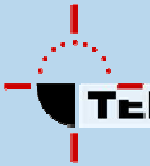


Industrial BBr3 Boron Furnace Doping for High-Efficiency N-type Cells

James Hwang, Amtech/Tempress

Ard Vlooswijk, Tempress Systems BV

July 14, 2011

TEMPRESS®

Expert Source for Diffusion/PECVD Technology

Outline

- Introduction of Amtech Systems and Subsidaries
- Overview of High-Efficiency N-type Cell (N-Panda)
- BBr3 Boron-Emitter Process for N-type Cell
- Dry HF Etcher for PSG/BSG Removal and Clean Surface Passivation

Amtech Group:

TEMPRESS®

PR HOFFMAN®

AMTECH SYSTEMS

Nasdaq: ASYS

R2D automation®

Bruce Technologies®

Amtech History *(Diffusion Experts)*

(Founded 1981)

1983 → Acquired Intel Corp invention: Diffusion processing tool (ATMOSCAN).

1994 → Acquired Tempress® Systems: Diffusion furnace business.

1997 → Acquired P.R. Hoffman®, silicon polishing consumable business.

2004 → Acquired Bruce Technologies® from Hitachi Kokusai; Diffusion furnace business. Became No. 1 Semi horizontal Diffusion company in the world.

2006 → Entered into Joint Development Agreement with ECN for N-type Diffusion Technology.

2007 → Acquired R2D™ Ingenierie SAS; Solar Diffusion Automation.

2008 → Entered into 3-party Collaboration Agreement: Tempress, Yingli, and ECN for N-type technology.

2009 → Introduced Solar Dry Etch (PSG removal) product, in addition to Solar PECVD.

Amtech Products, Brands & Applications

Diffusion Furnace, PSG & PECVD

TEMPRESS

Bruce Technologies Inc.
A Subsidiary of AMTECH SYSTEMS INC.

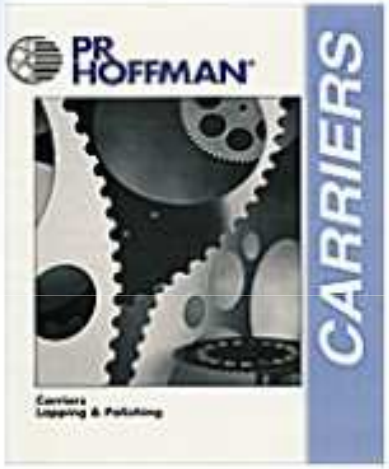
Furnace Automation & Wafer Handling Systems

R2D automation

S-300

Solar Cells & Semiconductor Chips

Wafer Carriers



PR HOFFMAN

Silicon Wafers

About Tempress as the preferred furnace supplier

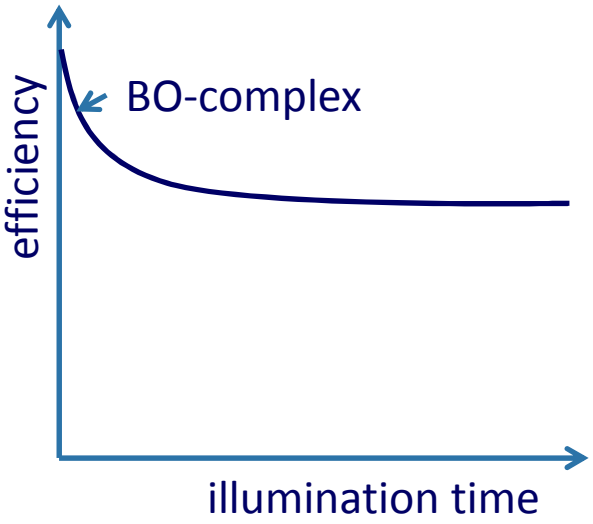
- Proven track record since 1968 in Semiconductor and Solar industry
- One company supplying both furnace systems and wafer automation equipment (one contact point for service and support)
- Worldwide service organisation with local service offices in Europe, USA, China Taiwan and Singapore
- Close cooperation with ECN (Energy Centre Netherlands) on POCL3, BBr3, Oxidation and PECVD process development for higher efficiency mono-Si cells
- Tempress POCl3 furnace market share in China > 35%
- Tempress POCl3 furnace market share in Taiwan > 40%
- Tempress POCl3 installed cell capacity in Asia > 10 GWatt
- Tempress BBr3 boron emitter is a well production-proven technology demonstrated by volume production of bi-facial n-type cell at Yingli (n-Panda) with high-efficiency.

