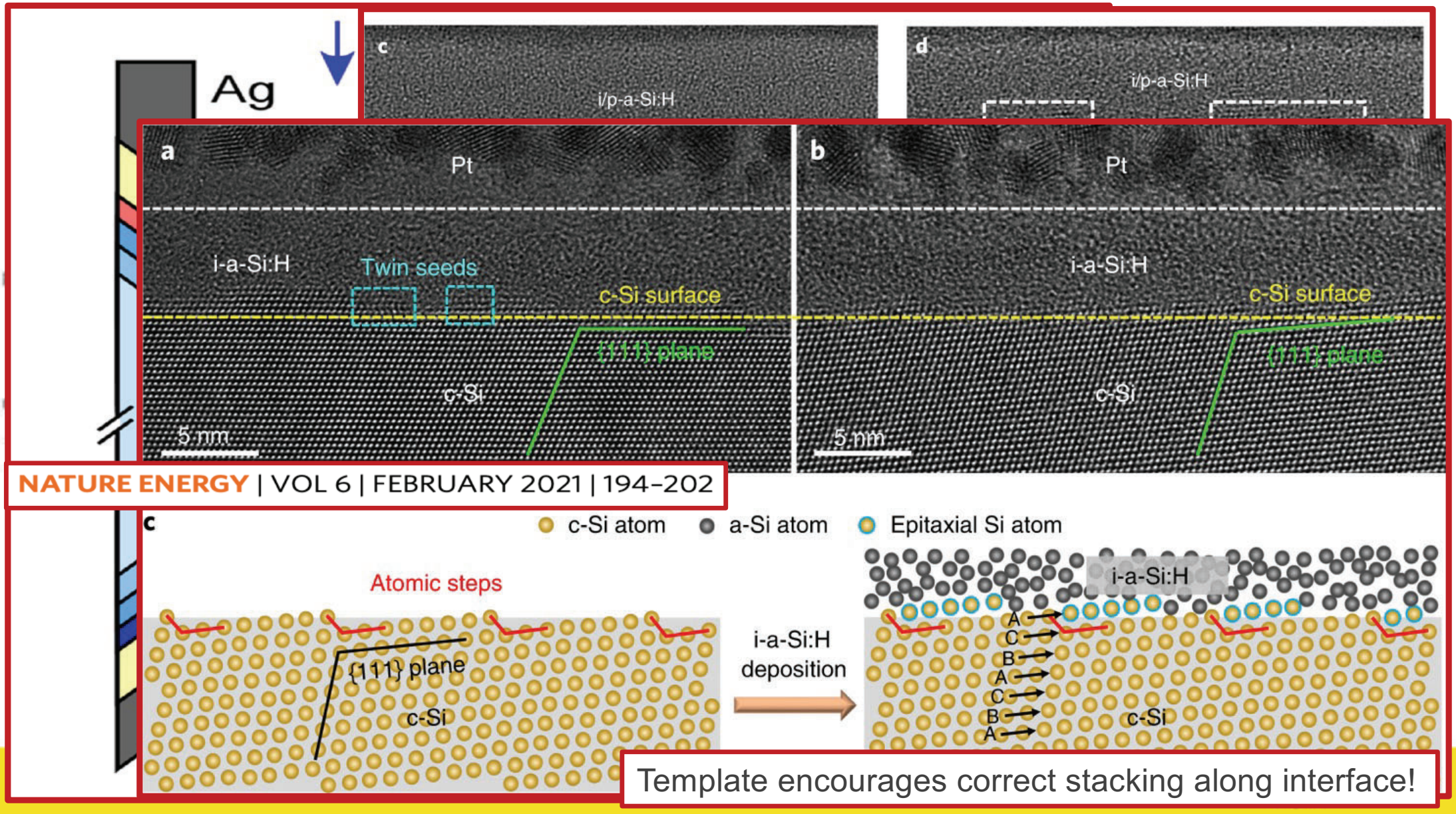




Avoid nanotwins! *(Voc & FF up >0.3%!)*



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Template encourages correct stacking along interface!

Efficiency limits for HJT

Continue improving to 26% & beyond in production:

. ***better wafers***: > 30 ms lifetimes for hi-resistivity (P & Ga) → *supercharged FF*

. ***improved surfaces***: J_o contribution < 2 fA/cm^2 → *supercharged FF*

. ***improved contact selectivity***: $S_{10e,h}$=15 -16; *S_{10t} > 15 (Jo & Contact R)*

. decrease top absorption! (eliminate ITO; pattern a-Si?)

. increase pFF towards hi-injection Auger limit!!