PRAXAIR®
Making our planet more productive

Keeping an Eye on Implant Materials

Dennis Brestovansky

Technology Commercialization Director

Outline

PRAXAIR®
Making our planet more productive

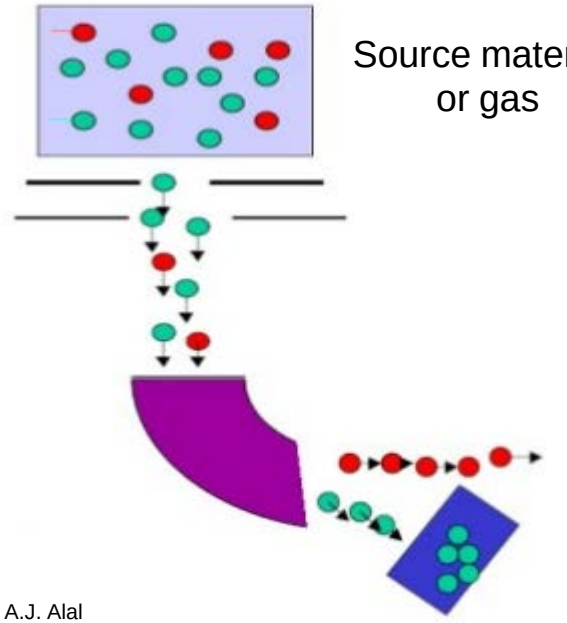
- Some important characteristics of Ion Implantation
- Properties of Source Materials
- Materials Handling Considerations
- Materials Choice Tradeoffs
  - Handling / Packaging
  - Supply Chain Robustness
- Influence of Source Material Choice on Cost and Performance
  - Throughput
  - Maintenance
- Overview of Materials Landscape
- Emerging Materials

Implant Process

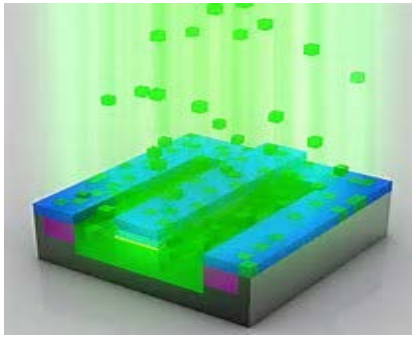
PRAXAIR®
Making our planet more productive

Ion Implantation

- **Form energetic ion beam of dopant molecules**
- **Bombard wafer surface with beam**



A.J. Alal
www.slideshare.net/ajal4u/ion-implantation-37881199



www.semiwiki.com/forum/content/4152-ion-implant-its-not-just-doping-anymore.html

Unique Materials Supply Situation

PRAXAIR®
Making our planet more productive

- Toxic / flammable / corrosive materials
- Stored inside tool – not remotely
- In vicinity of personnel
- Tool shutdown to change

Common Materials and Hazards

PRAXAIR®
Making our planet more productive

	Arsine	Phosphine	Boron Trifluoride
Phase	Liquified Compressed Gas	Liquified Compressed Gas	Compressed Gas
Hazard	Highly flammable	Highly flammable	Highly corrosive
OSHA PEL	0.05 ppm	0.3 ppm	1 ppm

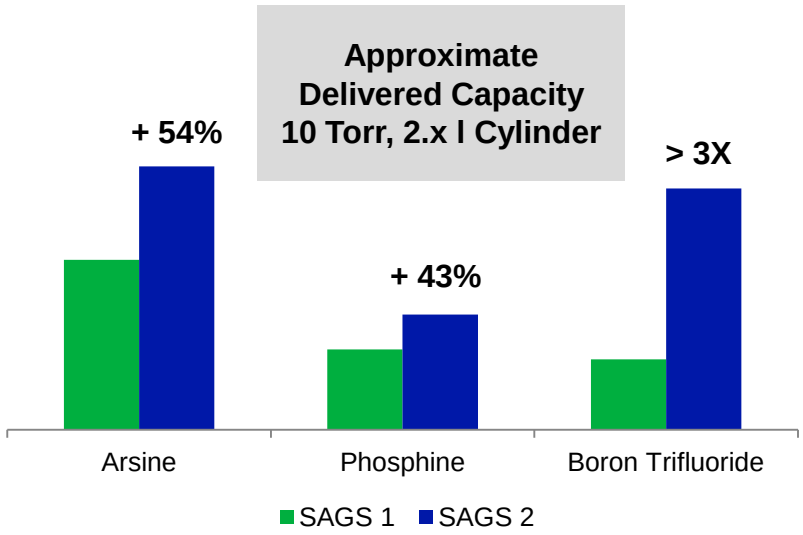
- Convenient gas phase at room temperature and pressure
- Careful handling required to protect personnel and equipment
- Implanter design considerations prohibit remote storage, e.g. sub-fab