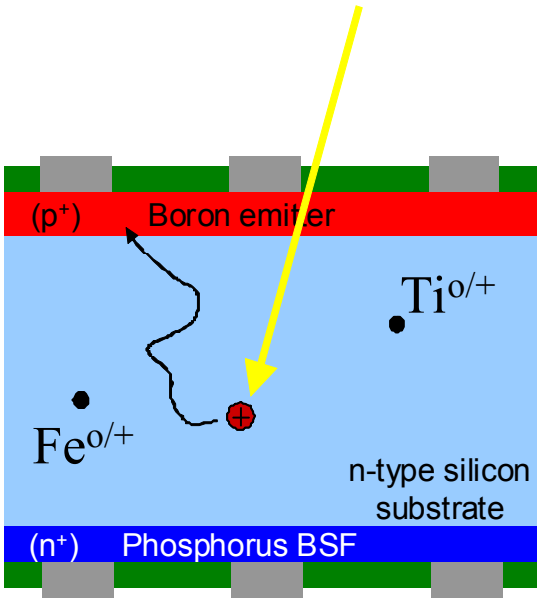
N-type: the road to higher efficiencies

- N-type cells lead to higher efficiency:
  - No light-induced degradation
  - Less sensitive to metal contamination.

- Boron-emitter formation and passivation are key technologies for n-type cells

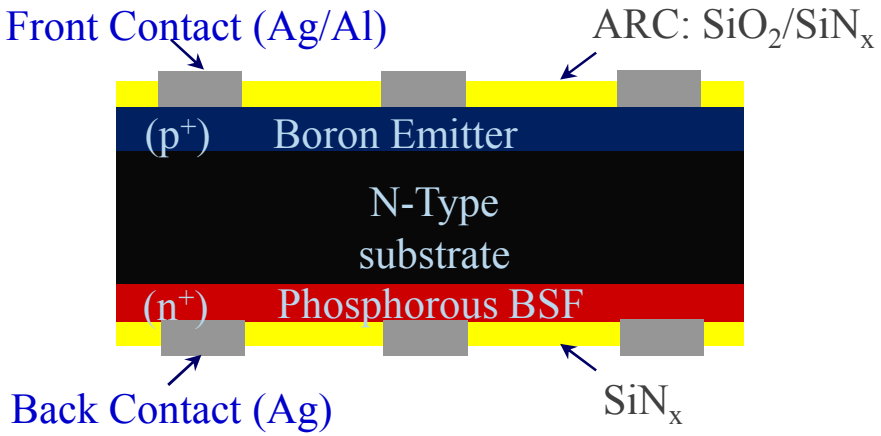
- Tempress provides industrial BBr3 diffusion for boron-emitter and POCl3 for BSF (Back Surface Field).

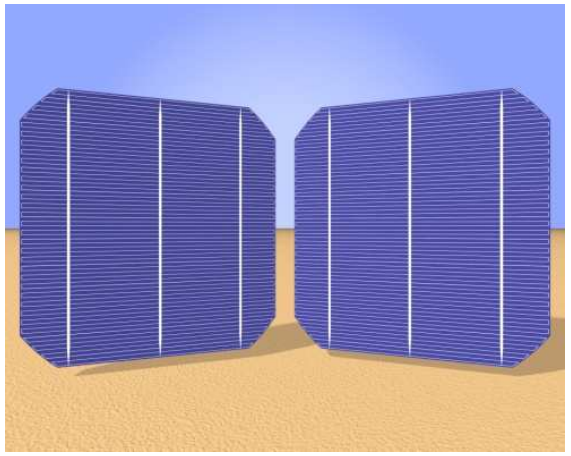




N-type Bifacial Cell (N-Panda)

