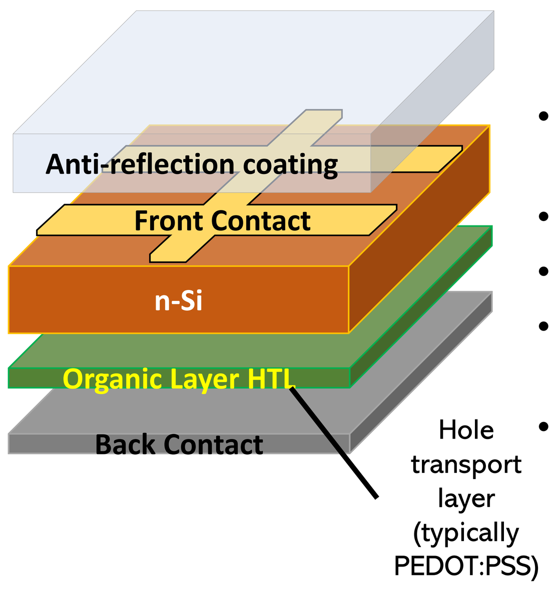
Development of self-doped PEDOT/Si hybrid solar cells

Introduction

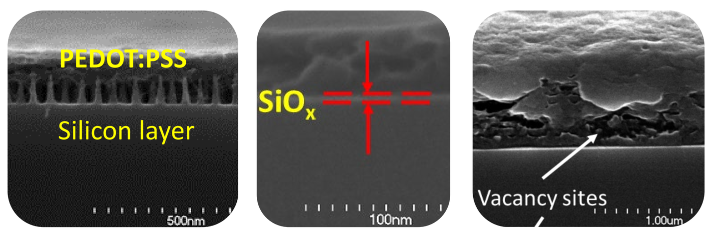
Silicon-Organic Hybrid Solar Cell (SOHC)



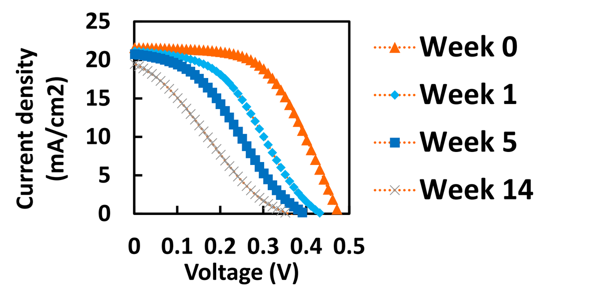
Schematic of a typical SOHC

- High efficiency (~17%) [1]
- Low material cost
- Easy fabrication
- Low temperature processes (>300°C)
- Easy to recycle

Challenges

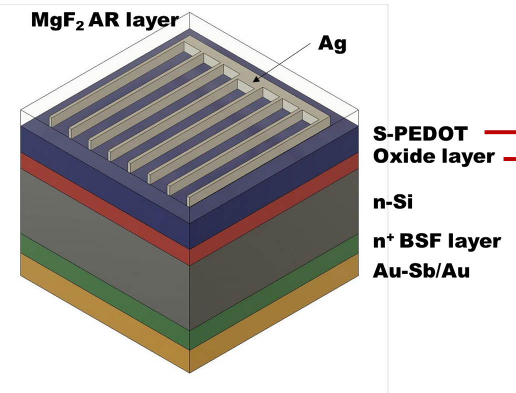


Poor junction interface | Growth of SiO_x interlayer [2] | Defects in PEDOT:PSS layer



Degradation of *J–V* characteristics over time

This Work



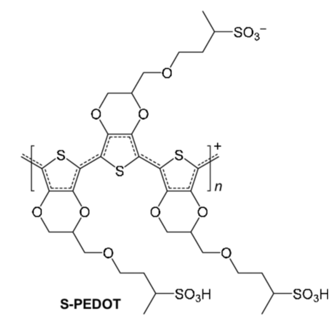
Schematic of SOHC fabricated in this study

Aim:

To improve the durability of SOHCs through a combination of high-quality passivation layer and a novel self-doped PEDOT

Self-doped PEDOT (S-PEDOT) [3]

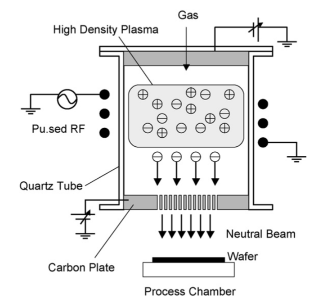
- Soluble in water
- Better conformality to nano structures
- Less void defects in thin film
- Similar conductivity to PEDOT:PSS



