PULSION® HP: Tunable, High Productivity Plasma Doping

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Introduction

- Plasma doping in R&D for over 2 decades
  - Ultra-shallow junctions
  - Conformal doping of trenches and fins
- In production today for two very high dose, DRAM applications
  - Polysilicon gate counter-doping
  - Contact doping
- Parasitic effects due to reactive plasma at wafer surface
  - Etching of surface materials
  - Enhanced oxidation
  - Deposition of films
- Key features of PULSION® HP
  - Dual Region Chamber© design that enables a high density plasma with low chamber pressure
    - Minimizes undesired side effects
    - Enables wide process space
    - Low gas flow rates
  - Special chamber and wafer electrode designs that optimize doping uniformity

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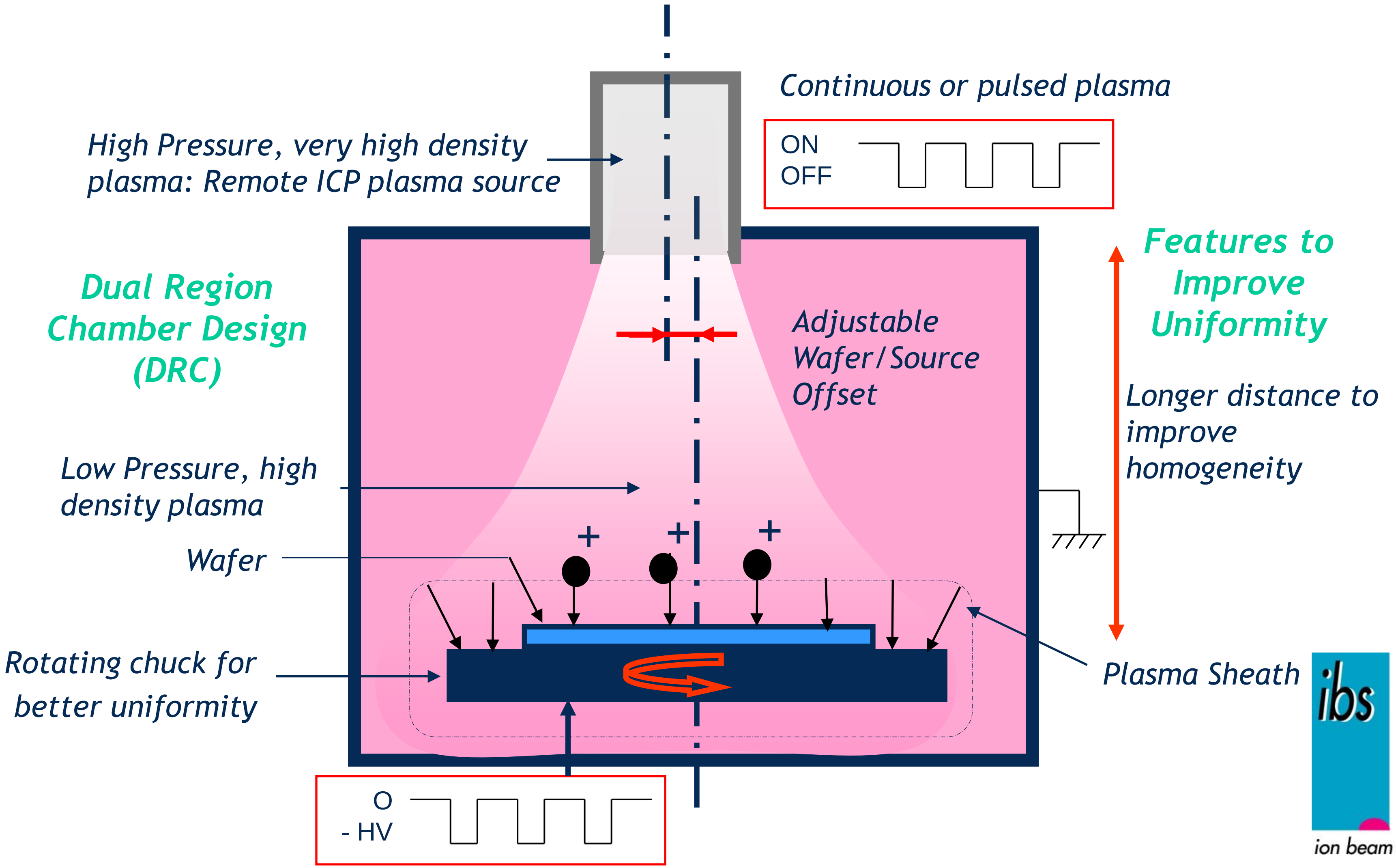
Unique Features of PULSION HP®



