

Well Passivated a-Si:H Back Contacts for Double-Heterojunction Silicon Solar Cells

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NREL, Golden, Colorado, USA

2006 IEEE 4th World Conference on Photovoltaic Energy Conversion

May 7-12, 2006

Hilton Waikoloa Village, Waikoloa, Hawaii

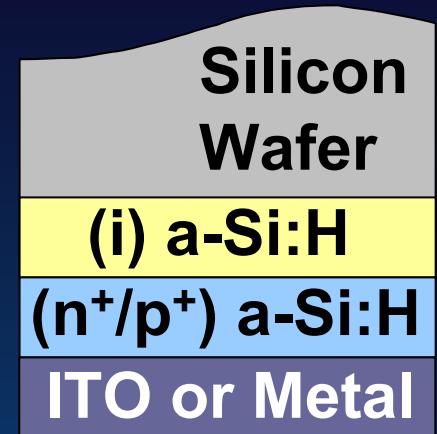
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Outline

- ⇒ Advantage of doing back contact with Silicon Heterojunction (**SHJ**)
- ⇒ Hot-Wire CVD (**HWCVD**)
- ⇒ SHJ back-contact better than alloyed/diffused
 - both n- and p-type wafers
 - good back-surface-field (**BSF**)
- ⇒ Critical for good SHJ solar cell fabrication
 - layer optimization- **in brief, here**
 - **surface preparation**



SHJ at Back

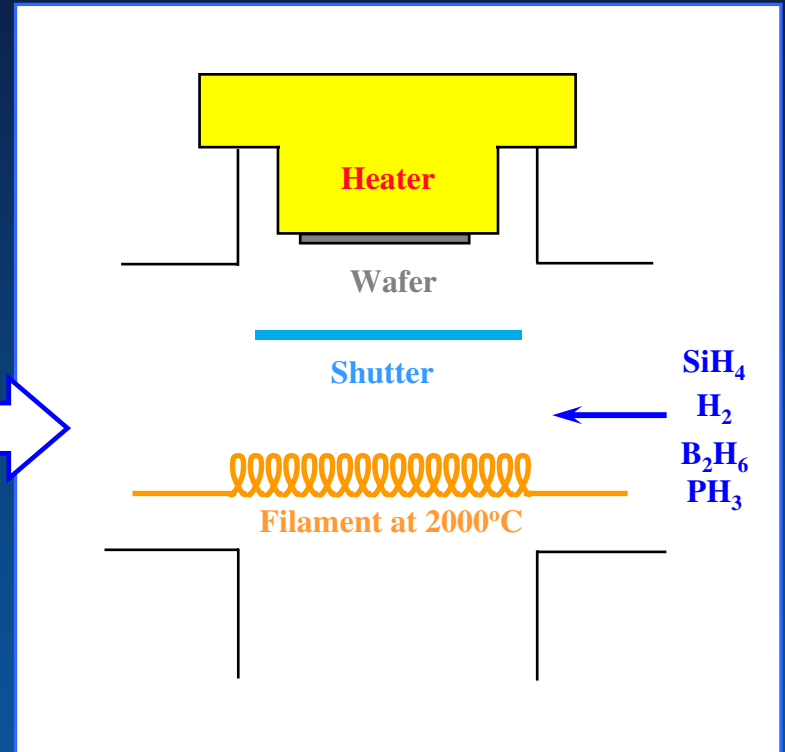
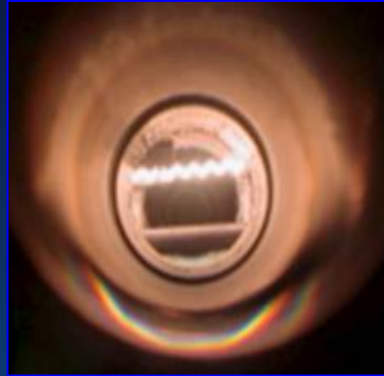
Advantages of a-Si:H/c-Si Heterojunction

- ⇒ Low temperature processing (< 250°C)
 - preserves high lifetime
 - compatible with gettering or hydrogenation
 - prevents bowing (< 200μm wafers)
- ⇒ Excellent passivation on c-Si
 - LOW minority-carrier recombination velocity
 - HIGH open-circuit voltage (V_{oc})
- ⇒ a-Si BSF better than alloyed or diffused BSF
 - both passivation and vertical current conduction
 - no direct metal/c-Si contact (**impurity source**)

