Faculty of Engineering
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Atomic layer deposited Nb_2O_5 thin film as electron selective contact on c-Si solar cells

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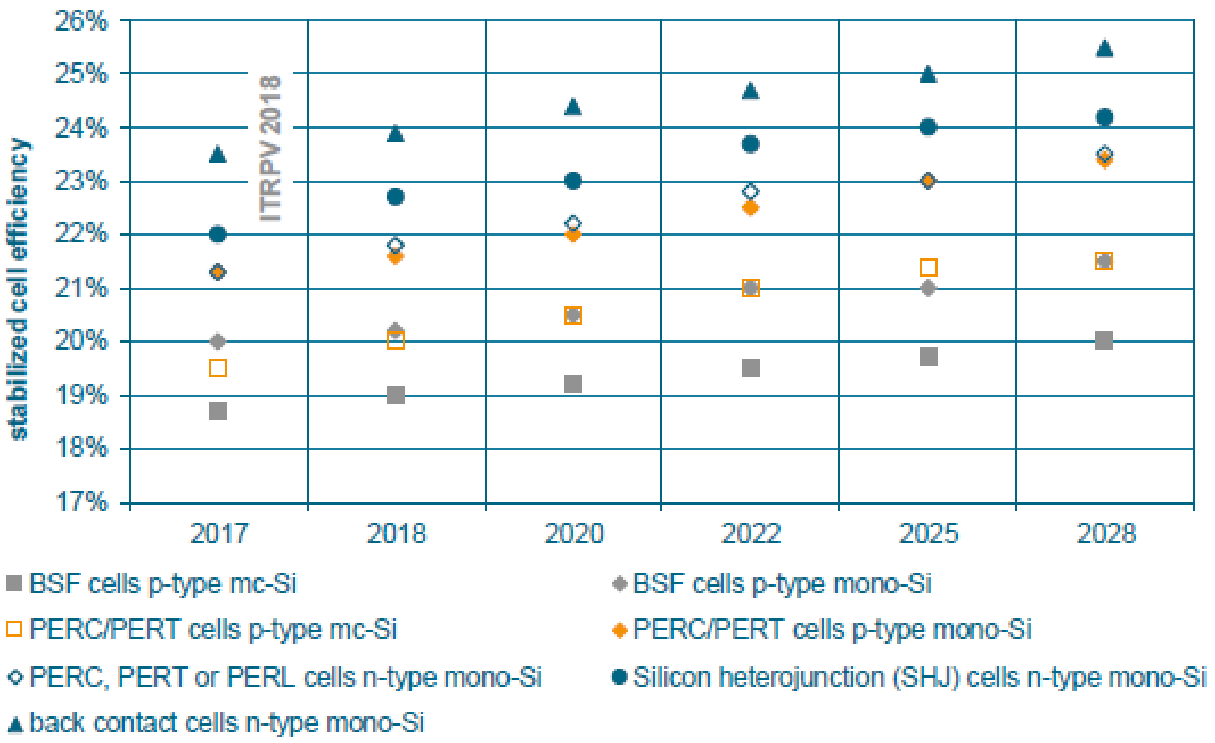
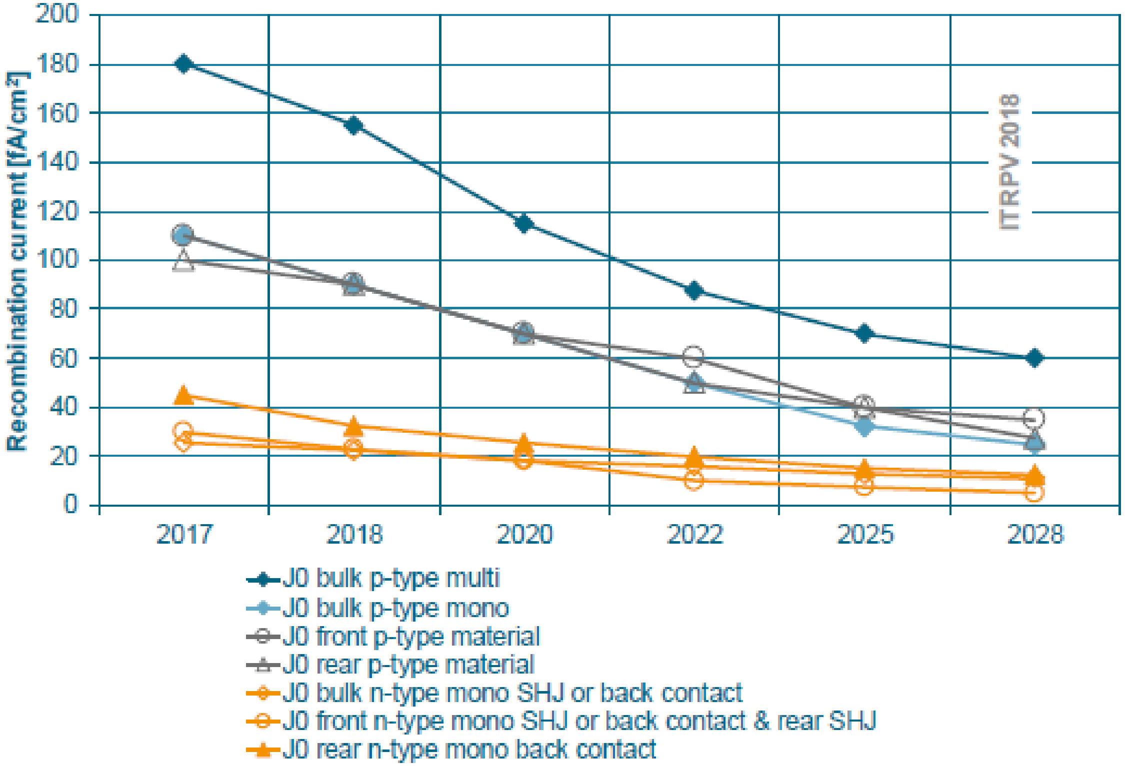
Introduction



