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LPCVD doped polysilicon with in-situ tunnel oxide

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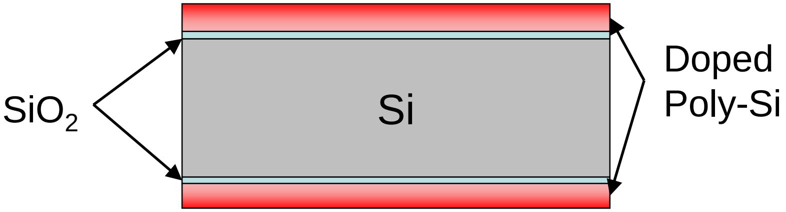
Introduction

LPCVD polysilicon at ANU

- Furnace retrofit in 2015: collaborative project between ANU-Tempress-ARENA.
- Includes Silane, and Oxygen.
- Enabling low pressure in-situ oxidation for the Poly-Ox deposition.



Fabrication Process

Diffused LPCVD Poly-Ox fabrication sequence

Tunnel oxide

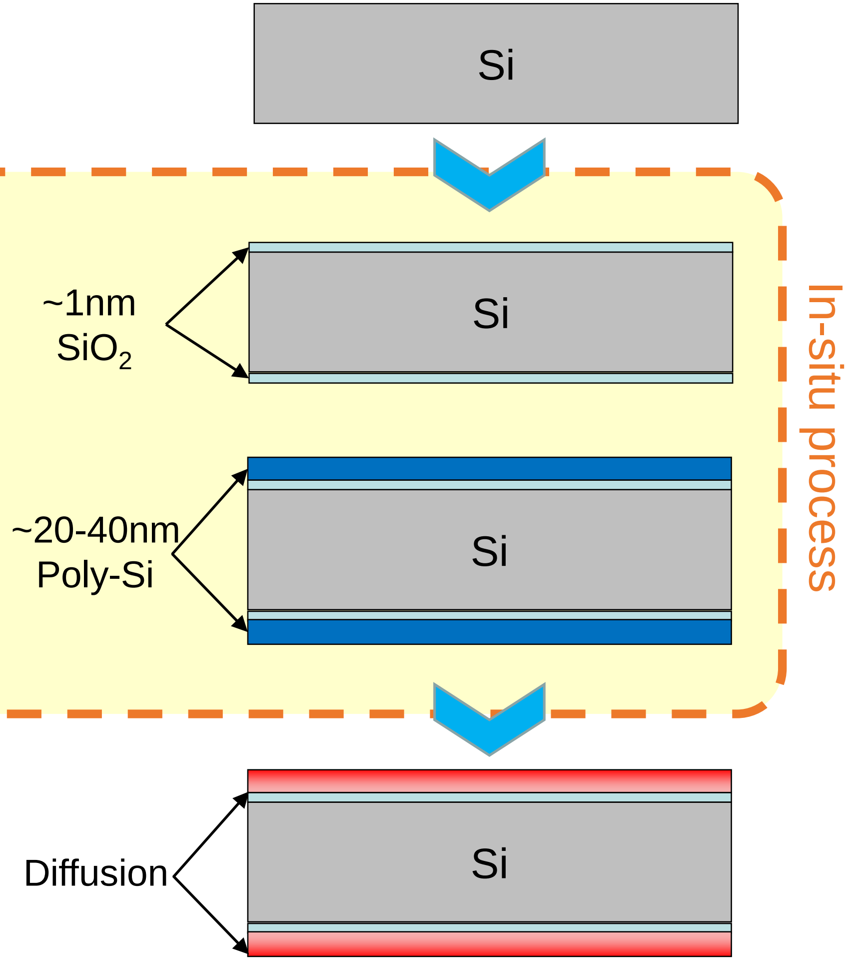
- LPCVD Chamber
- Low Pressure (600mTorr)
- 700-800 ^{o}C, 10 minutes