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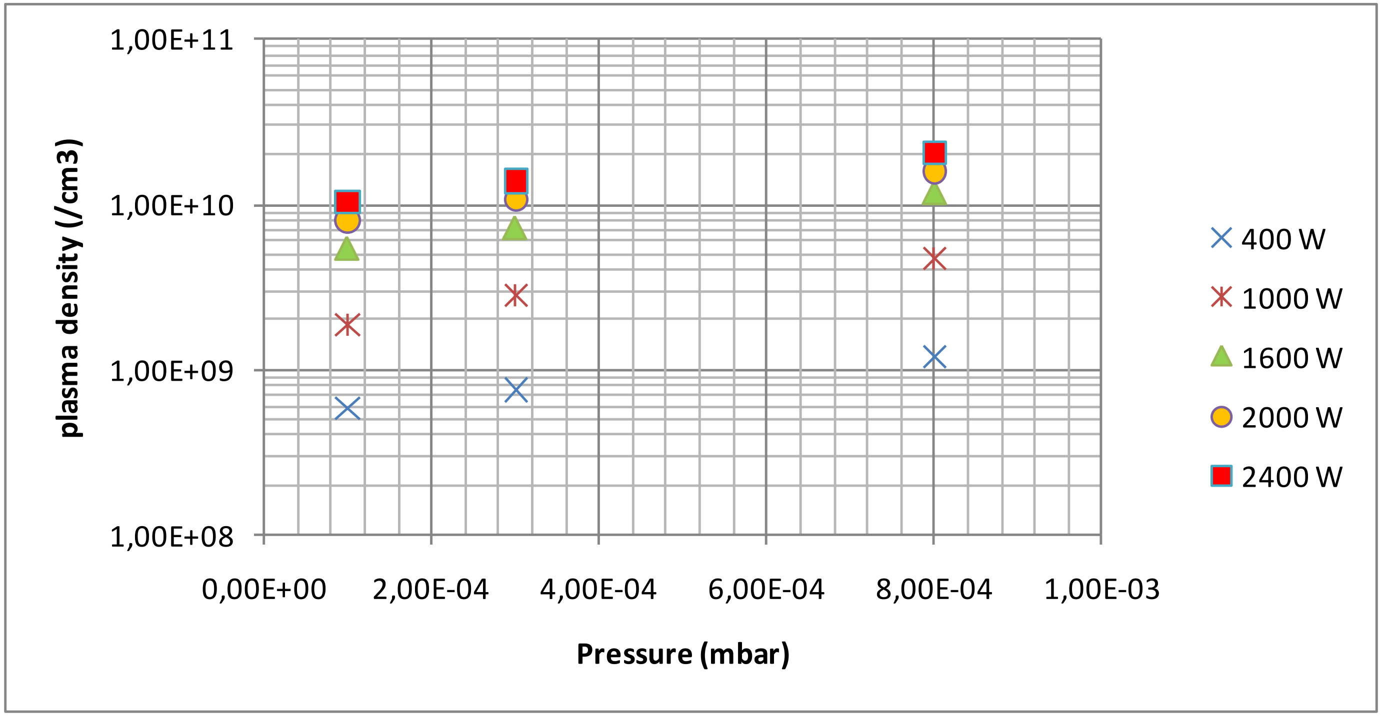
Independent Tuning of BF_3 Plasma Density and Chamber Pressure



- **Adjustable pressure differential of ≤ 2 orders of magnitude between plasma source and process chamber**
  - **Plasma source RF power is primary control of plasma creation and density and implant current**
  - **Chamber pressure can be independently varied to achieve desired chemistry effects at the wafer surface**

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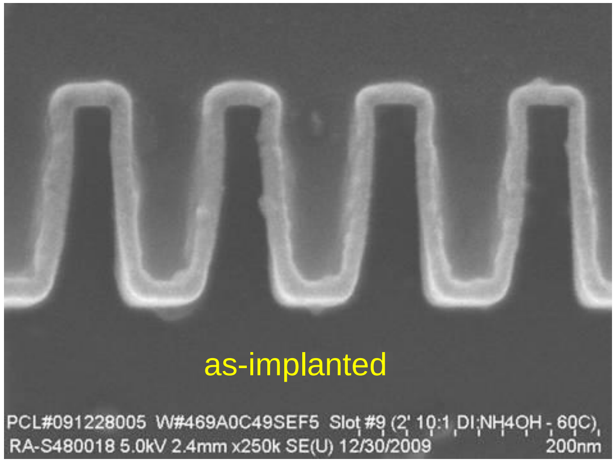
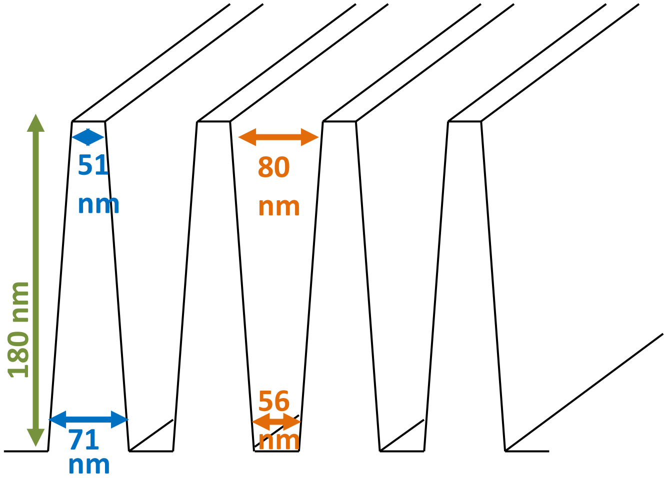
Conformal Doping with Boron Plasma Implant