S-PEDOT Structure

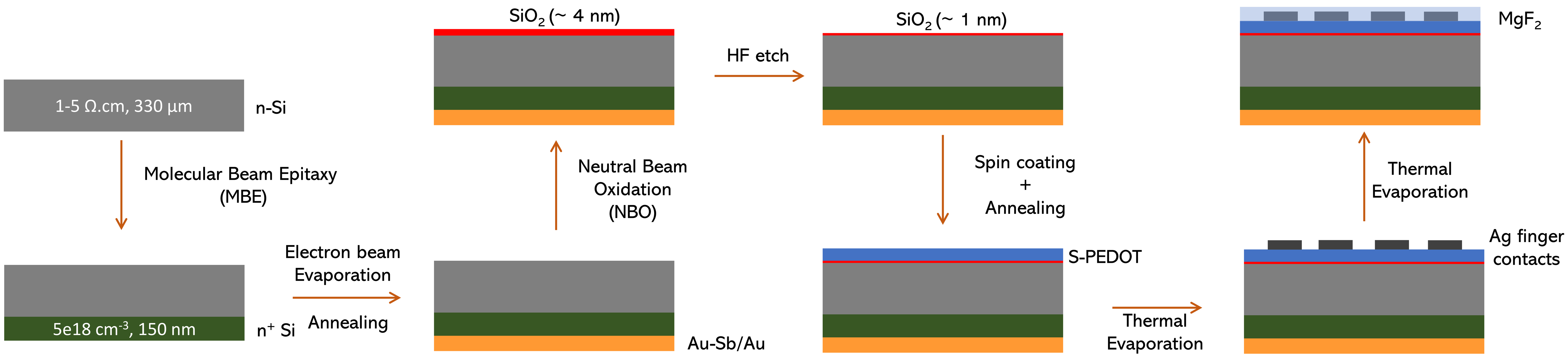
Neutral Beam Oxide (NBO) Layer [4]

- Room temperature process
- >95% pure SiO_2
- 3 nm thin layers in 300 s
- Defect free SiO_2 layer



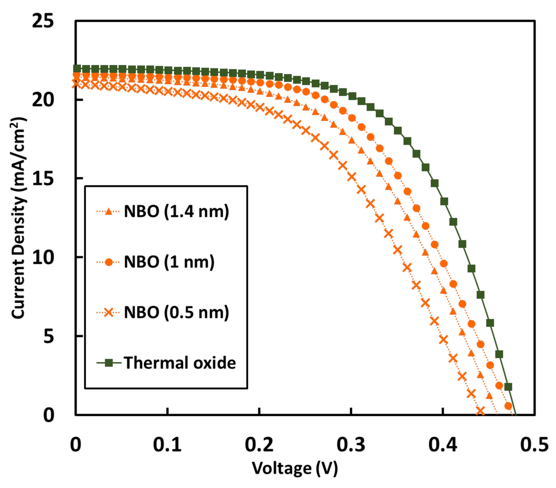
NBO process

Device Fabrication

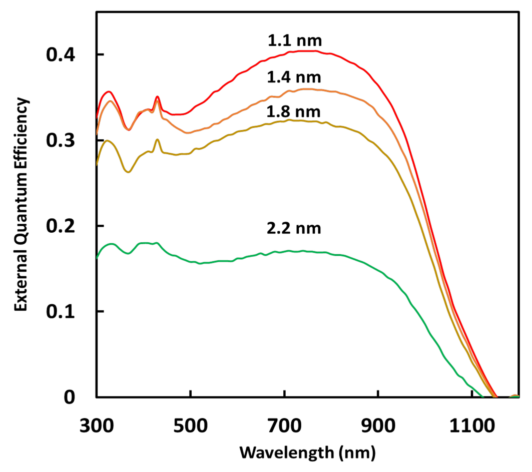


Results and Discussion

Dependence of PV characteristics on NBO film thickness



Illuminated *J–V* curves for each champion SOHC with different interfacial oxide layers.