Polysilicon deposition

- LPCVD chamber
- Silane SiH_4
- 250 mTorr
- 520 ^{o}C

Dopant diffusion

- Ex-situ process
- Boron from BBr
- Phosphorus from POCl



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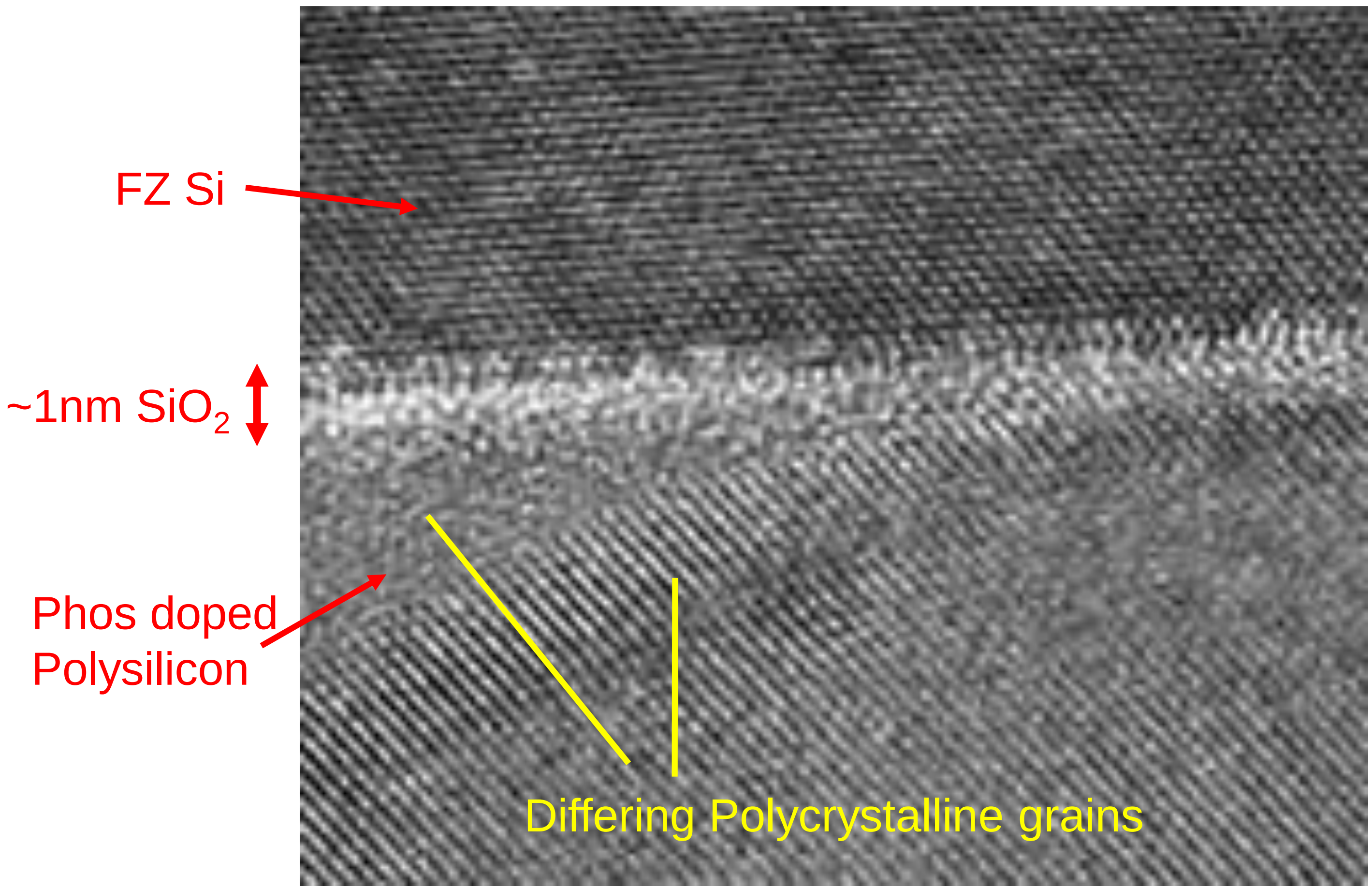
TEM of Poly-Ox layer

TEM of Phosphorus difufsed Poly-Ox structure (after 900ºC anneal)

- Oxide ~ 1 nm
  Appears fuzzy on both sides, with no clear boundary.
- Poly-Si appears crystalline with numerous grains of varying crystal orientation