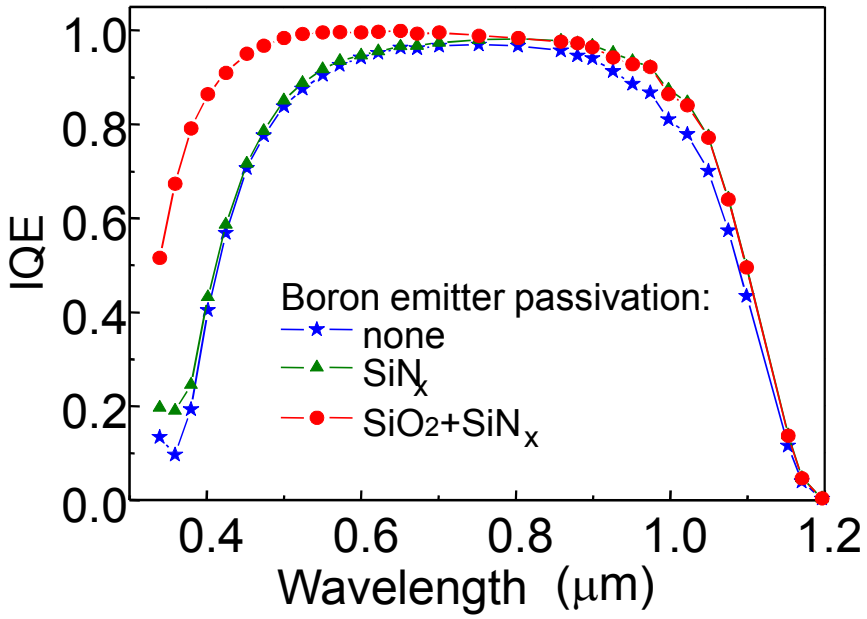
Self aligned selective emitter

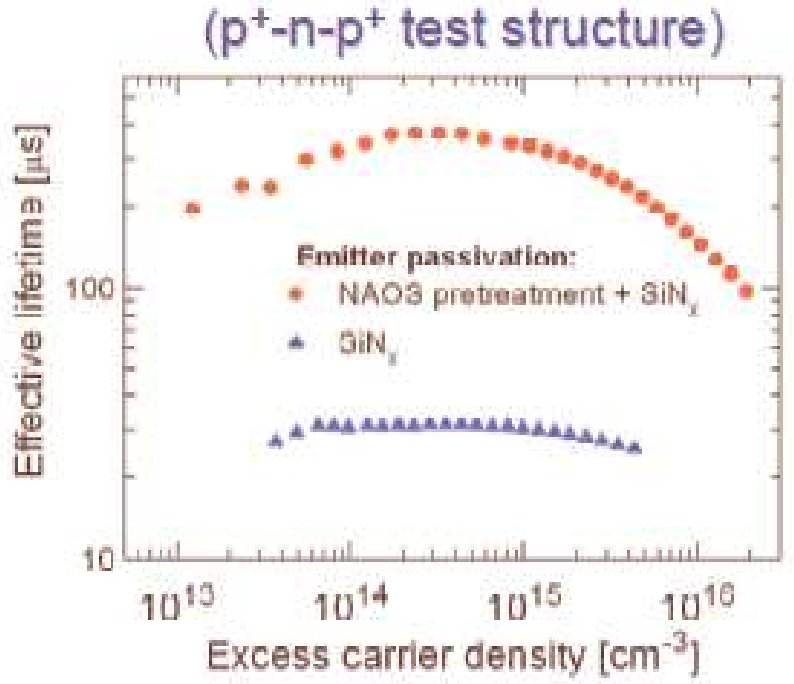




Breakthrough in boron-emitter passivation

Simple chemical oxide passivation (ECN Patent)





I_{sc} A	U_{oc} V	FF %	Area cm^2	J_{sc} mA/cm^2	Eff. %
9.0	636	78.14	239.8	37.5	18.71%