- Conformal doping of 3D structures requires dominance of deposition and implant
- Equal thicknesses of all doped regions
- Actual doping of fin Si, since no change in fin dimensions
- No evidence of corner rounding or fin erosion

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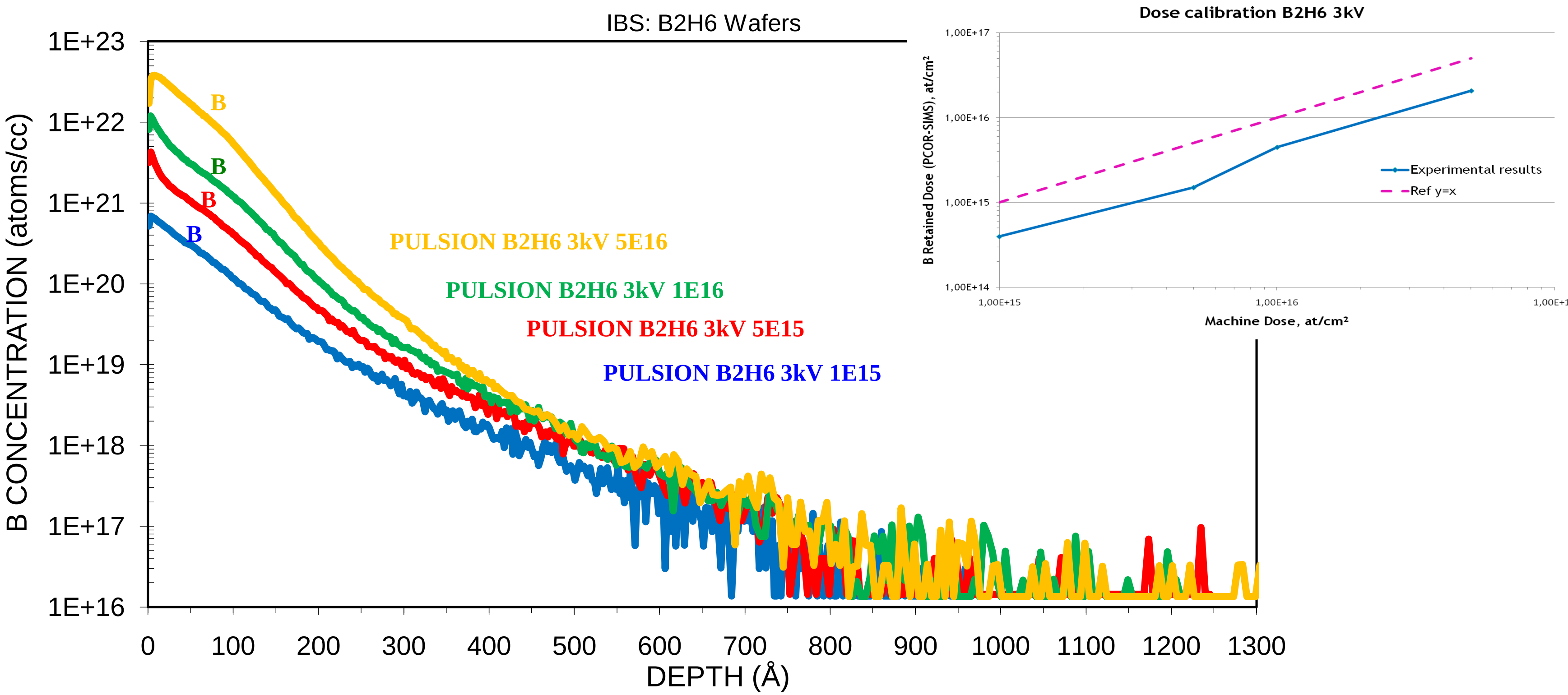
Minimal B Deposition: SIMS Dose Response for 3kV B_2H_6