Solar cell efficiencies are predicted to keep increasing in the next 10 years.

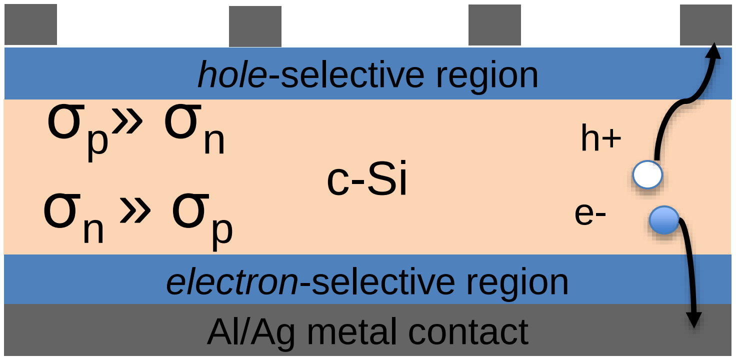
Source: ITRPV, *Itrpv*, March, pp. 1–37, 2018.

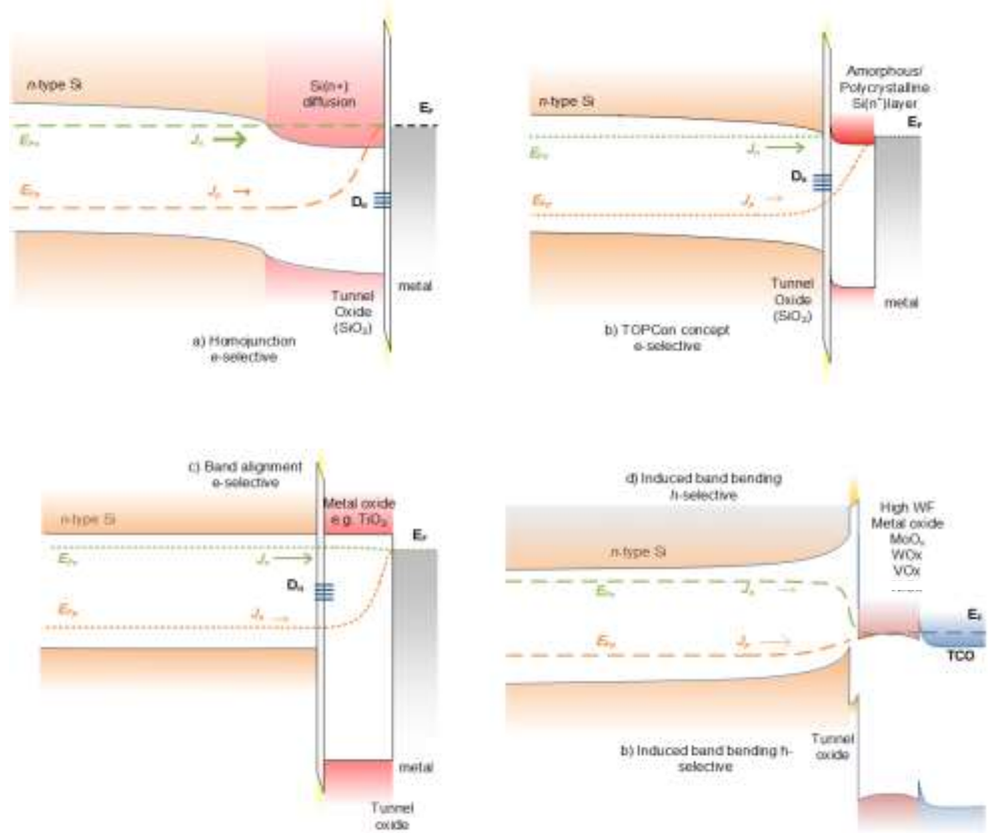
Introduction



Recombination current density should keep decreasing to be in line with increased efficiencies.