Passation Quality

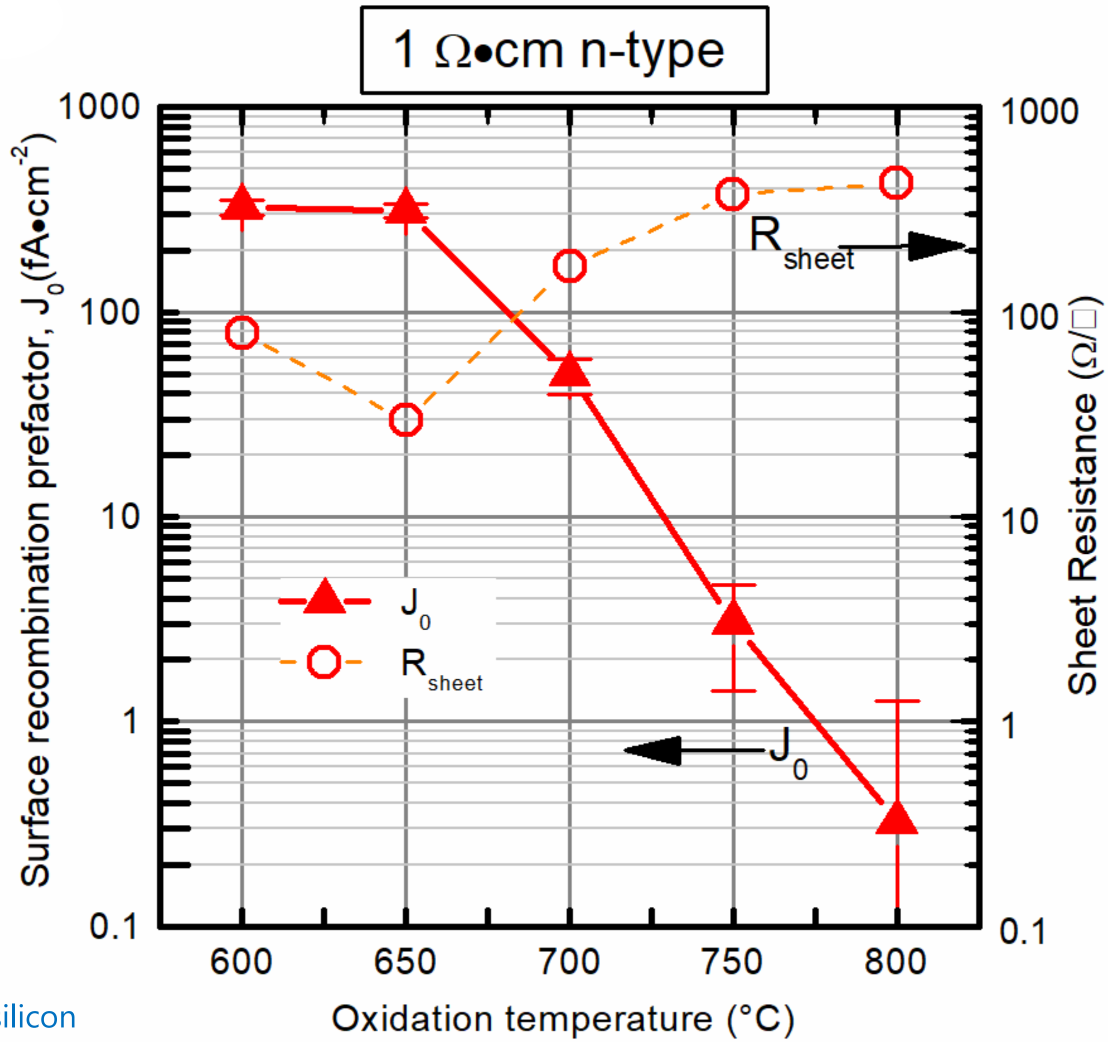
Best passivation of ~0.3 fA cm^{-2} is measured, with implied V_{OC} of 735mV.

Oxidation temperature is the key parameter.