- **DRAM contact doping requires implantation with balance of minimal etching, sputtering, and deposition**
- **Can vary B surface concentration and implanted dose while keeping junction depth constant - ideal to reduce contact resistance**

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See Poster P2-41

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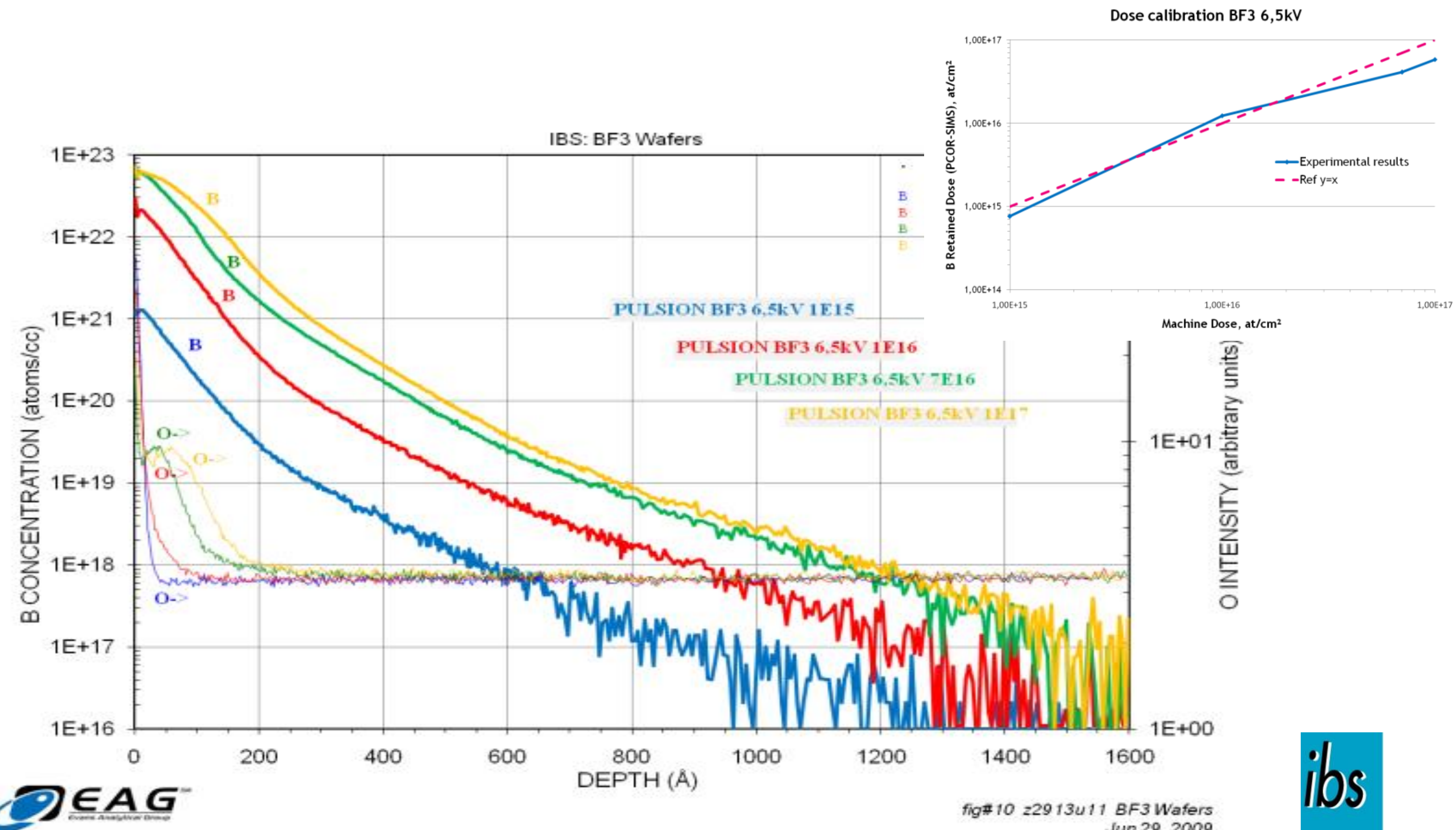
BF_3 Dose Response for Typical Poly Counter-Doping



- As dose increases, all points in SIMS profile increase
- Different behavior than B_2H_6