Advantages of Hot-Wire CVD

⇒ HWCVD

- simple
- scalable
- fast deposition
- no ion bombardment of c-Si surface



Plasma damage to c-Si a major issue using PECVD

Optimization of SHJ Devices

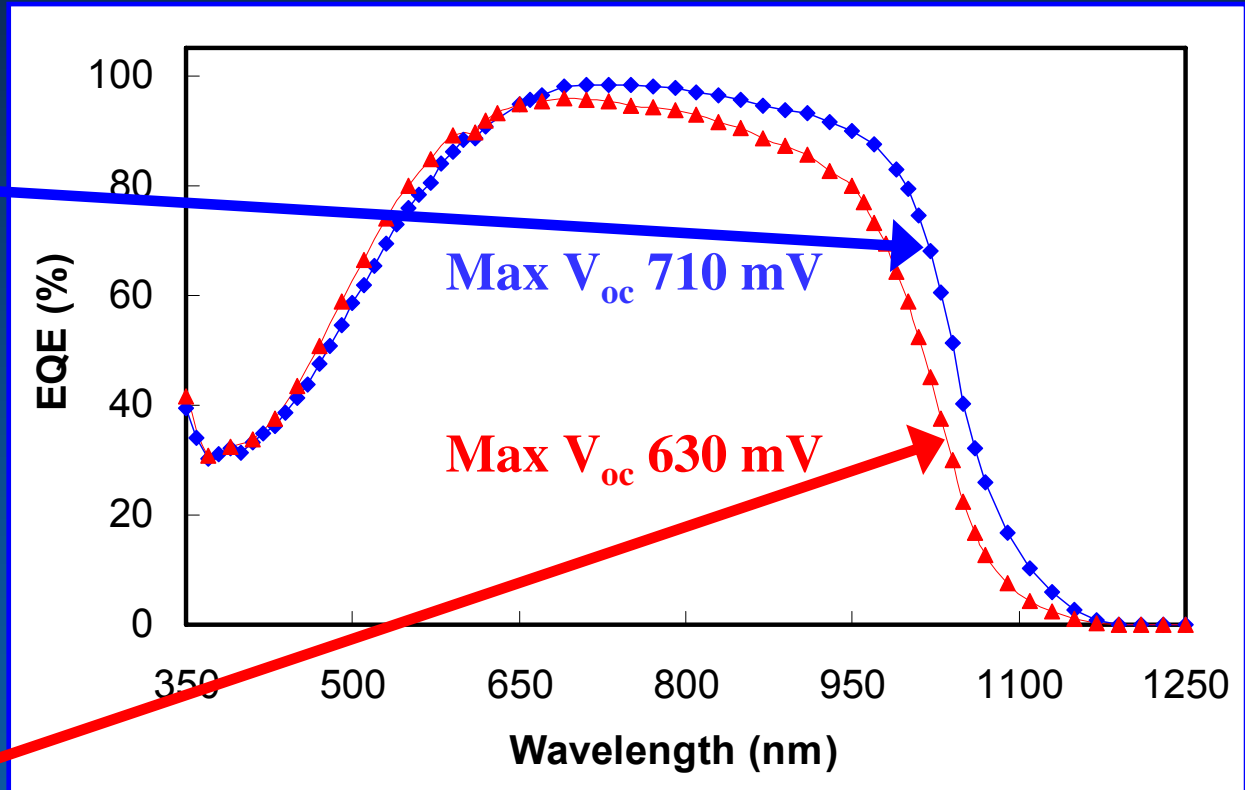
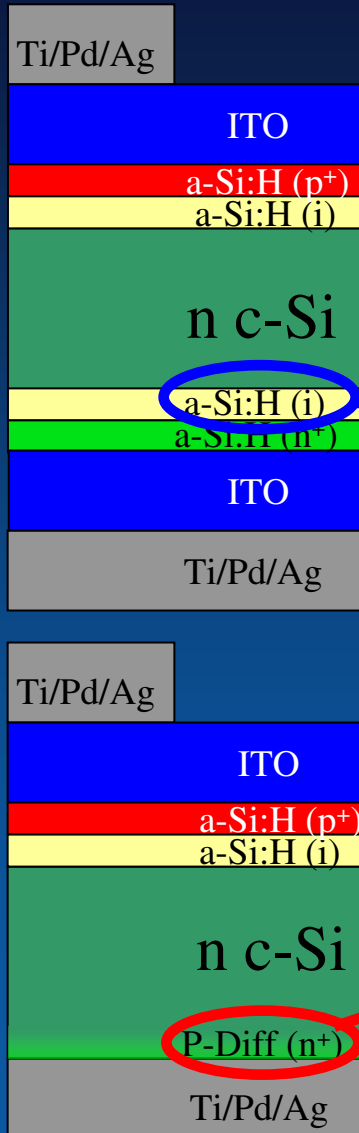
⇒ Critical: 1. preparation, 2. deposition