p+ emitter: materials choice & technique

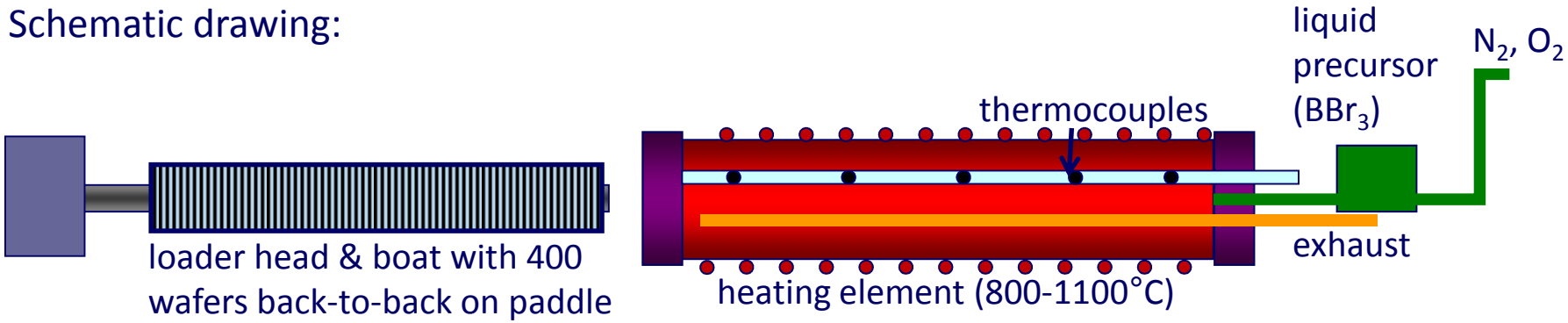
Possible dopants for p+ emitters on the front side of n-type solar cells:

Gallium		Low solid solubility, very fast Ga diffusion in SiO_2	
Aluminum		No proper high temperature treatment for high-doping level	
Boron		Various methods available:	
Deposition:	CVD	B_2H_6 (doped poly)	not for uniform front side (HIT, IBC)
	print, spin	BSG paste, H_3BO_3	Ferro, Filmtronics, Honeywell
Implant:	Solar implanter	B, BF_3	Tempress, Varian
Diffusion:	Solid-source	BN	semiconductor industry
	Liquid source	BBr_3	Tempress: solar PV industry
	Gas source	BCl_3	semiconductor R&D

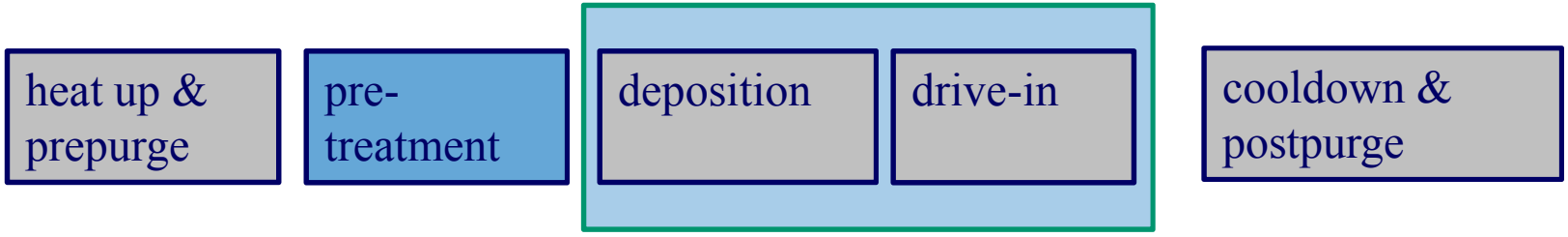
A major disadvantage of the first two categories is that they require a separate drive-in and/or oxidation process step. Amongst the single-step diffusion methods, there is only one industrial process to form a front p+ emitter fro n-type cells:

Standard BBr3 diffusion processing

Schematic drawing:



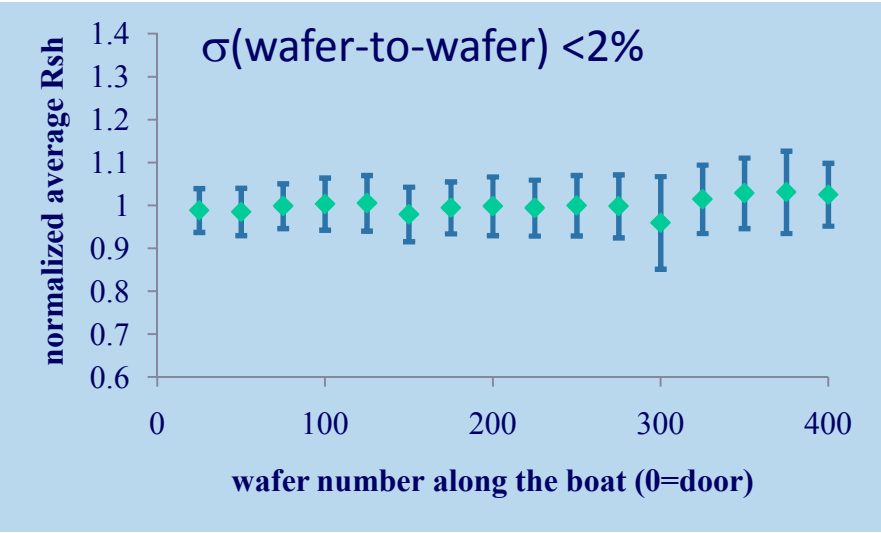
A standard process sequence of the diffusion can consist of several steps, shown schematically here:

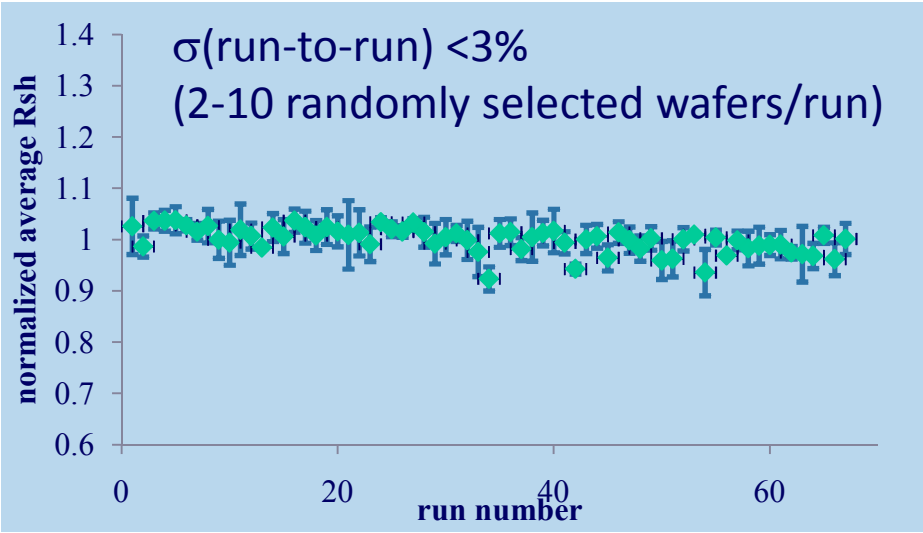


P+ emitter: BBr_3 optimization

Optimized the BBr_3 conversion rate to achieve a uniform load size of 400 wafers/run and are still working on further improvement:

σ(within wafer) <2%



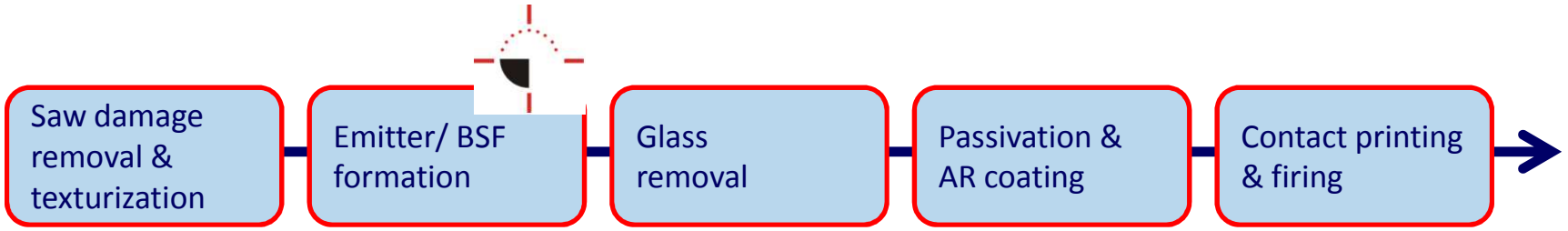


uniformity within load

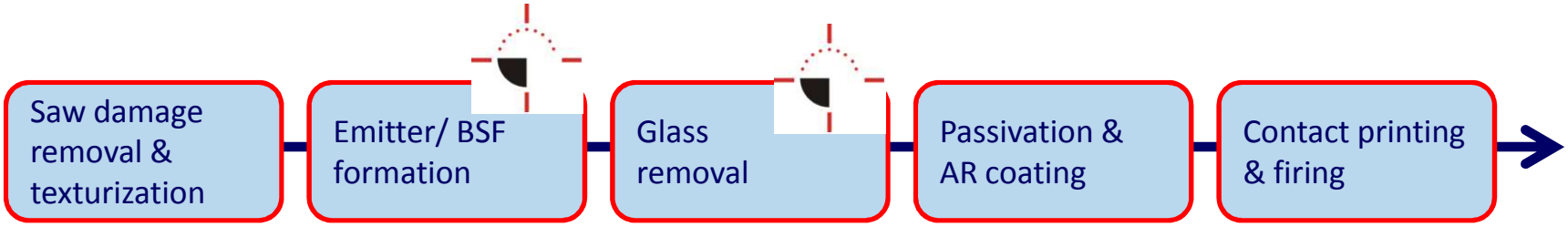
run-to-run stability

Current status & future outlook

- Tempress is the largest & most experienced company supplying BBr_3 systems used industrially. Yingli Solar uses these for mass-production of high-efficient n-type Panda cells (average η=18,7% in mass production).

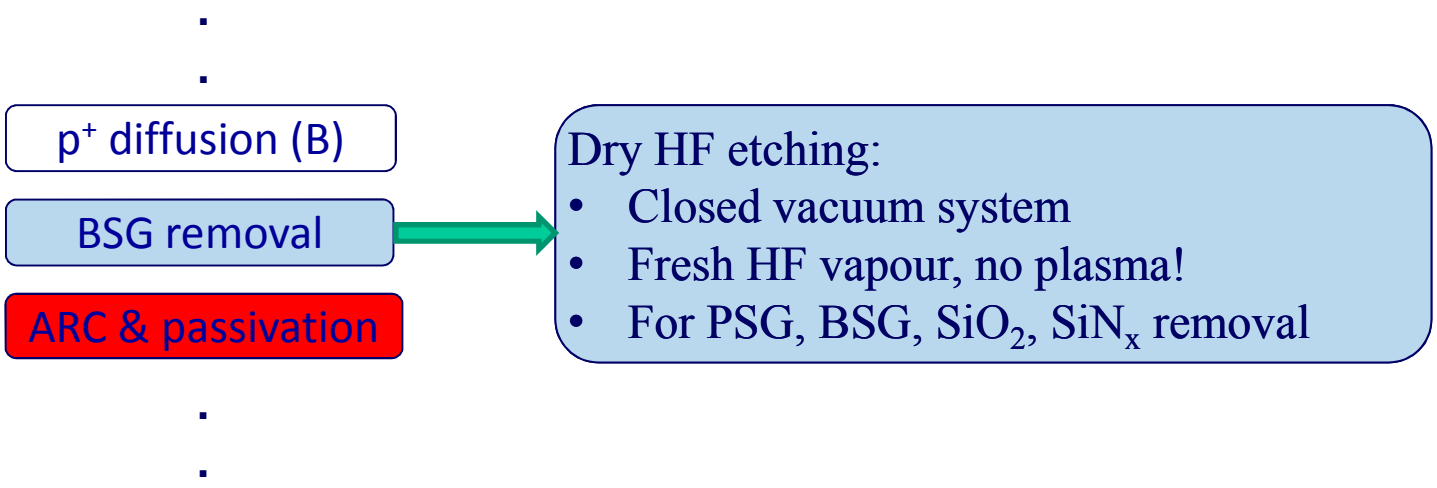


- Further n-type cell efficiency improvement is on-going using new available technologies including HF dry etching for high quality surface passivation.



Dry HF Etcher: BSG removal & clean surface

Dry HF etching is a stable glass removal process providing a very clean surface which is critical for high-quality surface passivation.