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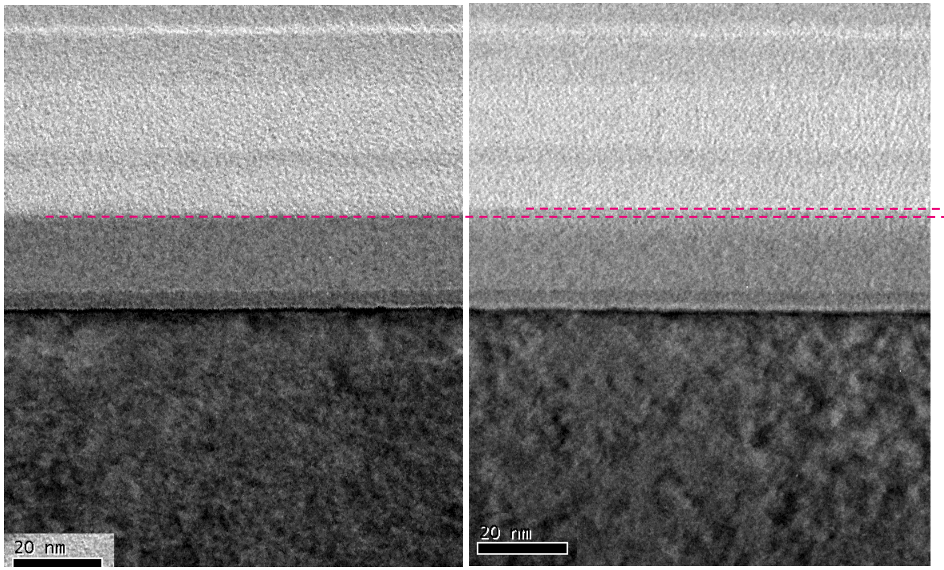
Minimal Si Etching: HRTEM Implanted / Unimplanted Samples