Temp: 600-800 ^{o}C, 10mins,

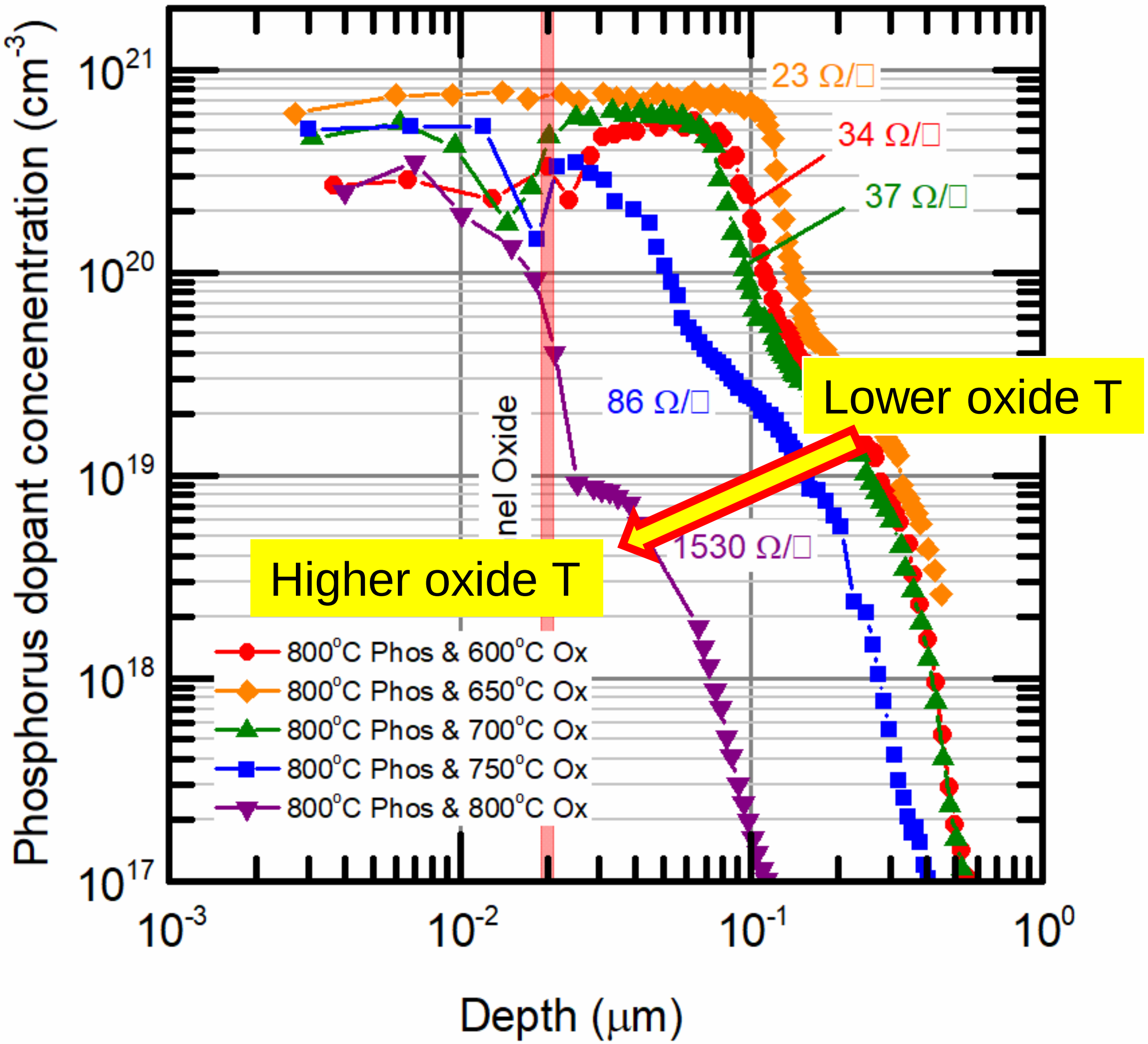
- SiO_2 → 1-1.2nm
- J_0 → ~350fA – 0.3fA !

Will be apparent from diffusion profile.



K. C. Fong *et al.*, "Phosphorus diffused LPCVD polysilicon passivated contacts with in-situ low pressure oxidation," *SOLMAT*, 2018.

Diffusion Profiles



Diffusion profile is extremely sensitive to oxide growth condition

Ox Temp: 600-800 °C

- SiO_2 → 1-1.2nm
- J_0 → ~350fA – 0.3fA
- R_{sheet} → 23 Ω/□ to 1530 Ω/□

To achieve <1fAcm2, there must be only a small amount of dopant penetration to the wafer bulk, so as to avoid massive Auger recombinations.