Dry HF Etcher

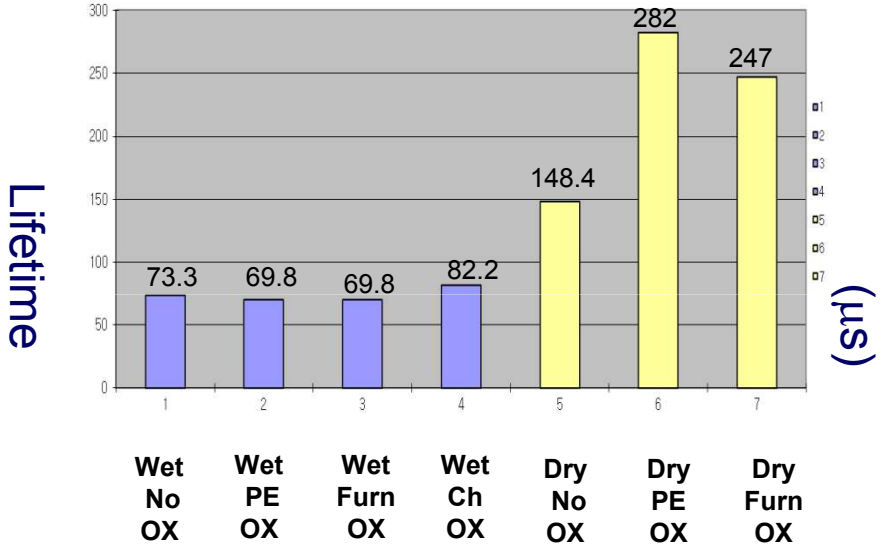
Key Attributes:

- Compact Footprint:
  - 1/3 of wet bench
- Large Batch Size:
  - 500 wafers per load
- High Throughput:
  - 3000 WPH
- Easy Maintenance:
  - Wall residue prevention
- Wide Temperature Range:
  - RT to 200C

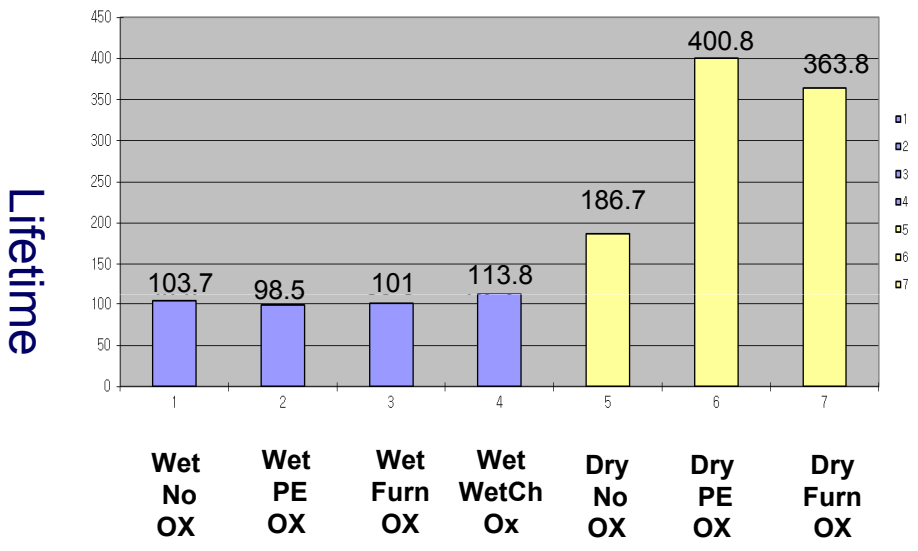
Lifetime Test Results

(FZ Wafers + POCl3 Doping)

Before Firing



After Firing



Summary

○ We have successfully developed industrial BBr3 diffusion technology for high-efficiency n-type cells.

○ BBr_3 diffusion is in volume production as a proven industrial process (η~19.0% in mass production at Yingli).

○ Further efficiency improvement is underway using some new techniques including HF dry etching for high-quality surface passivation.

Special thanks to our co-workers:

Peter Venema, Henri Geerman, Malcolm Harris, Ronald Naber
(Tempress Systems, Solar Process Development Group)

Bart Geerligs, Yuji Komatsu, Teun Burgers, Nicolas Guillevin
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Cindy Hu, Faye Li, Mark Song, Zhang Wei
(Yingli Solar, Technology Team)

Thank you for your attention!