Innovative Packaging

PRAXAIR®
Making our planet more productive

SAGS-1 - Adsorbent

SAGS-2 - Mechanical



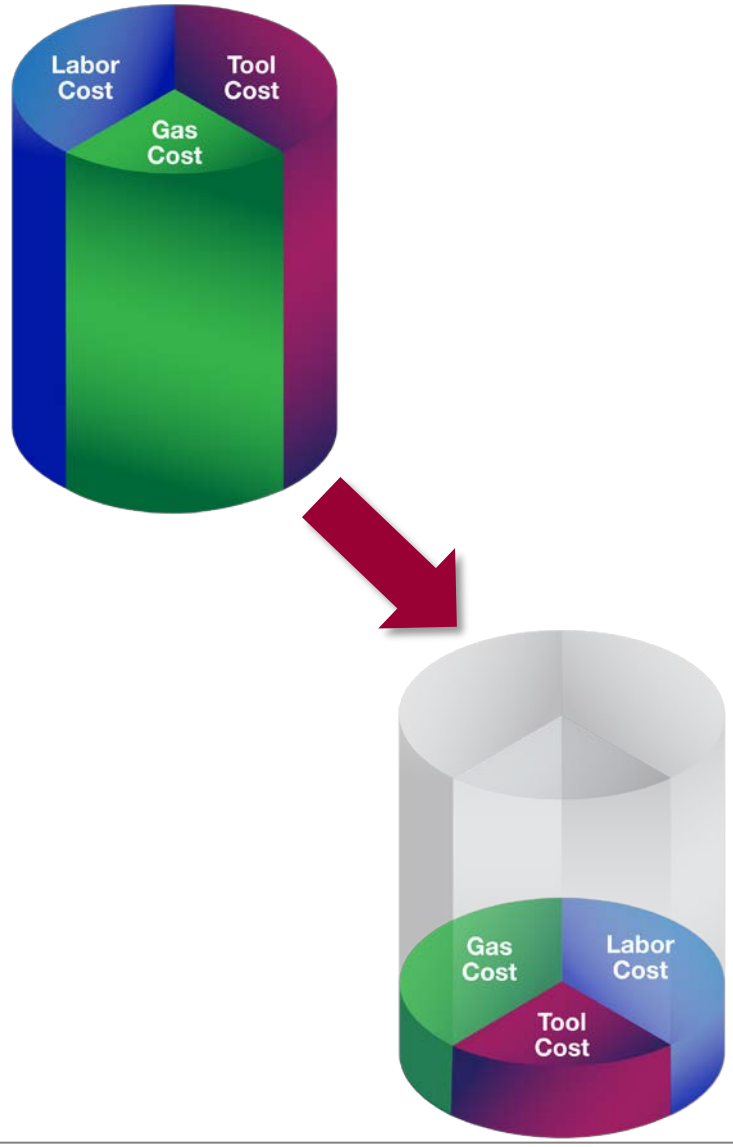
Tradeoffs / Considerations

- Physics
  - Temperature
  - Air infiltration
  - Pressurization
- Capacity
  - Handling frequency
- Utilization
  - Cost
- Design
  - Absorptivity
  - Mixture capable