This highlights the importance of excellent control in oxide growth conditions.

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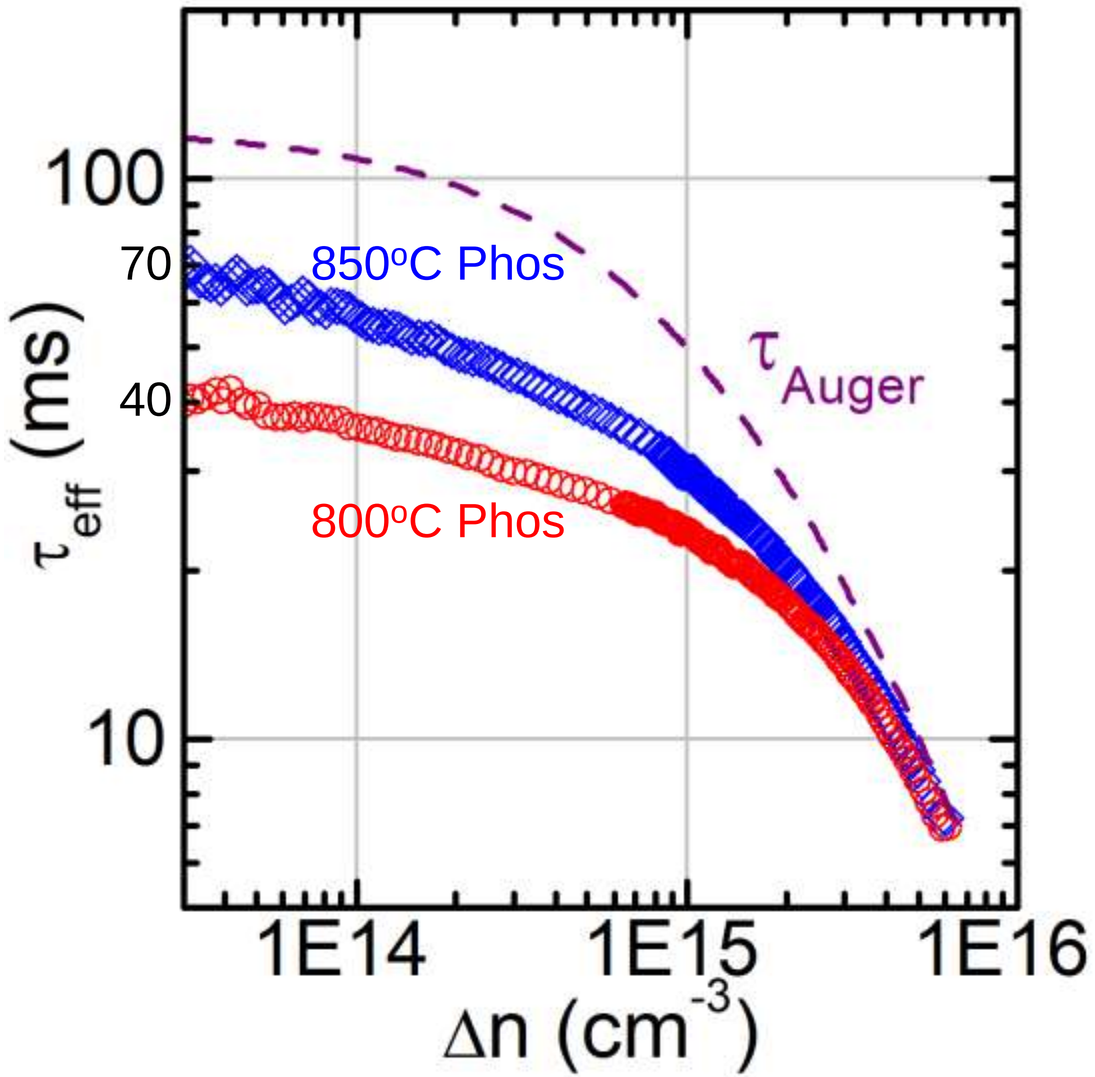
Bulk lifetime