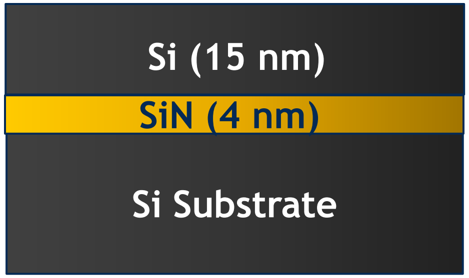
BF_3 4kV, 1.5E16 atoms/cm²



+~1 nm

Oxide Growth

Unimplanted **Implanted**



Implanted structure

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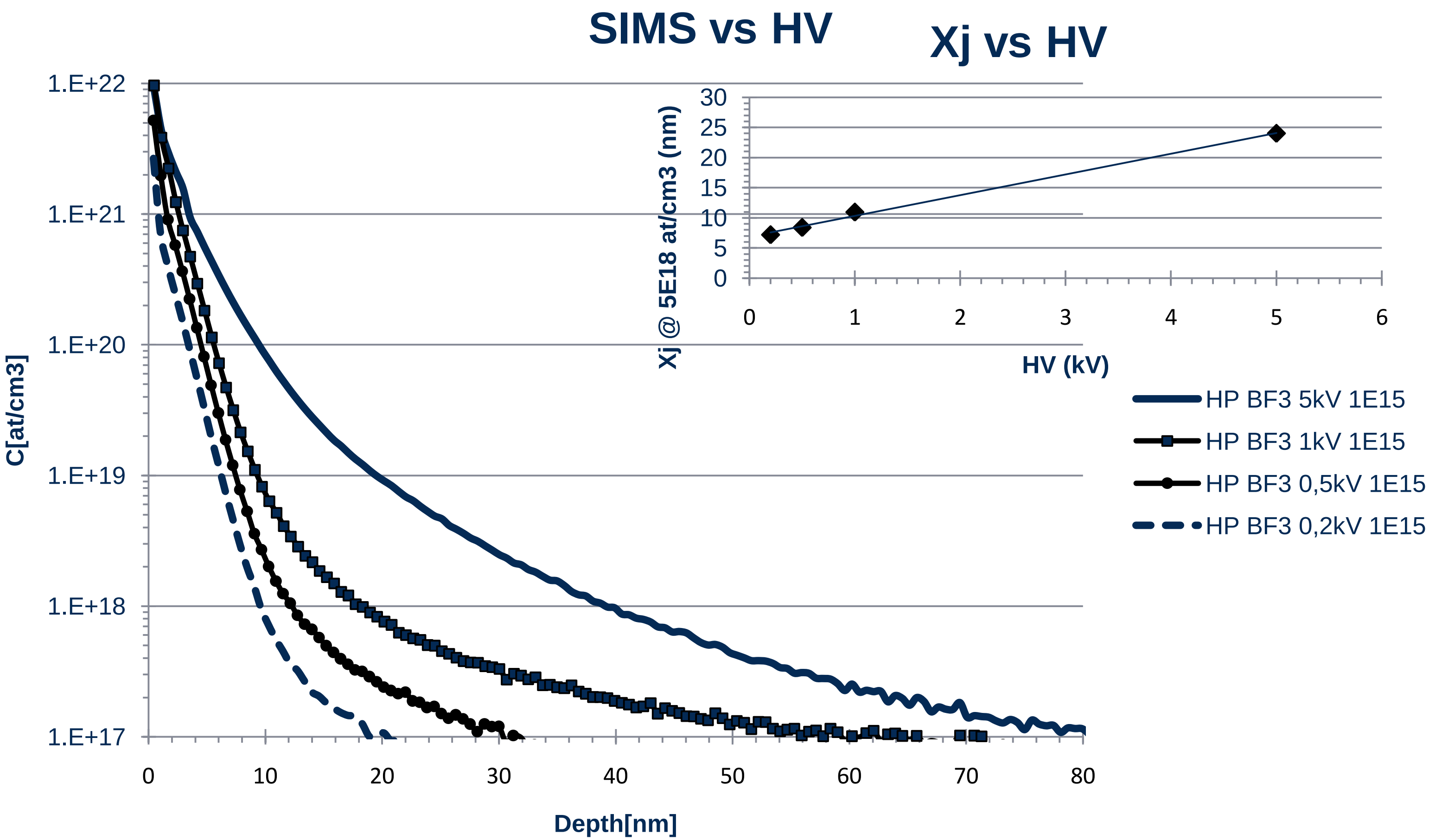
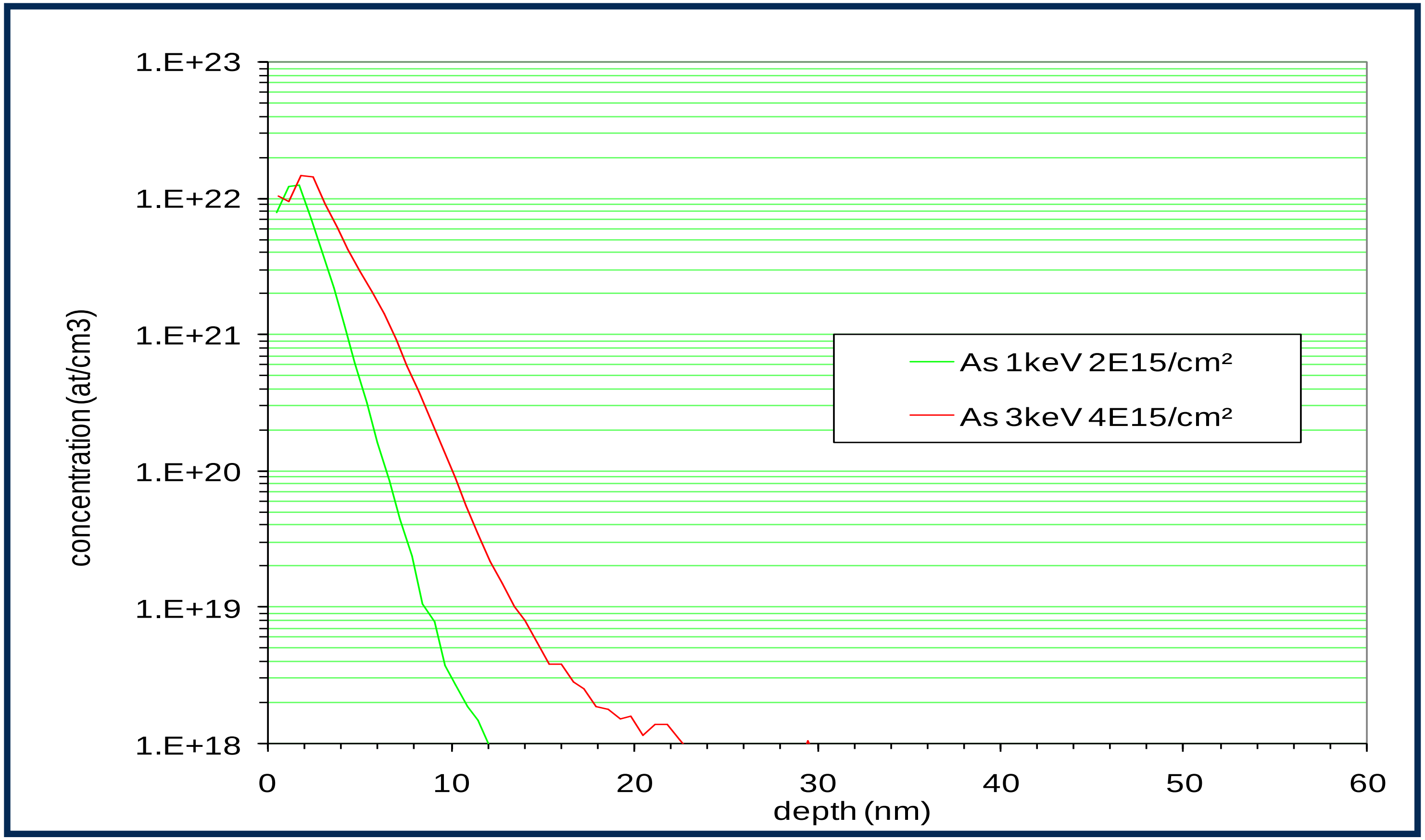
SIMS Profiles: Voltage Response for BF_3