Ion Implantation Cost Factors

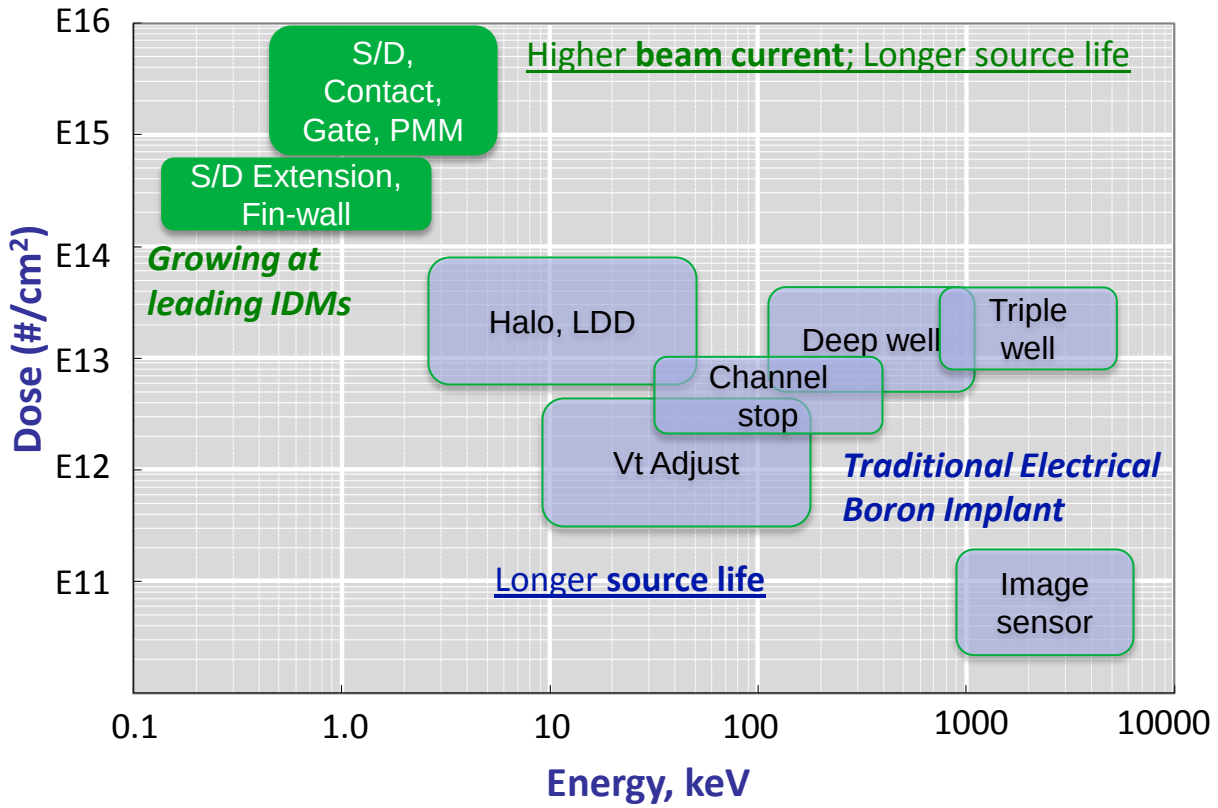
PRAXAIR®
Making our planet more productive

- Source Material Costs
  - Price per unit
  - Utilization
- Labor Costs
  - Source material change frequency
  - Tool MTTR / MTBF
- Productivity
  - Throughput
    - Ion beam current
    - Species changeover speed
    - Tool availability
  - Yield
    - Particles
    - Glitch rate / beam uniformity