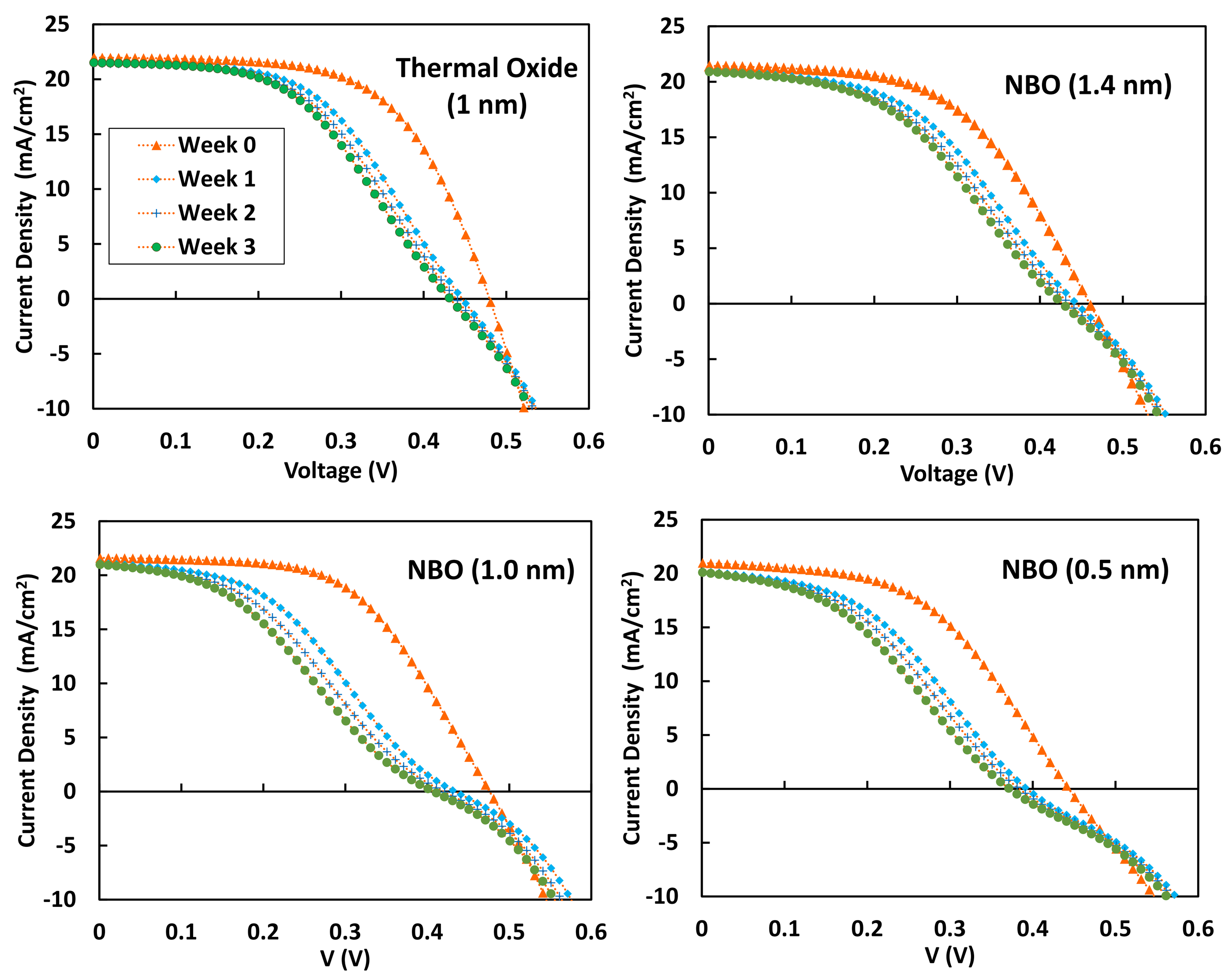


EQE spectra for S-PEDOT/Si cells with different thicknesses of the neutral beam oxide (NO) inter-layer.

Table for the PV characteristics of the measured samples:

SOHC	V_{OC}(mV)	J_{SC} (mA/cm²)	FF (%)	PCE (%)
NBO (1.4 nm)	453.25 ± 6.75	21.41 ± 0.28	50.25 ± 3	4.92 ± 0.33
NBO (1.0 nm)	474.25 ± 8.75	21.73 ± 0.45	54 ± 2	5.59 ± 0.10
NBO (0.5 nm)	419.5 ± 13.50	21.25 ± 0.70	49.5 ± 0.5	4.43 ± 0.2
Thermal oxide	460 ± 22.00	21.54 ± 0.45	55 ± 6	5.53 ± 0.82