Using High-res n-type:

- High effective lifetimes above 70ms can be achieved.
- 735mV i-Voc

100 Ω cm n-type FZ

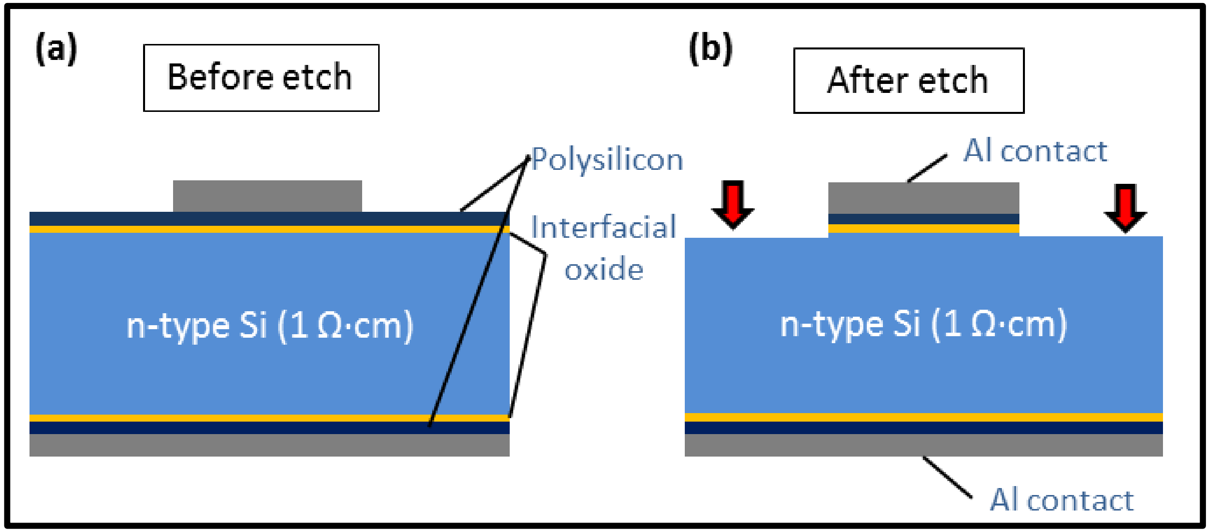


Contact Resistance

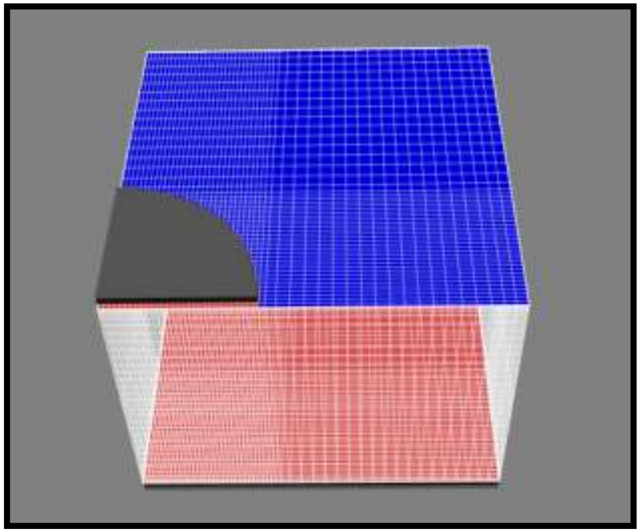
Modified Cox & Strack circular dot structure

- Using the lifetime sample, we evaporate metal dots, and etch surrounding poly-Ox
- This allows the use of the same wafer for lifetime & contact measurement.
- I-V curve is measured & ρ_c is calculated via iterative fitting to 3D ohmic model, assuming symmetrical front & rear ρ_c

Test structure (cross section)