Evolution of Implantation

PRAXAIR®
Making our planet more productive

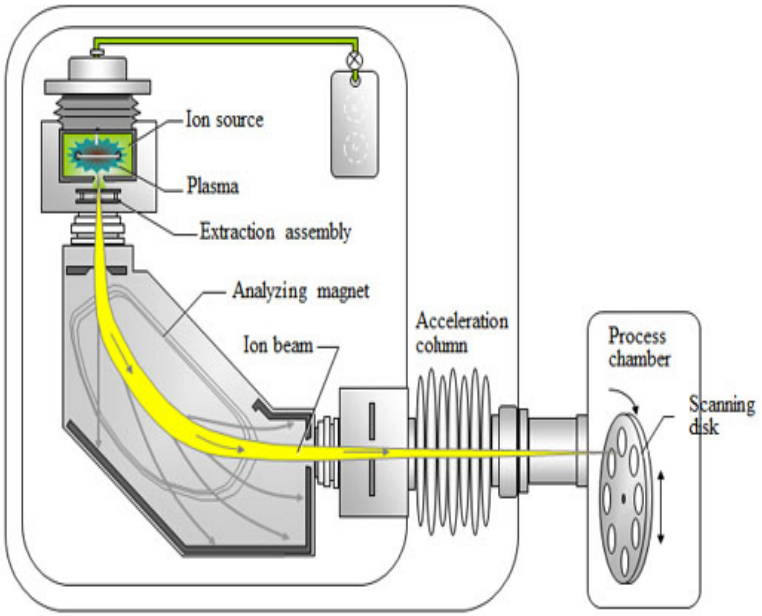


- **Remains an important process even with advancing nodes**
- **Electrical and materials modification applications**
- **Increasing demands on process, source materials and delivery**
  - **Example : Higher current = higher desired beam current**
  - **Example : Dedicated species operation = ion source life strain**

return

Cost Reduction Approaches

PRAXAIR®
Making our planet more productive



After : www.samaterials.com

How to ?

- Reduce preventive maintenance
- Increase throughput when fab is loaded – run as fast as possible
- Minimize defects

Options:

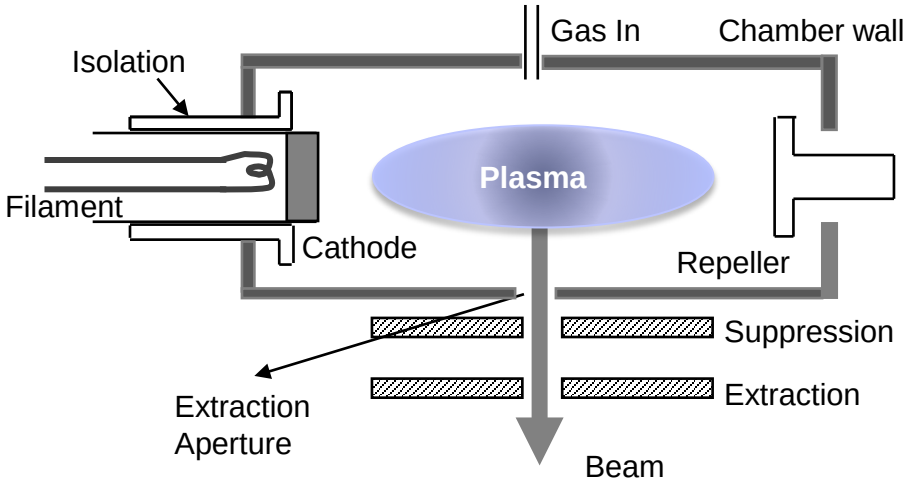
- Increase number of tools
- Tool / Equipment modification
- Operating mode – species swap
- Choice of source molecule(s)

Source molecule selection can be a “drop in” productivity enhancer

A Key Maintenance Issue

PRAXAIR®
Making our planet more productive

IHC Source Schematic



Initiation

$aXF_z + be \rightarrow X^+ + F^+ + XFx^+ + F + X + XFy$

Etching

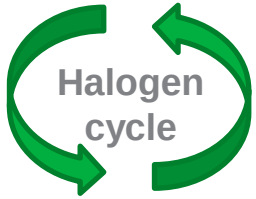
F/F2+ W → WFy

XFx + W → WFy + XFz

Deposition

WFy → W + 0.5yF2

X = e.g. B or Ge



- "Halogen Cycle"
- Source materials can degrade implanter components
- Eventually, ion source chamber must be repaired / replaced leading to downtime and cost