- 1. Very clean SHJ interface preparation (V_{oc})
 - stringent cleaning before a-Si:H deposition
 - junction and contacts close to interface
- 2. High quality intrinsic and doped a-Si:H
 - no epitaxy at interface (V_{oc})
 - low interface defect density intrinsic a-Si:H (V_{oc})
 - high dopant activation in emitter and BSF (V_{oc}/FF)
 - low blue absorption in a-Si:H (J_{sc})
 - good front/back contacts to ITO/metal (FF)

SHJ Back-Contact Passivation (n-type FZ)

Phosphorus Diffused vs. **SHJ/ITO**

Absolute External Quantum Efficiency



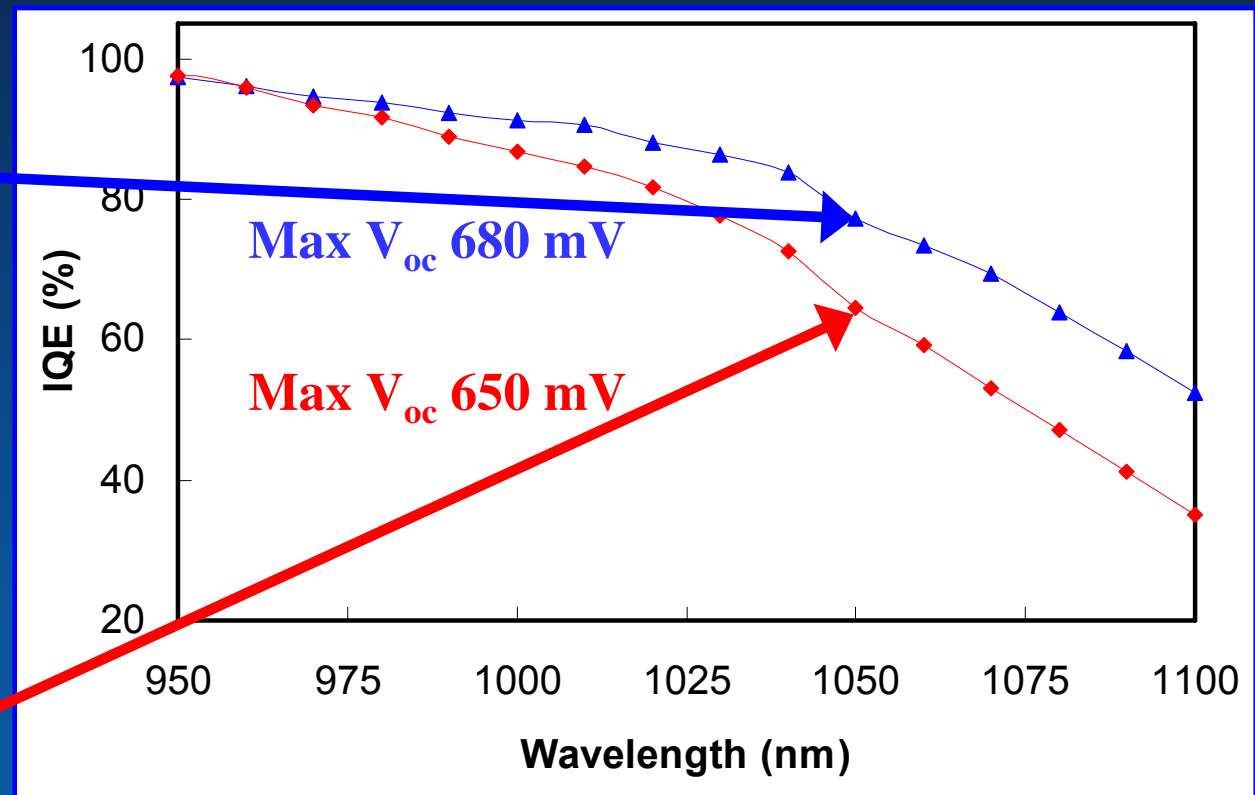
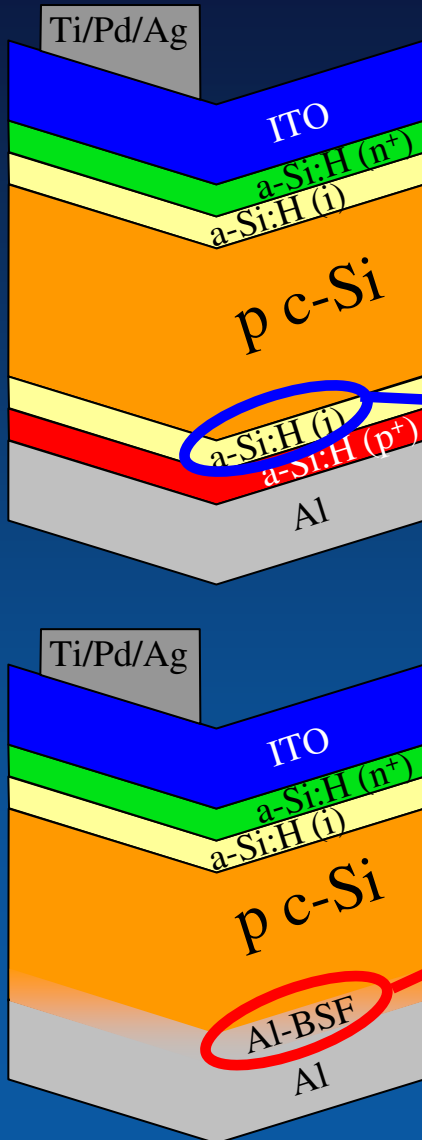
SHJ Back-Contact Passivation (p-type FZ)