Carrier selective passivating contact





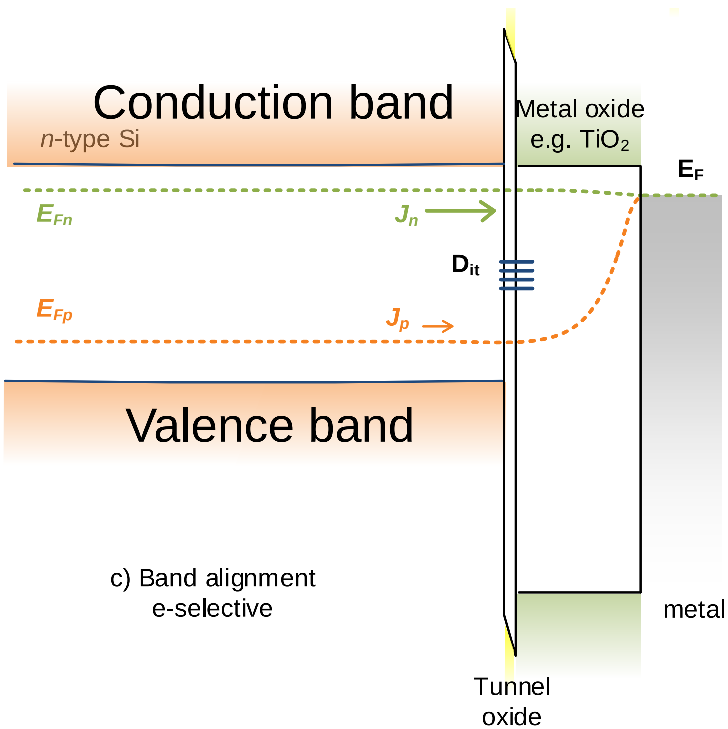
Passivating contacts act as :

- Passivation layers
  -Minimize surface recombination

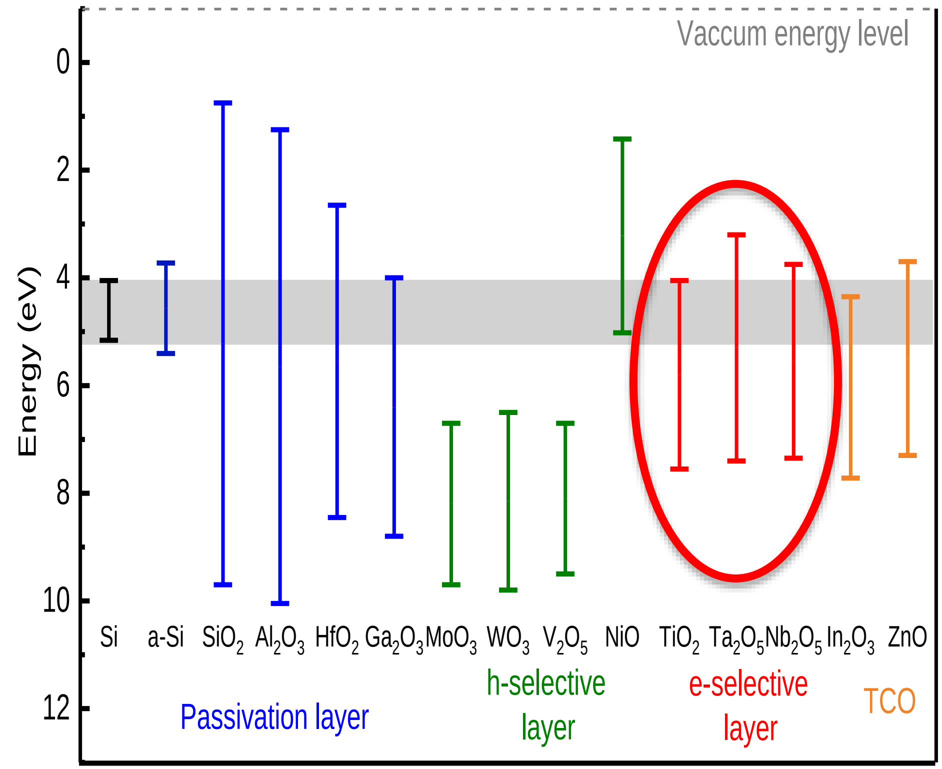
- Contacts
  -Efficient charge extraction

Different passivating contacts band alignments

Electron selective contact (ESC)