Durability of measured solar cell samples



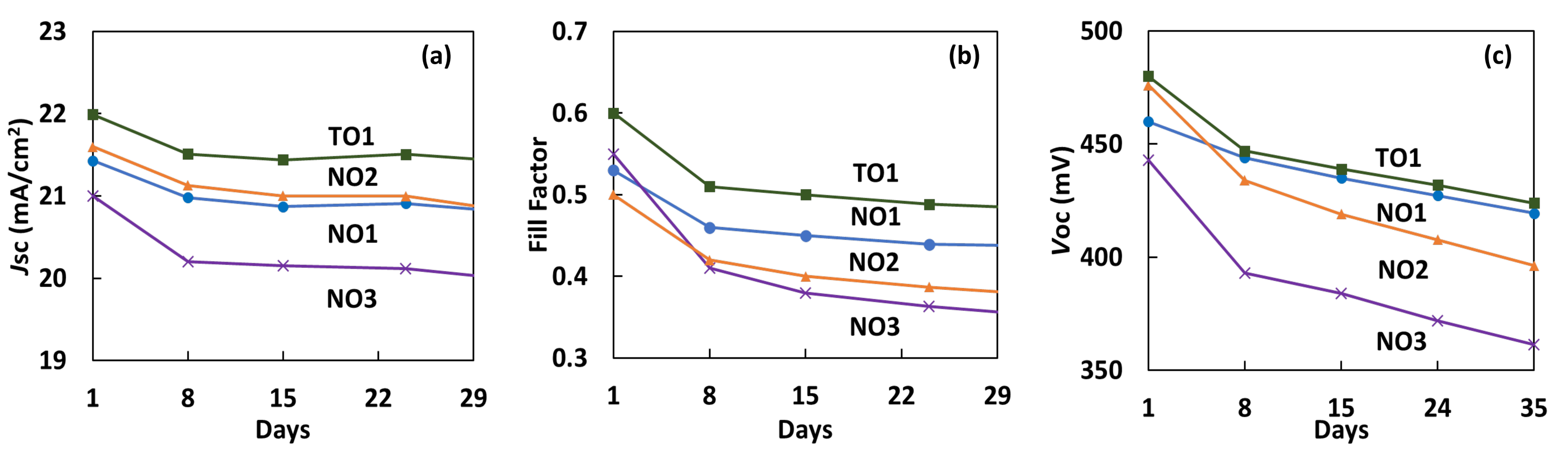
J–V curves for champion SOHCs with different oxide interlayers over 4 weeks

- 1 nm thermal oxide interlayer may perform better but NBO layers of the same thickness show better consistency over multiple samples.
- Oxide interlayers with the highest oxygen saturation (i.e. highest percentage of SiO_2) show the least degradation in photovoltaic performance.
- S-shaped *J–V* curve develops within the first week of storage pointing possible loss in PEDOT carrier concentration

Table for the thickness and saturation of the interlayers:

Preparation	Thickness (nm)	Oxygen Saturation (%)
NBO for 400 s	4.6	95
30 s HF etch after NBO	1.4	83
40 s HF etch after NBO	1.0	43
50 s HF etch after NBO	0.50	55
150 °C for 15 min	1.0	54

Results (contd.)



Durability of (a) J_{SC}, (b) *FF*, and (c) V_{OC} of the TO1 (thermal oxide), NO1 (NBO 1.4 nm), NO2 (NBO 1.0 nm), and NO3 (NBO 0.5 nm) samples over time.

Summary

- We fabricated simple planar silicon-organic hybrid solar cells (SOHCs) using a new self-doped PEDOT, which overcomes some of the limitations of PEDOT:PSS. The best performing cells achieved an efficiency of 6.35% with 482 mV in V_{OC} and 21.99 mA/cm² in J_{SC} for a cell with a 1 nm-thick interfacial oxide layer.
- Two probable degradation mechanisms caused the development of s-shaped J–V responses:
  - (i) reaction of S-PEDOT with unsaturated silicon sub-oxides
  - (ii) the degradation of S-PEDOT over time.
- The use of a thin, homogeneous, and highly saturated silicon oxide layer using neutral beam oxidation (NBO) proved effective against mitigating the first factor.

References:

1. D. Zielke et al., Solar Energy Materials & Solar Cells 2014, 131, 110–116.
2. Sara Jackle et al., ACS Appl. Mater. Interfaces 2016, 8, 8841–8848.
3. Hirokazu Yano et al., Sci. Adv., 2019, 5, eaav9492.
4. Seiji Samukawa, Jpn. J. Appl. Phys., 2006, 45, 2395.

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