3D model



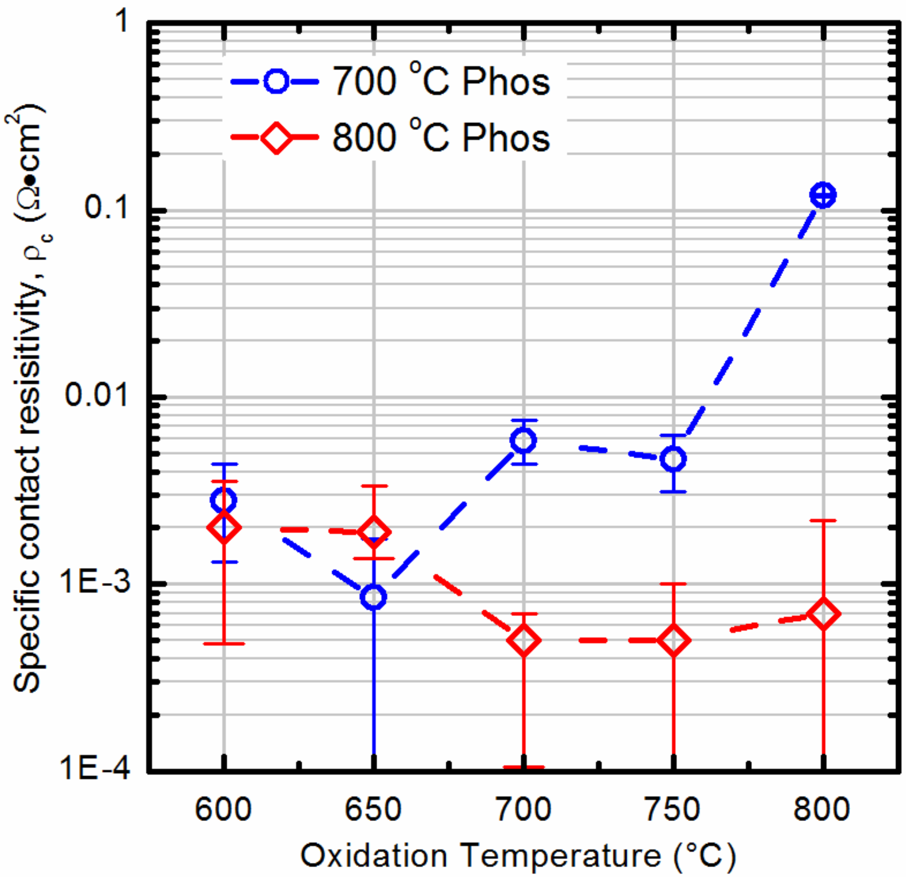
K. C. Fong *et al.*, IEEE Conference Proceedings, 2018.

Contact Resistance

Excellent contact resistance below 1 mΩ cm^2 is measured for a wide range of conditions.

Large error bars:

- Bulk resistance limits the accuracy of the method to ~ 1 mΩ cm^2.