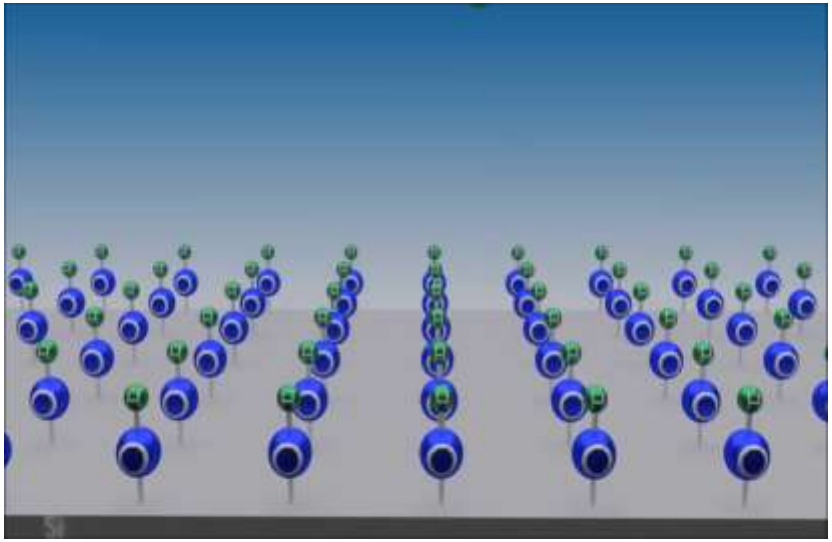


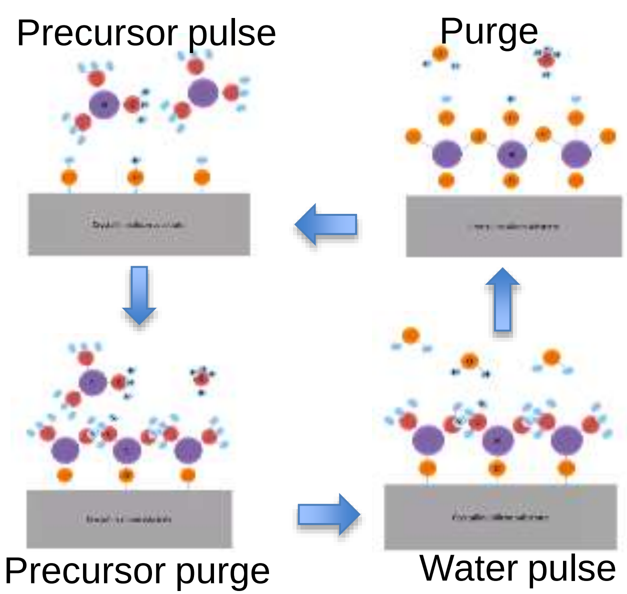
Band alignment – e-selective contact



Schematic illustration of the band alignment with Si of various metal oxides adapted from

Atomic Layer Deposition





Why Atomic Layer Deposition (ALD)?

- Ultimate control of thickness and composition of ultrathin layers
- Significantly lower precursor usage compared to alternative deposition technologies such as PECVD, sputtering, and thermal evaporation.
- Very low pinhole densities in material.
- Low temperature process

Source: https://pv-manufacturing.org/hot-topics-and-trends/atomic-layer-deposition/