- Implant depth control proportional to wafer voltage
- USJ depths below 10nm can be achieved by reducing the wafer voltage



PULSION® n-Type Doping
Shallow Implant Depth Capability

PULSION AsH_3 As-Implanted profiles



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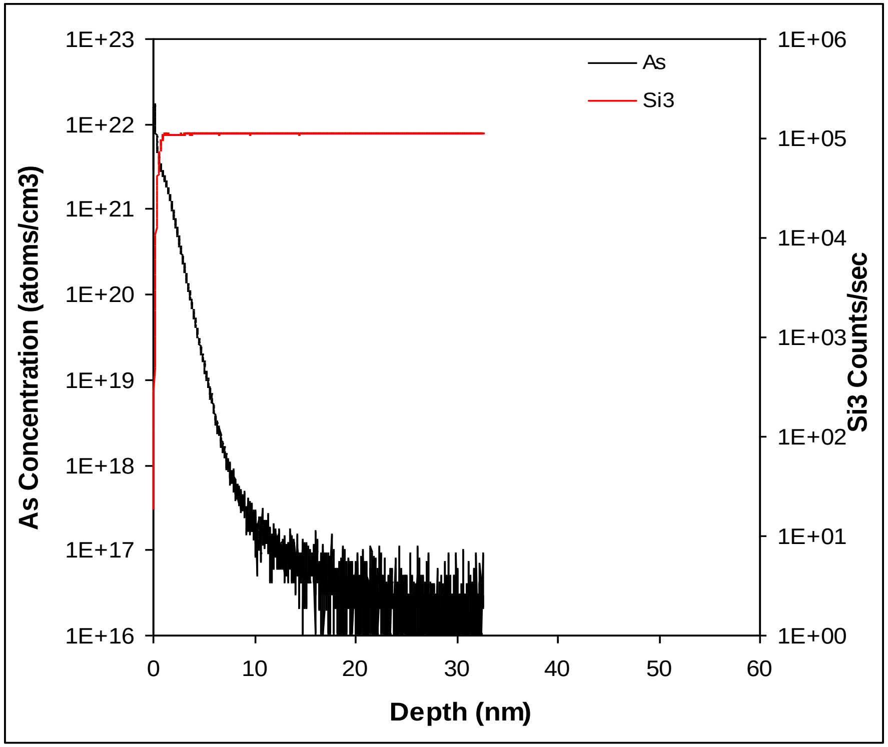
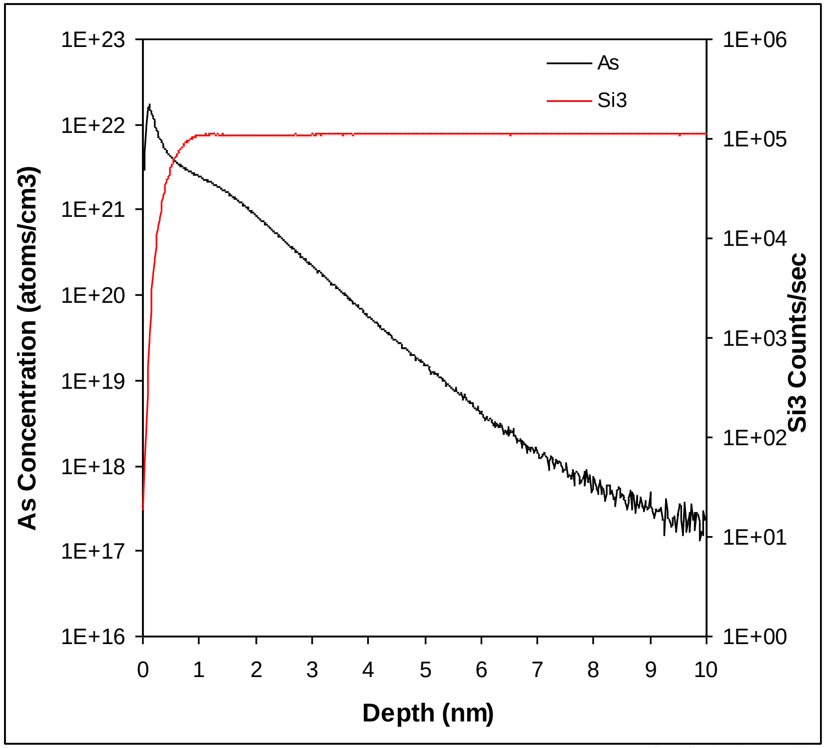
Arsenic USJ with Flash Anneal