Alloyed Al-BSF

vs.

SHJ/Al

Absolute IQE- removing reflectance of front



SHJ Back-Contact is Excellent

⇒ SHJ better than Al-BSF on p-type wafer

- superior back surface passivation
- Fill-Factor greater than 78% achieved
- minority-carrier recombination velocity

- vs.
- 15 cm/s for SHJ ⇒ (i/p) a-Si:H/Al
 - 1000 cm/s for Al-BSF

⇒ SHJ better than Phosphorous diffused on n-type

- superior back surface passivation
- Fill-Factor greater than 74% achieved

⇒ SHJ interfaces are more critical than alloyed or diffused junction surfaces

Surface Preparation Important

⇒ 4 Generations (GEN-1 through GEN-4)

- increasing complexity
- developed for SHJ
- baseline deposition for each GEN's maximum V_{oc}

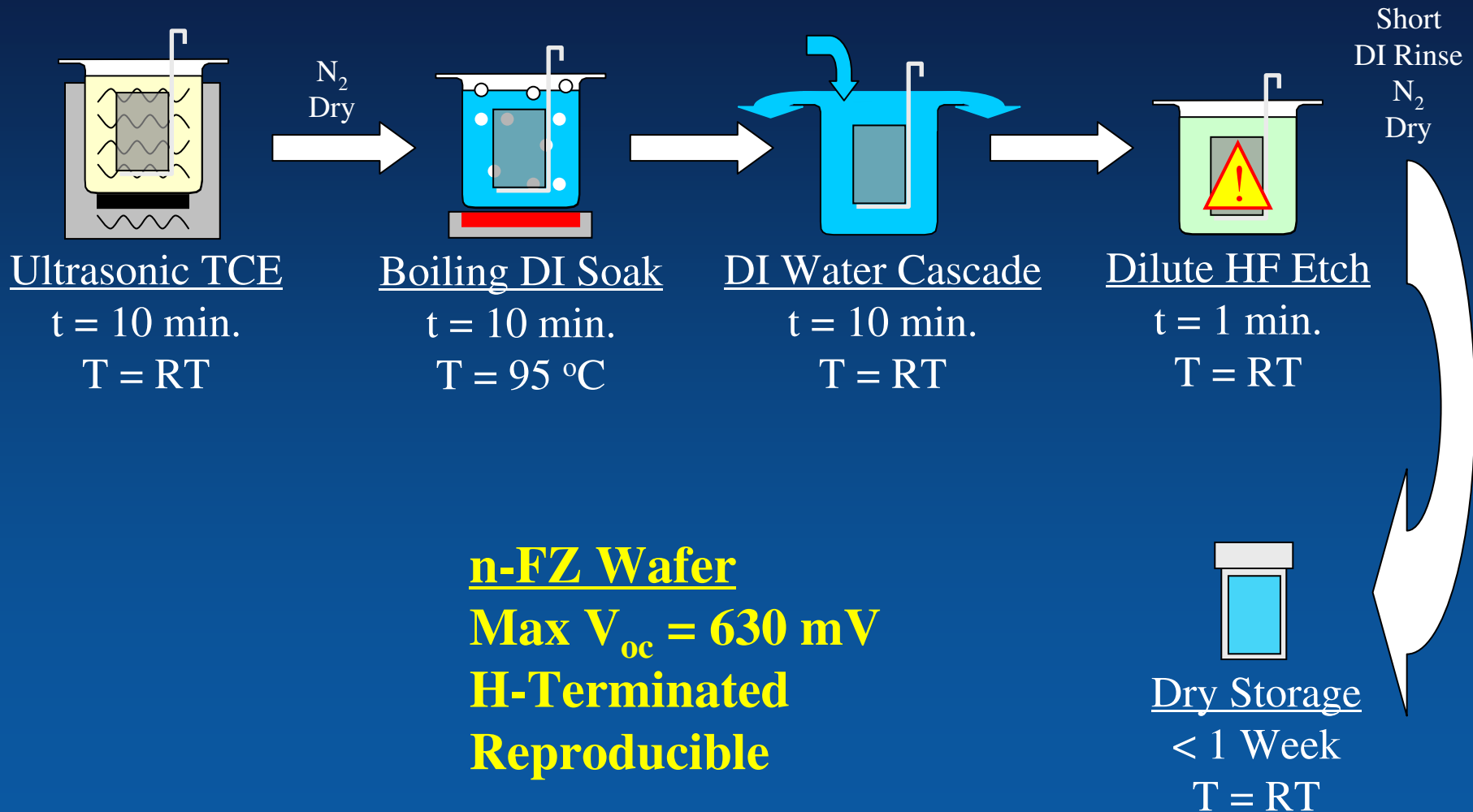
⇒ Stable oxide and interface

- store in clean box
- remove impurities trapped in oxide by final HF etch

⇒ Protective chemical oxide by RCA-2

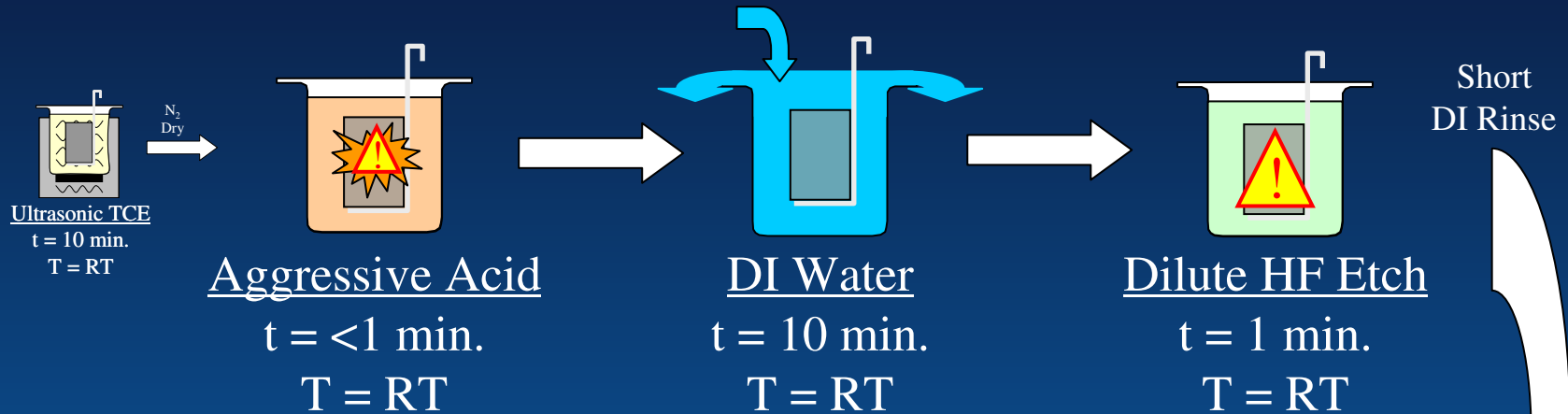
- 6:1:1 ⇒ $H_2O : HCl : H_2O_2$
- 2.5% HF strip before deposition