ALD System – Ultratech® Fiji

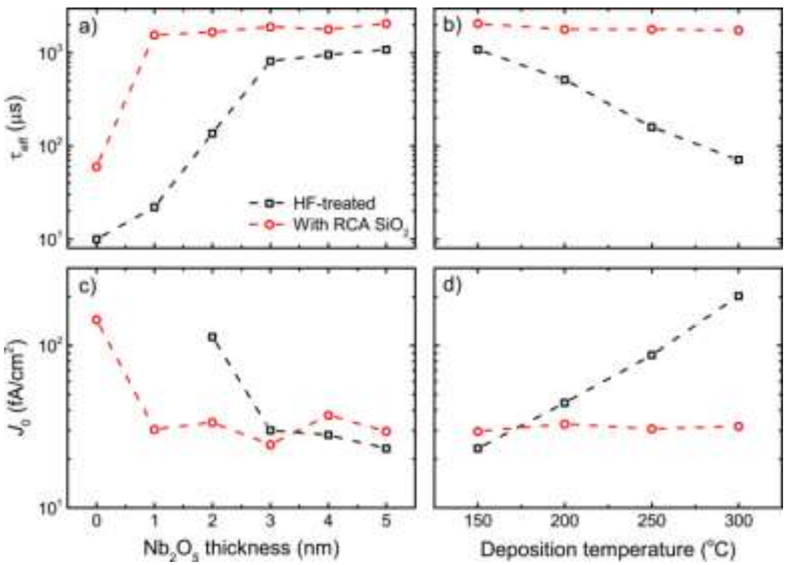
Plasma source

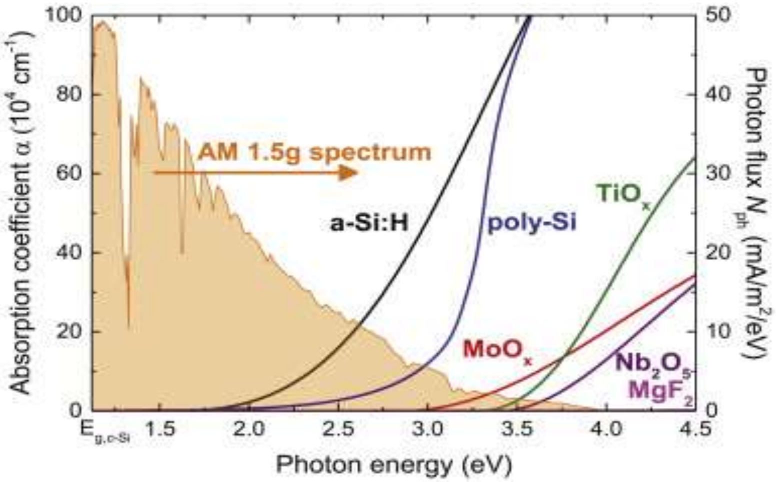
4 precursor ports

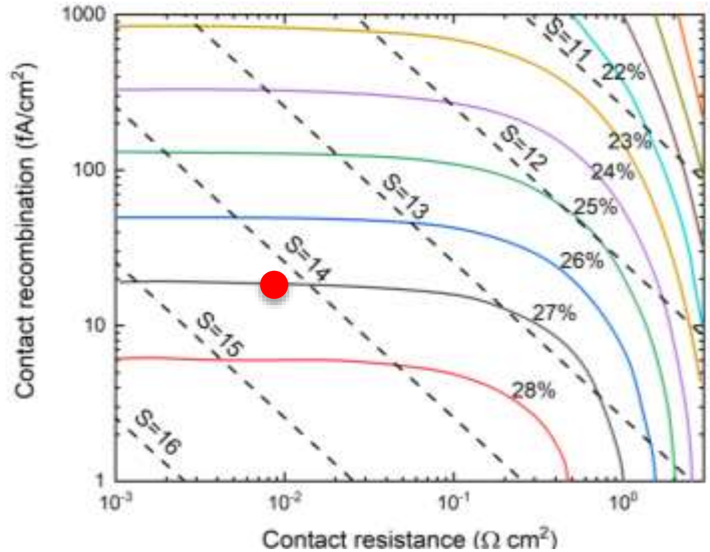
In-situ Ellipsometer

UNSW SYDNEY

Motivation – Nb_2O_5 as ESC



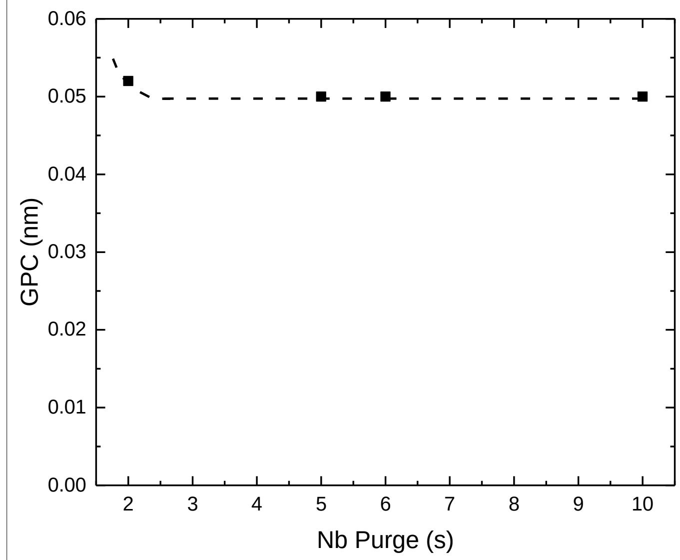


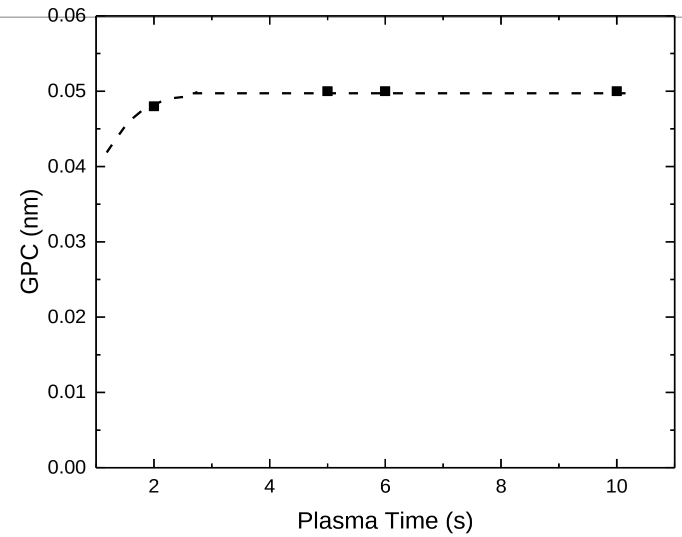


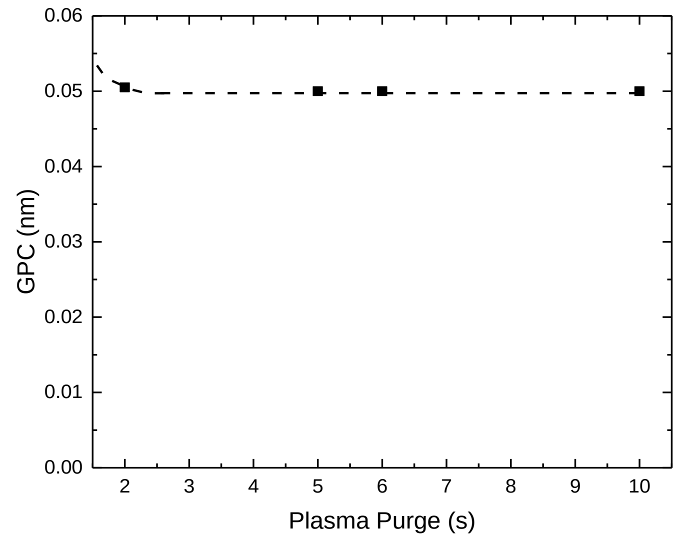