- 300 V As, 2E14 cm^{-2}
- 1200C flash anneal





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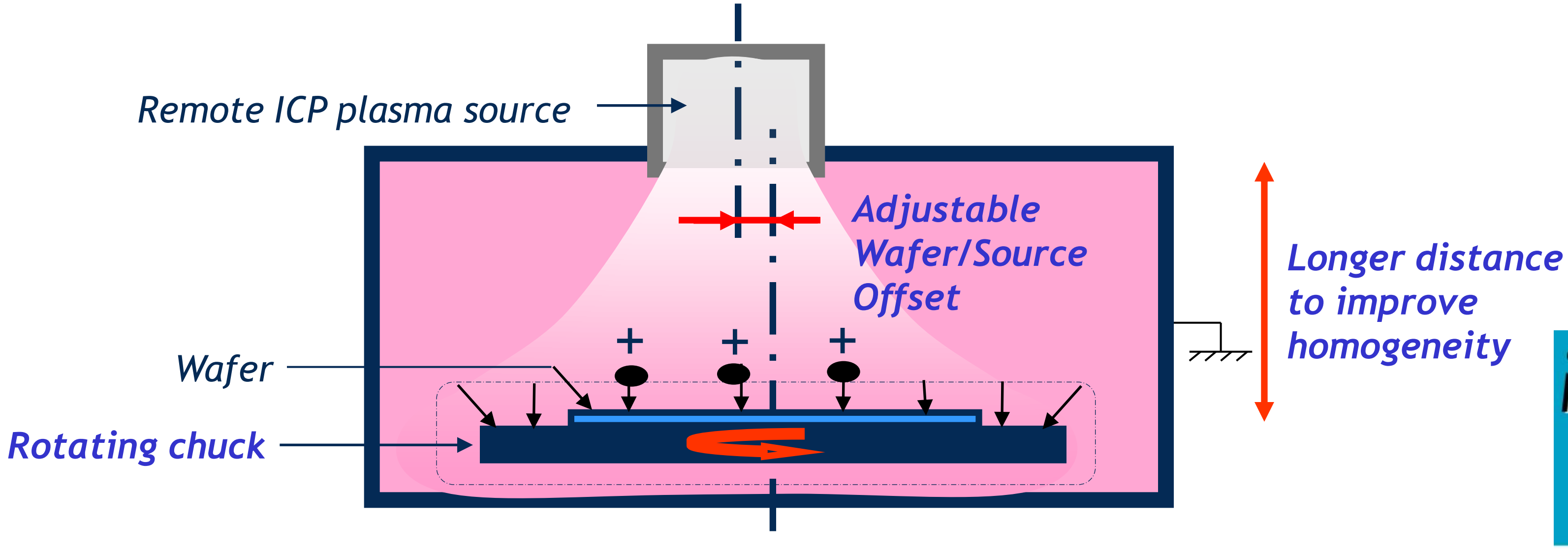
PULSION® HP Uniformity Advantages

- Tall chamber design
  - Longer distance between source and wafer
  - Improves uniformity of plasma flow
- Adjustable wafer/plasma source offset
- Rotating wafer
  - Enhances implant uniformity at wafer level



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R_s Uniformity and Repeatability

Mean Rs (ohms/sq.)	Uniformity (%, 1σ)
162.55	0.828
161.19	0.780
160.17	0.787
157.96	0.777
158.66	0.840

PULSION Repeatability Test

- **Uniformity (1σ) < 1%**
- **Repeatability (1 sigma) = 1.16%**

- **Typical poly counter-doping process**
  - **BF_3, 6.5 kV, 7E16 cm^{-2}**
  - **HF strip before anneal**
  - **1000C, 10 sec anneal**

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PULSION HP® – Max 4 Chambers, >100 WPH (Poly Counter-Doping)

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Summary

- **Dual Region Chamber© design of PULSION HP® enables a high density plasma with variable, low chamber pressure**
  - **Allows customer choice of dominant process mechanism: deposition, implant, or etch**
  - **Minimizes undesired side effects**
- **Special chamber and wafer electrode designs**
  - **Optimized doping uniformity**
  - **Wide process space**
- **High wafer throughputs necessary for high-volume production**
  - **High plasma density**
  - **Platform with up to four plasma doping chambers**

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