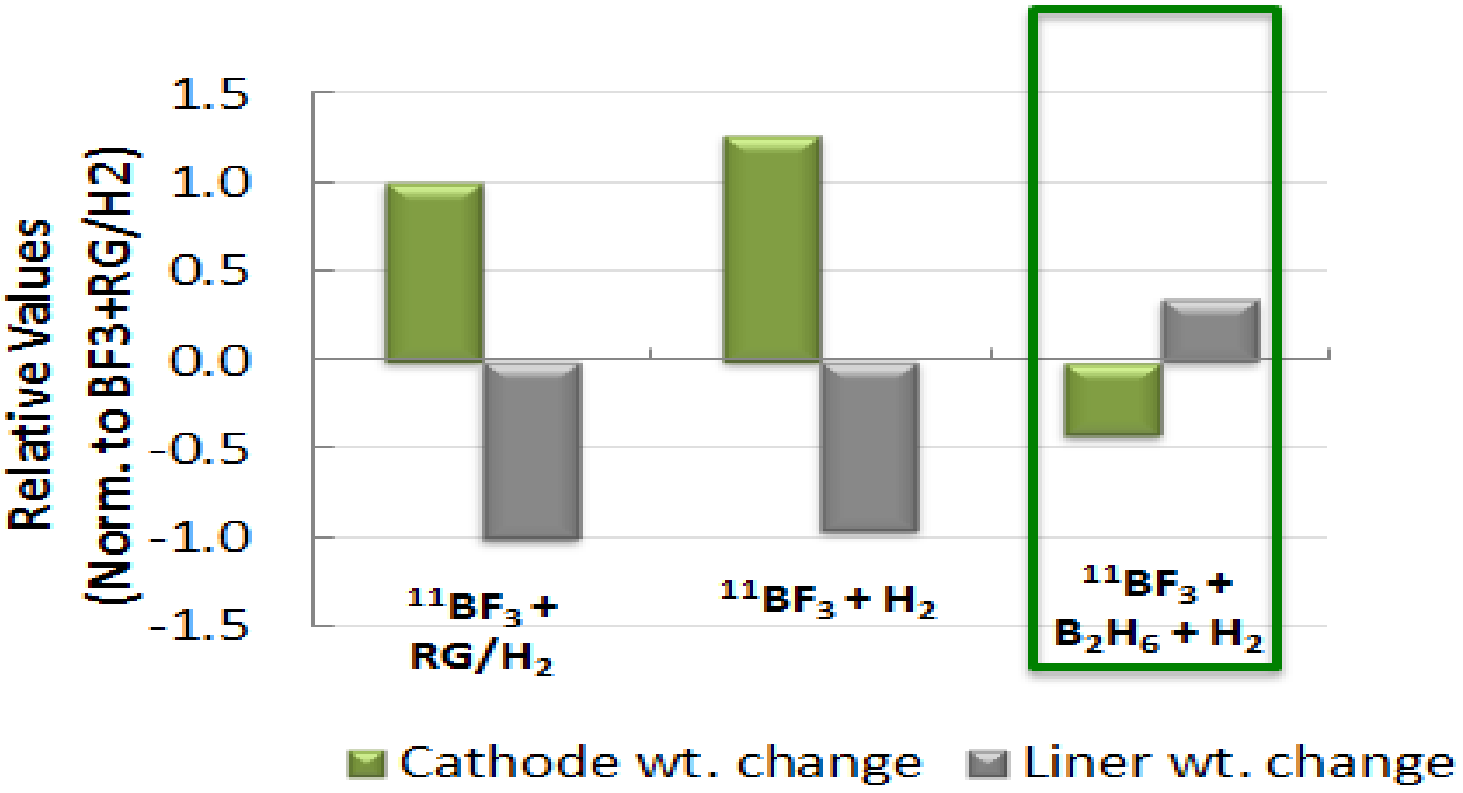
Want both long source life and beam current flexibility