Upper limit efficiency vs *ρc* and J_0 of Single junction silicon solar cell

Source: Brendel et al., "Contact selectivity and efficiency in crystalline silicon photovoltaics." *IEEE Journal of photovoltaics* 6.6 (2016): 1413-1420.

Plasma Enhanced ALD Nb_2O_5 Recipe Optimization



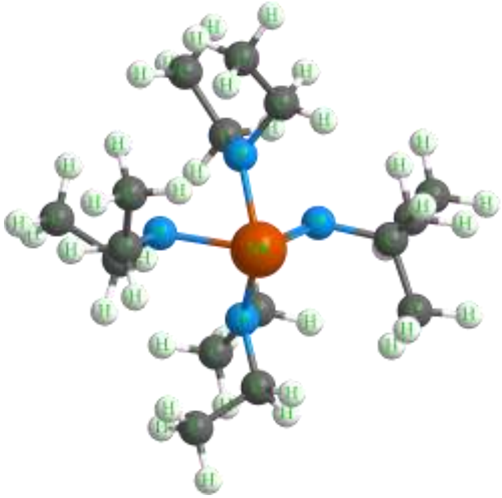




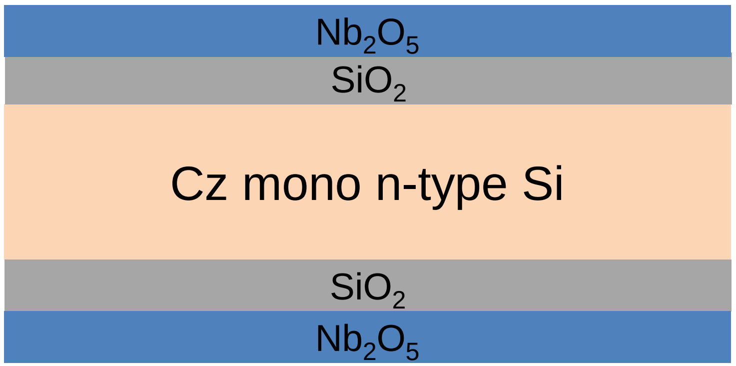
Plasma Enhanced ALD (PEALD)

Compared to Thermal-ALD:

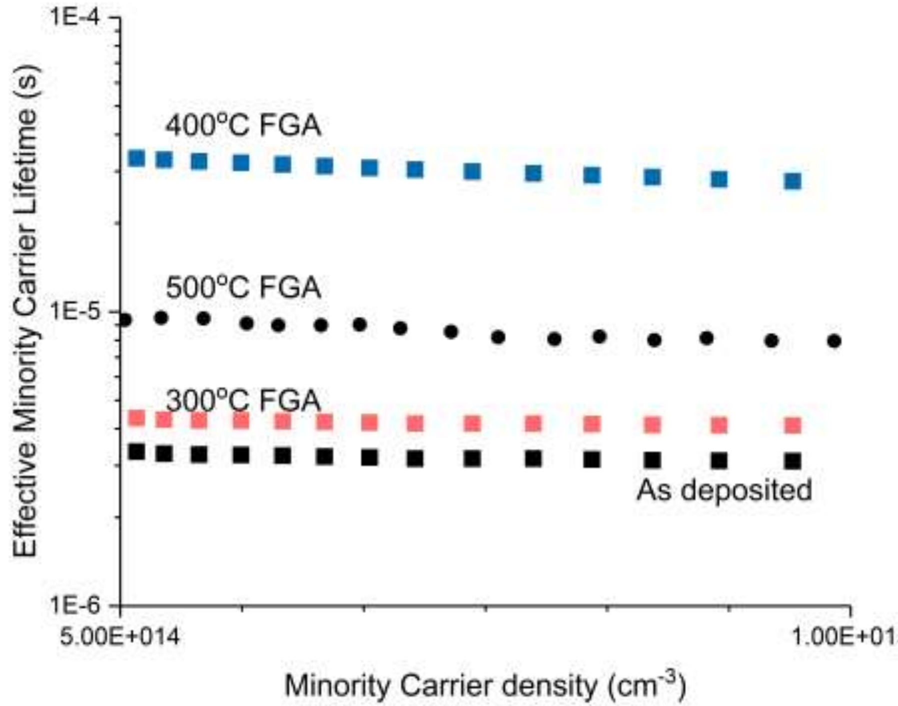
- Shorter nucleation time needed
- Higher GPC
- Shorter time cost per cycle: reduces from 60s/cycle to 20s/cycle



Effective Minority Carrier Lifetime

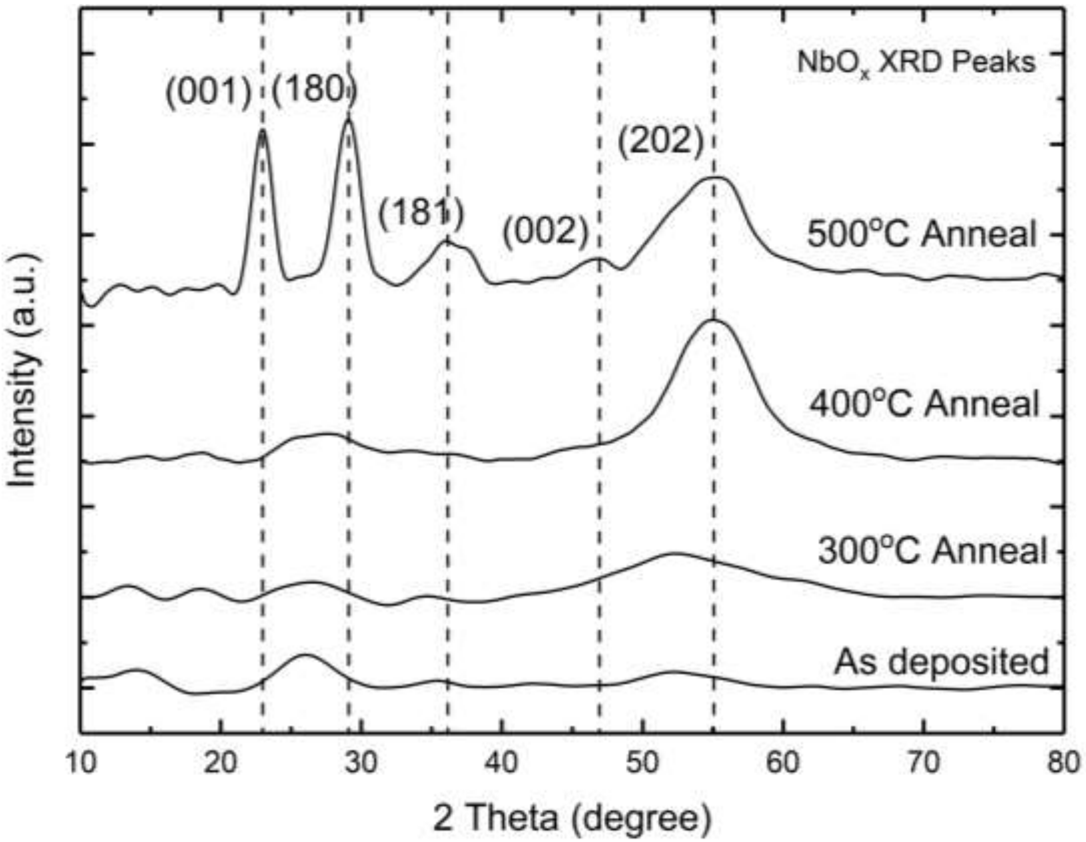


Plasma ALD
(~2.5nm with 1nm RCA SiO2)