GEN-1 Simplest Cleaning Procedure



GEN-2 Aggressive Acid Cleaning

Replaced Boiling DI Water

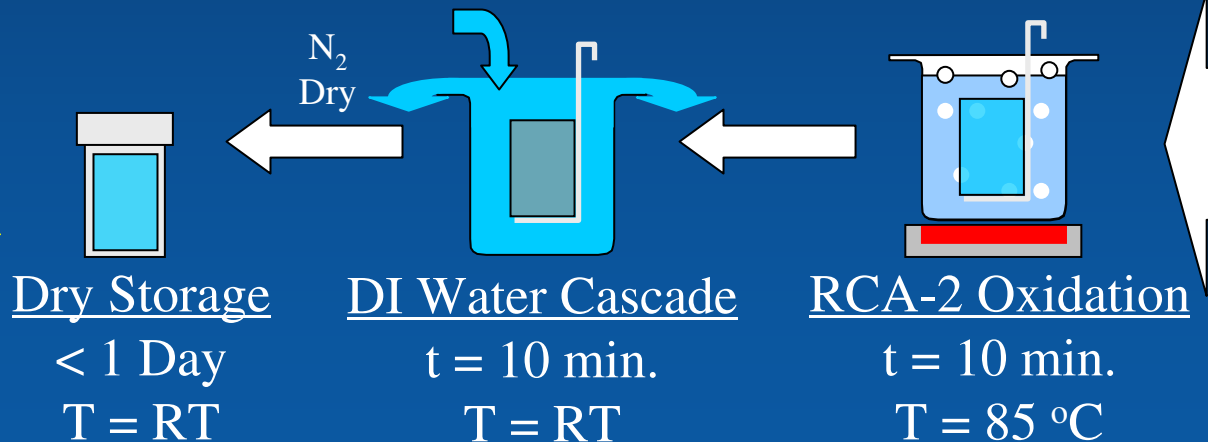


n-FZ Wafer

Max V_{oc} = 680 mV

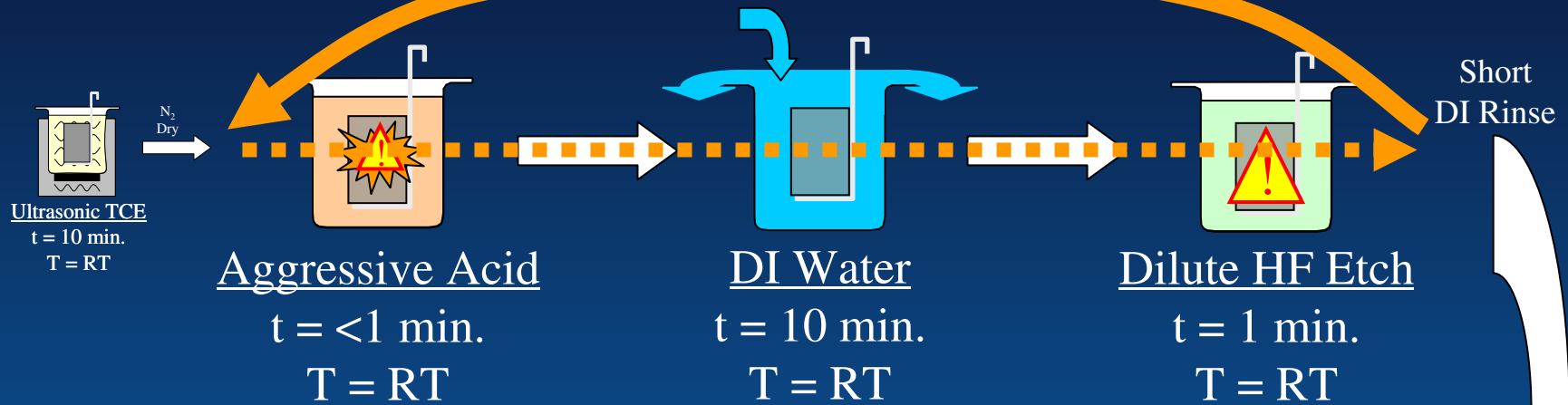
Full clean right
before deposition

Not reproducible



GEN-3 Repeat Aggressive Acid Cleaning

Repeat One Time-Fresh Acids

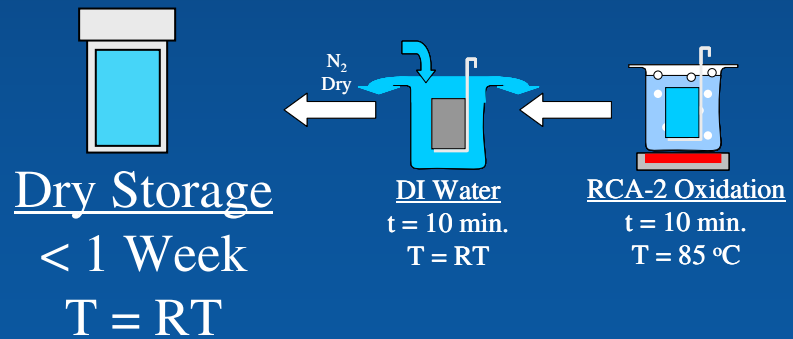


n-FZ Wafer

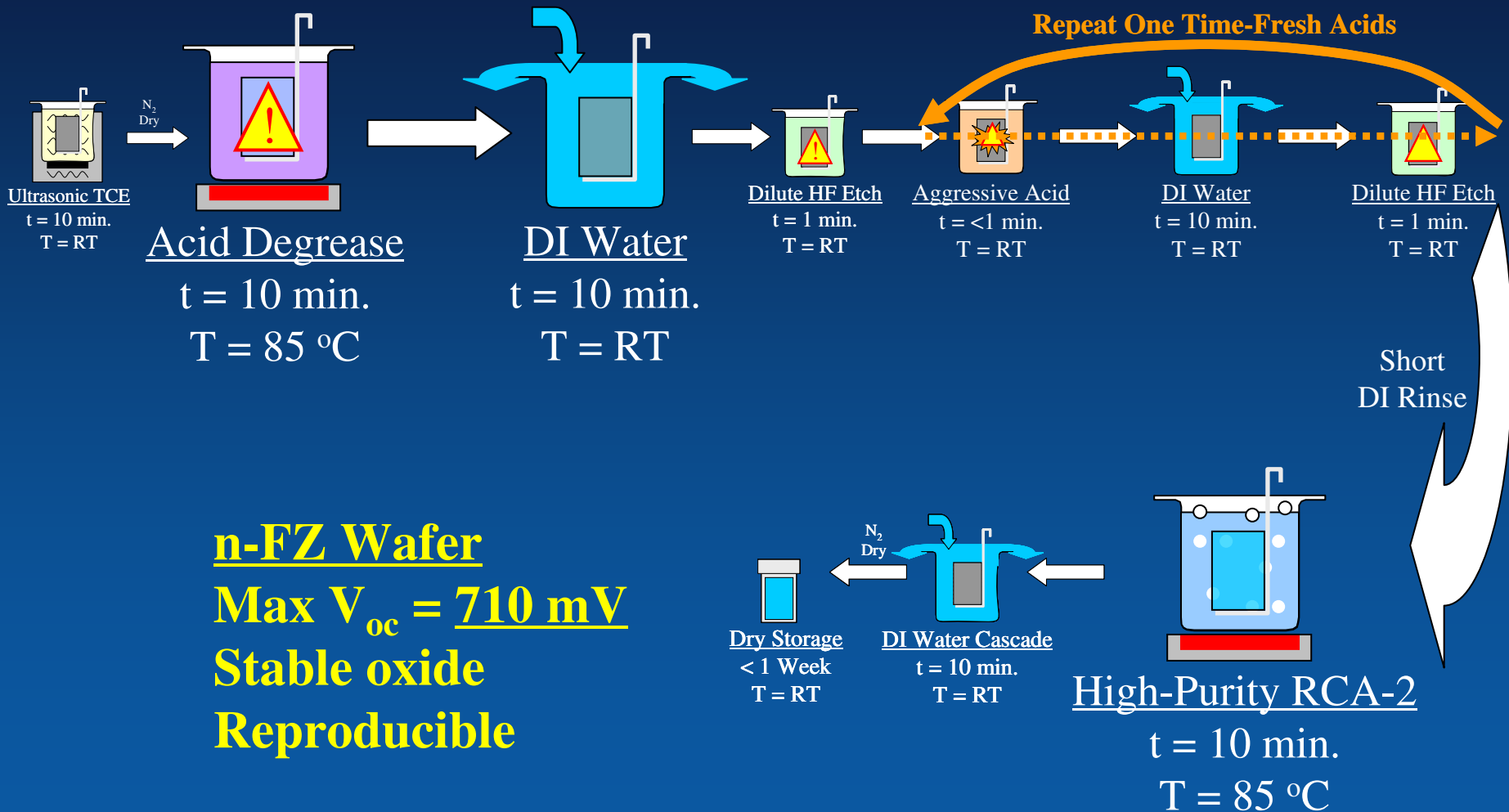
Max V_{oc} = 690 mV

Stable oxide

Not reproducible



GEN-4 Improved Degrease and Oxide Purity



n-FZ Wafer