Enhanced Productivity

PRAXAIR®
Making our planet more productive

Changing chemistry to reduce ion source degradation

- **+ 70% ion source lifetime …… > 230 hours**



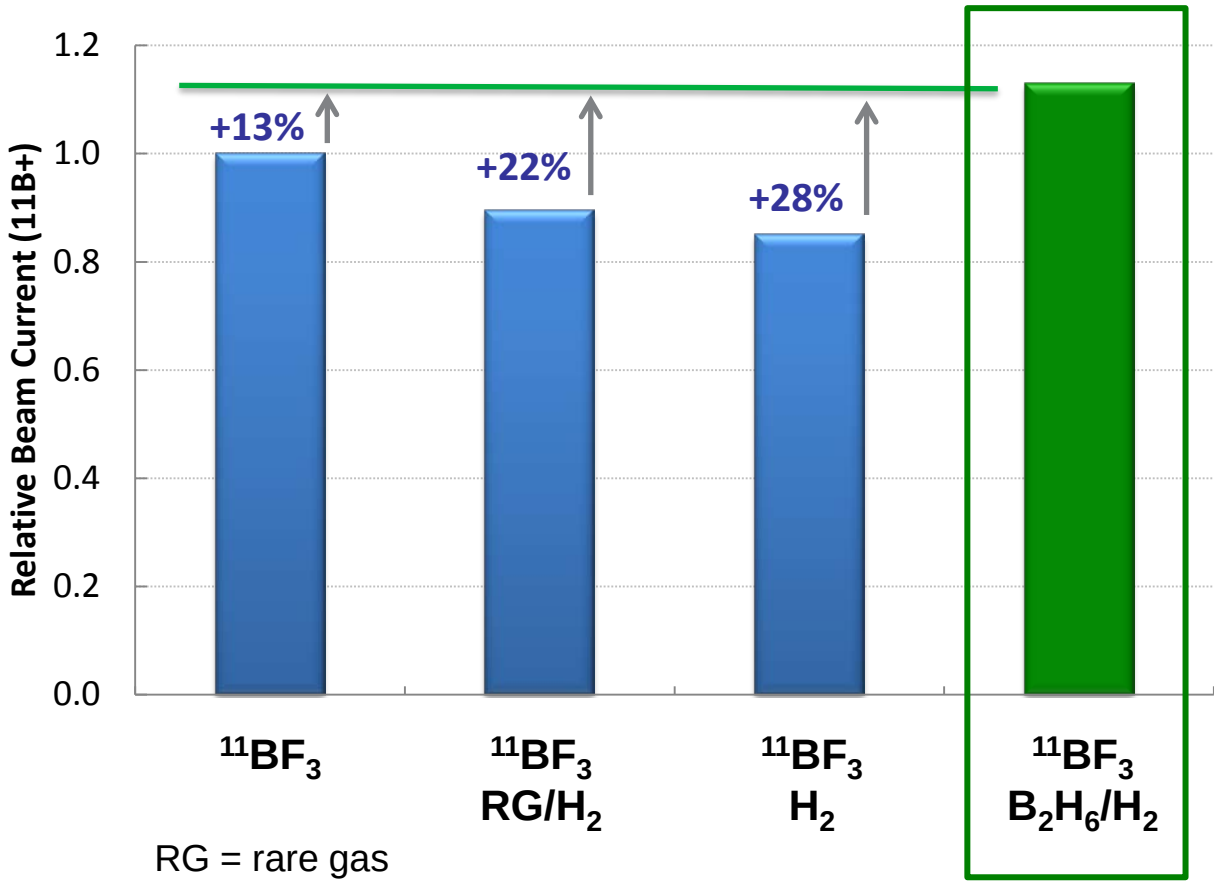
RG = rare gas

Enhanced Productivity

PRAXAIR®
Making our planet more productive

Source Material Impact on Beam Current

- 22 to 28% better beam current while extending ion source lifetime

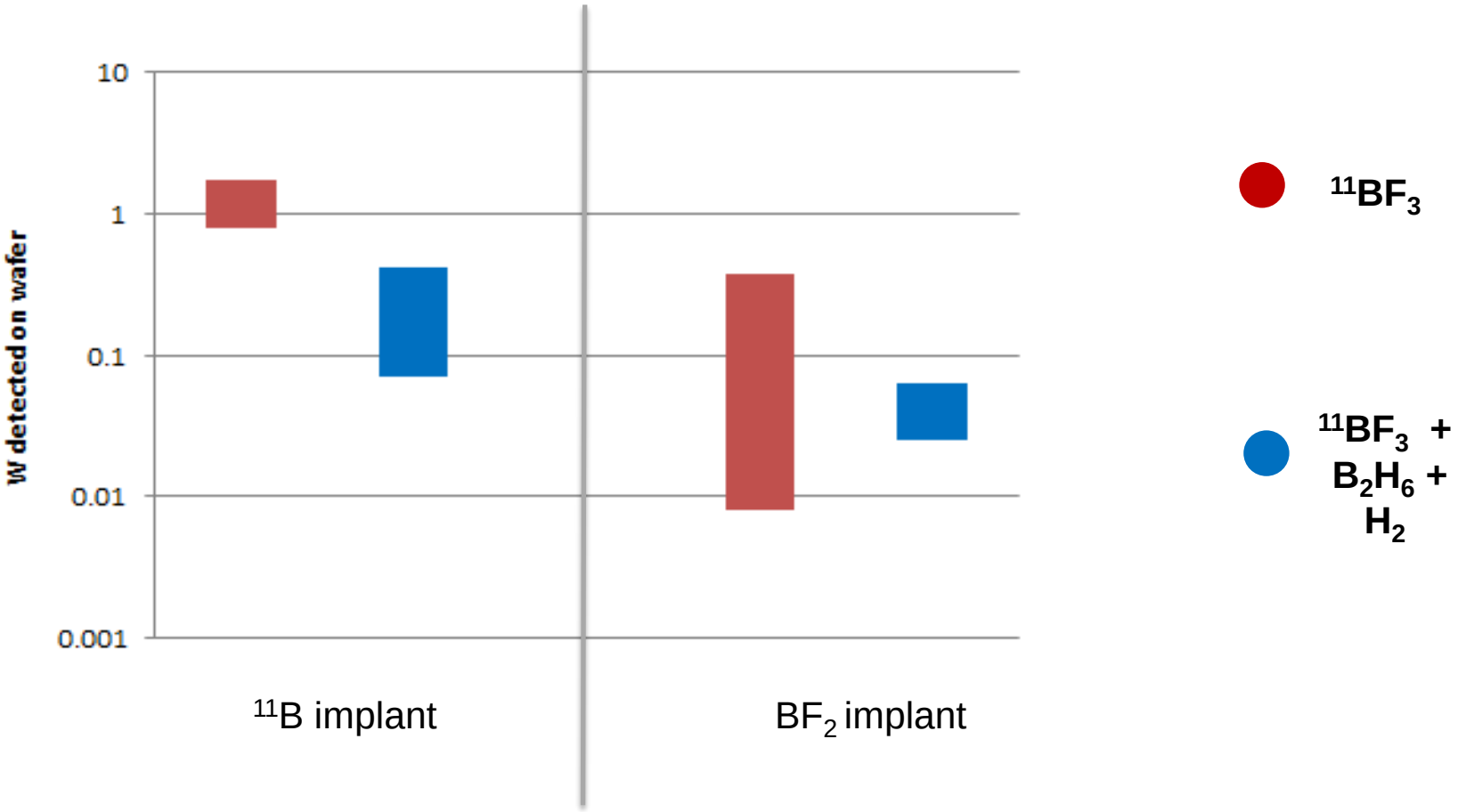


RG = rare gas

Enhanced Yield - Contamination

PRAXAIR®
Making our planet more productive

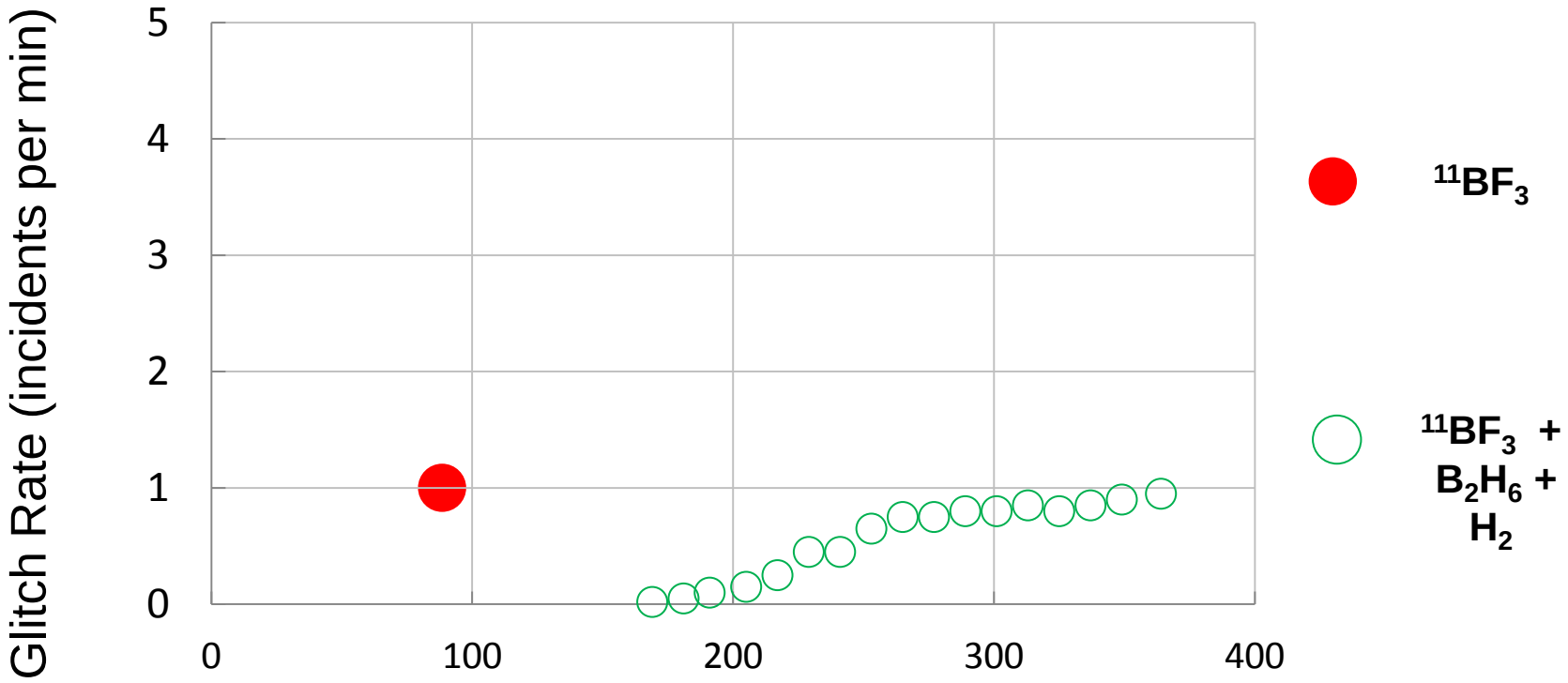
Reduced levels of W on wafer from particles ……..+20% yield



Enhanced Yield – Dose Precision

PRAXAIR®
Making our planet more productive

Better beam stability through 370 hours at +20% beam current



Options

PRAXAIR®