- No passivation when as deposited
- After Forming Gas Annealing (FGA)
- Effective minority Lifetime degrades at higher temperature

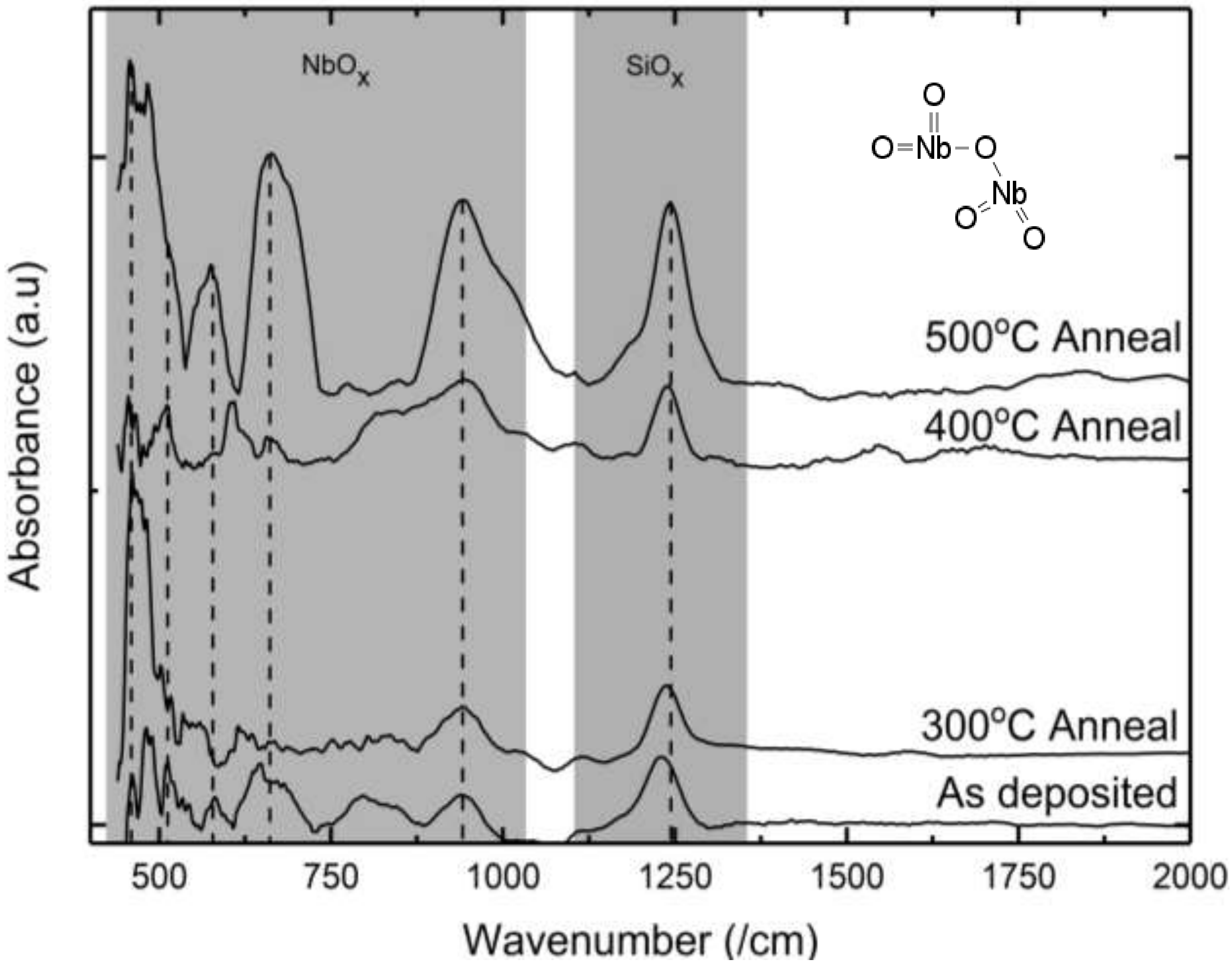
X-Ray Diffraction



Plasma ALD Nb_2O_5 on Si (~20nm)

- Until annealing temperature reaches 500^{o}C, there is no peak detected
- Two obvious peaks are detected after 500 ^{o}C annealing
- 'Humps' are observed

Angular Fourier Transform – IR (FTIR)



Stability under illumination

In-situ Sinton Effective Lifetime measurement

1 sun illumination/Dark
Open air
Room Temperature

Conclusion

- PEALD has a higher growth rate that Thermal ALD
- PEALD Nb2O5 can provide surface passivation
- Passivation acquired at 400 ^{o}C FGA
- Crystallization happens at 500 ^{o}C
- Significant degradation under illumination
- Silicon oxide increases along with annealing process

Questions?

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