K. C. Fong *et al.*, IEEE Conference Proceedings, 2018.

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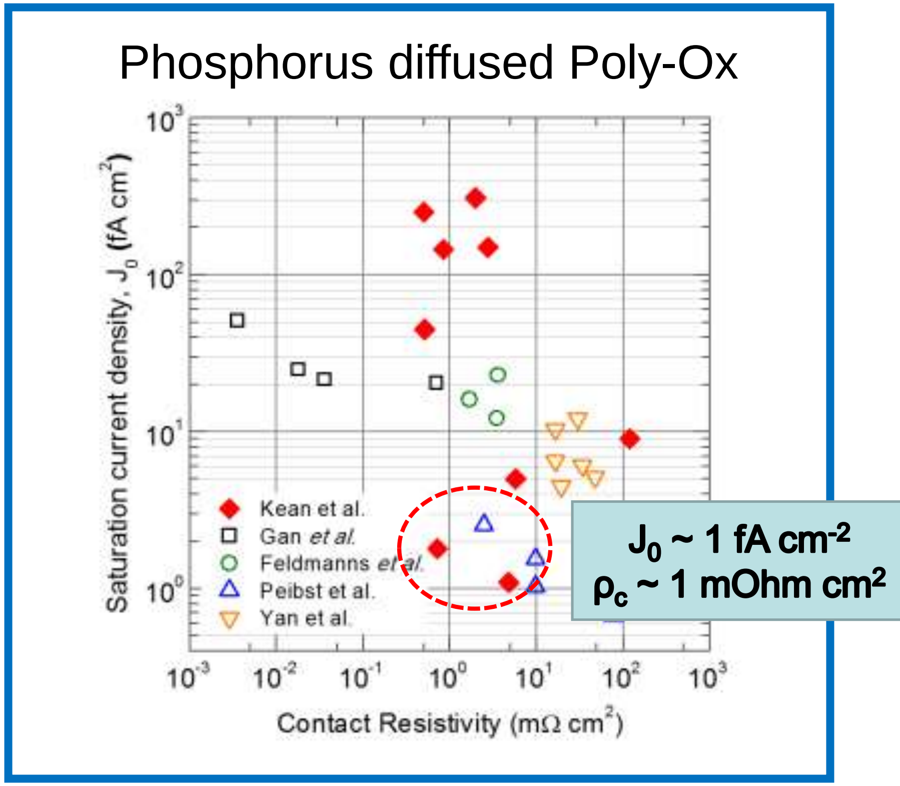
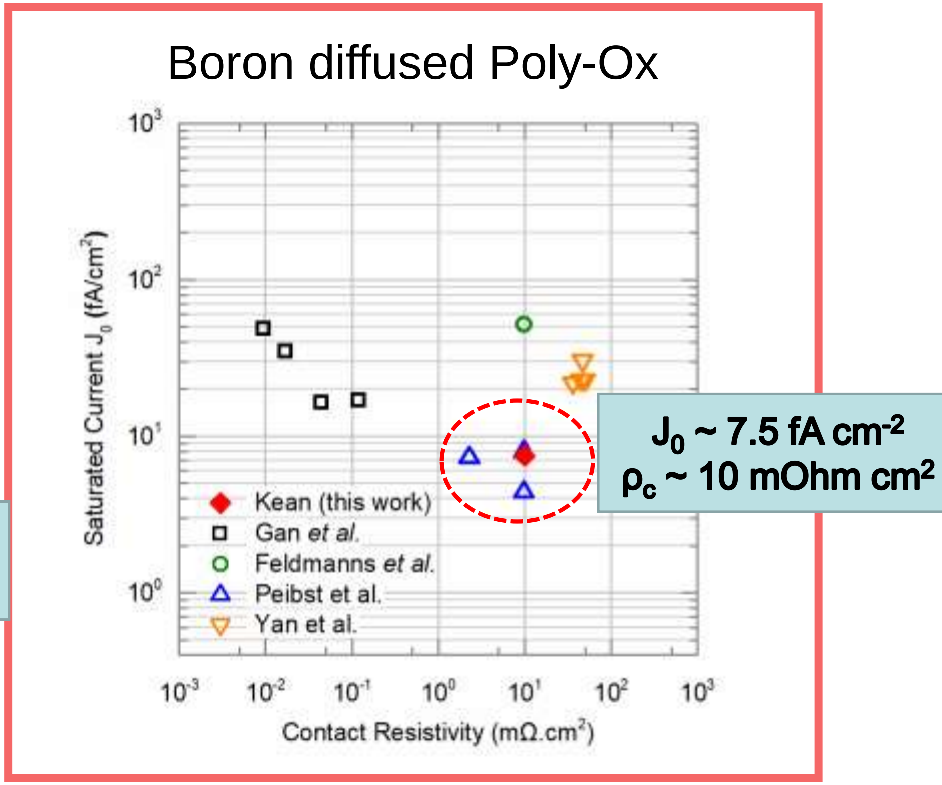
Passivation vs Contact R

Comparing to literature, we are on par if not better than the best reported values:





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Conclusion

This work:

- Demonstrated $J_0 < 1$ fA cm^{-2}, $\rho_c < 1$ mΩ cm^2 with phosphorus diffused LPCVD Poly-Ox
- Key novelty of in-situ process for Poly-Ox & low pressure oxidation step. Providing excellent process control.
- High bulk lifetimes ~ 70ms, with iVoc ~735mV.

Future:

- Boron doped LPCVD Poly-Ox
- Application to cells, PERL, IBC, Bifacials

- Open to collaborations (Cell fabrication, tandem devices, etc)

Acknowledgements

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Specific ACAP contributions to this work:

- ACAP PP1: Silicon Solar Cells
- ACAP PP6.32: Optical Properties of Passivated Contacts
- ACAP Fellowship: Transparent Doped LPCVD Polysilicon Passivated Contacts

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