Making our planet more productive

Dopant	Baseline Material	Beam Current	Ion Source Lifetime	Mixed Mode Operation	Considerations
As	AsH3	-----	------	------	------
P	PH3	-----	-----	PF_3	PF_3 not as widely used in other processes
B	$^{11}BF_3$	$^{11}BF_3$ / B_2H_6 / H_2	• $^{11}BF_3$ / H_2 • $^{11}BF_3$ / RG / H_2 • $^{11}BF_3$ / B_2H_6 / H_2	------	Package design
Ge	GeF_4	• $^{72}GeF_4$ • GeF_4/CH_3F	• GeF_4 / H_2 • GeF_4 / RG / H_2 • GeF_4/CH_3F	------	Supply chain- super highly enriched gas
C	CO_2 + PH_3	-----	• CO • CO / RG / H_2	CO/CF_4 + RG/H_2	Package design and material of construction

RG = rare gas

Considerations Overview

PRAXAIR®
Making our planet more productive

- Best materials
  - Supply chain reliability
  - Shelf life
  - Cost
  - Packaging and handling options
- Process flexibility
  - Co-flow offers mixture flexibility
  - Mixtures can add stability and shelf life
  - Consumes potentially limited “gas sticks”
- Implanter mode
  - High current, medium current, low energy – high dose
  - Dedicated vs. mixed

Possible New Implant Species

PRAXAIR®
Making our planet more productive

- New dopants required below 1X node
- Enhanced dosage for electrical or mechanical modification
- No clear gaseous source options yet
- New challenges for delivery, packaging, blending, etc.

Species	Molecule	Phase
Antimony	oxide	Solid
	trifluoride	Solid
Aluminum	trimethyl	Low VP liquid
	trichloride	Solid
Gallium	oxide	Solid
	trimethyl	Low VP liquid

Expanding beyond gaseous sources

PRAXAIR®

Making our planet more productive

Thank you for your time

Questions most welcome