Max V_{oc} = 710 mV
Stable oxide
Reproducible

Surface Preparation Summary

GEN-1 Simplest

- H-terminated

GEN-2 Aggressive Acid Cleaning

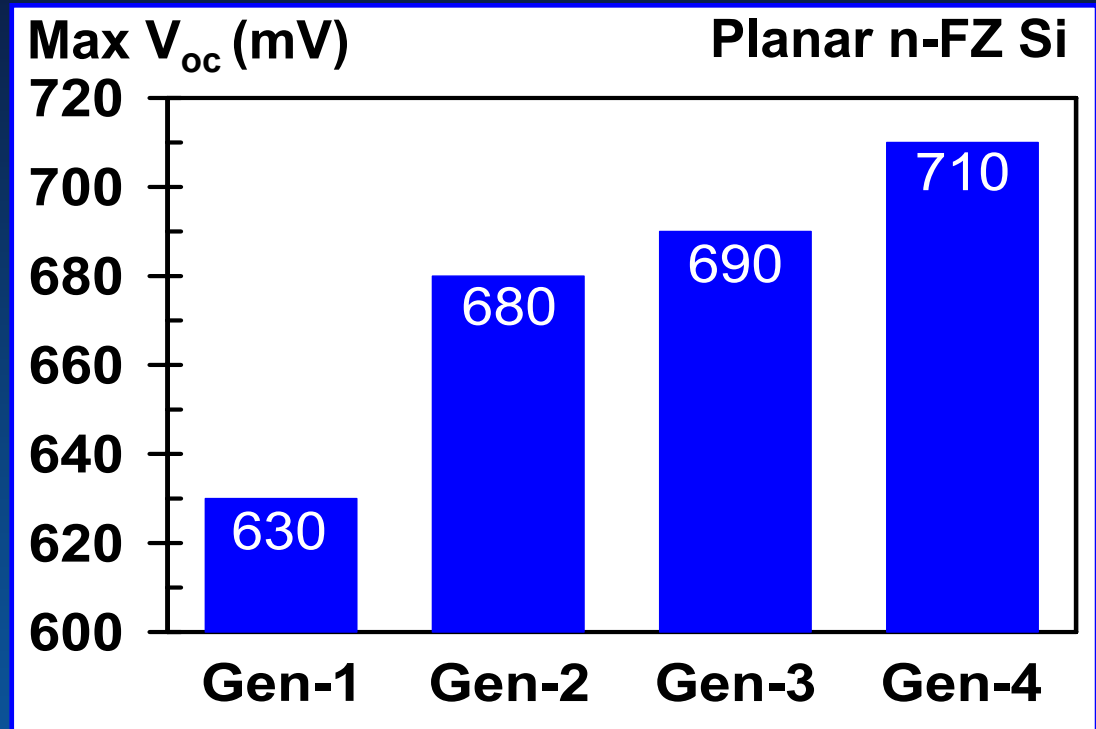
- just before deposition
- not reproducible

GEN-3 Repeated Aggressive Acid

- degrease interaction
- not reproducible

GEN-4 Improved Degrease & Oxide Purity

- reproducible
- stable chemical oxide

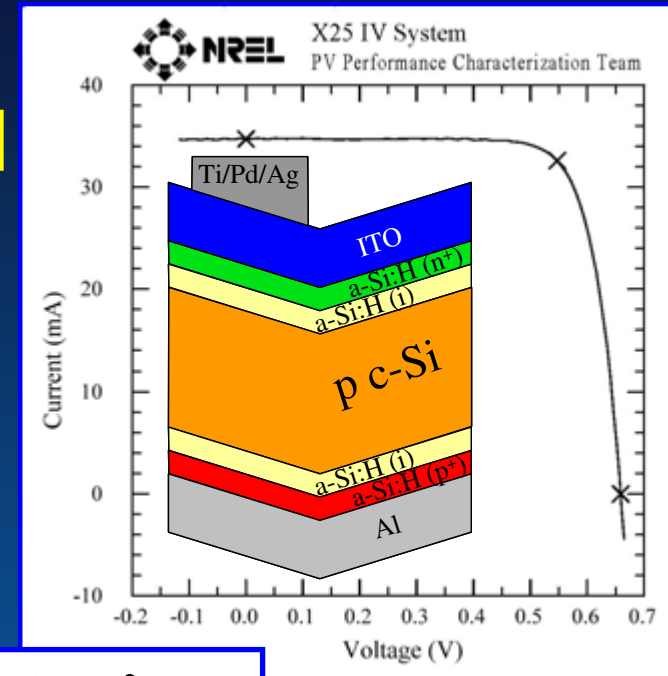


Conclusions

⇒ **SHJ successfully replaced** Al-BSF or P-diffused full area back contacts

⇒ **Surface preparation and a-Si:H optimization** are both critical for device performance

⇒ **Confirmed Efficiency**
➤ **18.2 %**



AM1.5 1-cm²

$V_{oc} = 667 \text{ mV}$

$J_{sc} = 35.5 \text{ mA/cm}^2$

$FF = 76.9 \%$

$\eta = 18.2 \%$

ISO-9000 AM1.5
Light I-V measured
by Keith Emery &
Tom Moriarty

Acknowledgements

- ⇒ Scott Ward, Russell Bauer, Anna Duda, and Bobby To for their valuable technical and scientific contributions.
- ⇒ Ajeet Rohatgi, and Vijay Yelundur of Georgia Tech for p-type Al-BSF wafers.
- ⇒ This work is supported or funded under U.S. DOE Contract No. DE-AC36-99G010337