A New Doping Material for P-type Ultra Shallow Junctions, $B_{18}H_{22}$ or ClusterBoron™

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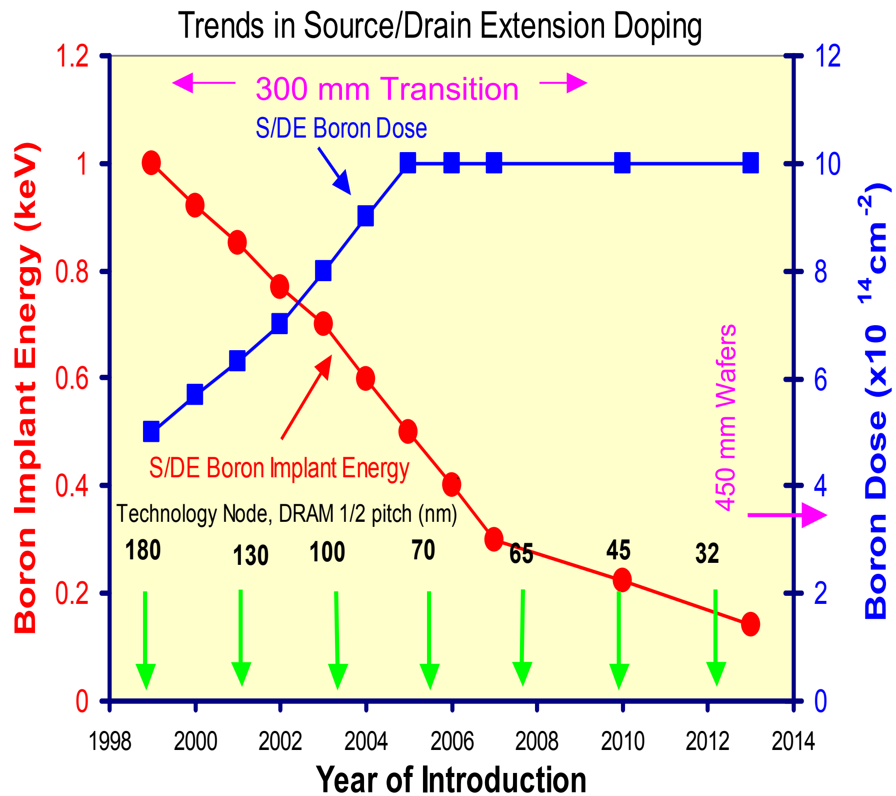
The Issues Facing USJ Formation

- Lower Energy
  - Driven by X_j Requirements
  - $I \alpha E^{3/2}$
    - Reduced Throughput
- Higher Dose
  - Driven by R_s Requirements
  - Scaling Requires Dopant Concentration to go up
    - Reduced Throughput
- 300 mm wafer size
  - Driven by Cost Reduction
    - Reduced Throughput



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Child-Langmuir Law

- Places an Upper Limit on Beam Current that Can Be Extracted from an Ion Source

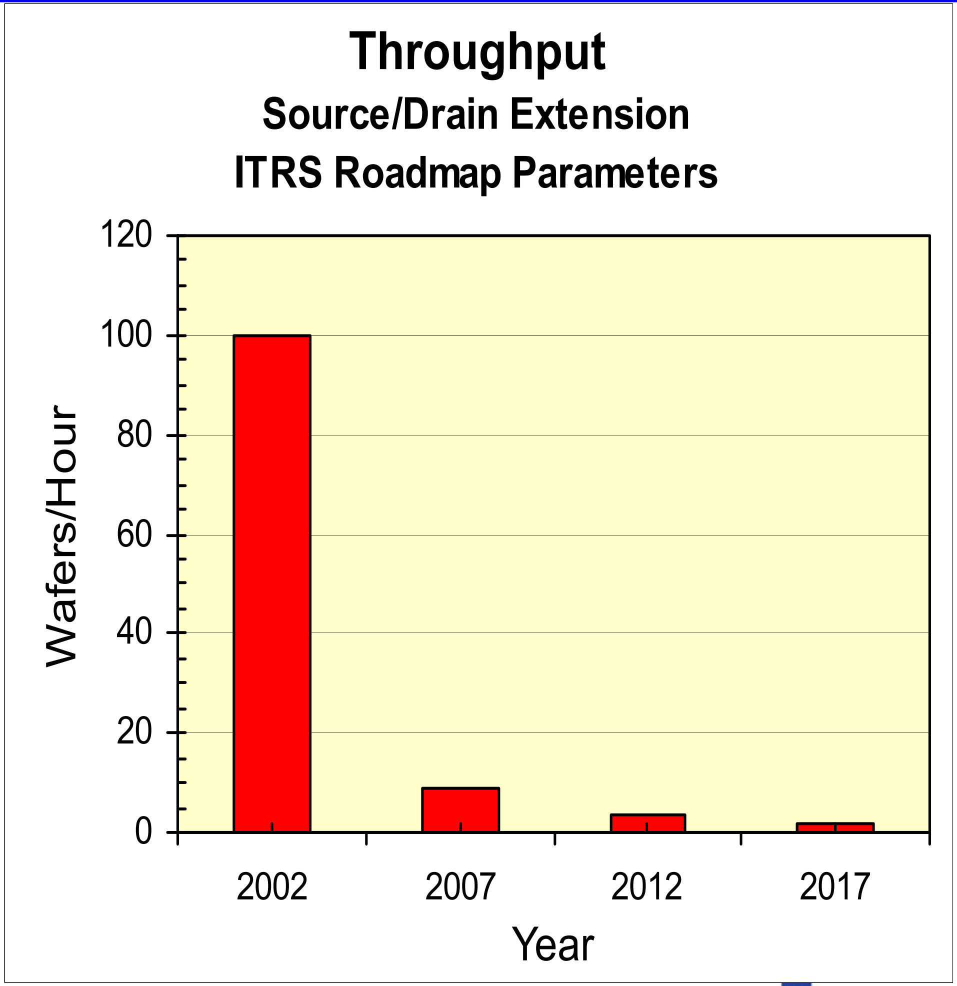
$$J = \frac{4\sqrt{2}\,\varepsilon_0}{9}\left(\frac{e}{m}\right)^{1/2}\frac{V^{3/2}}{d^2}$$

- $J \propto V^{3/2}$
  - *If E goes down by factor of 3 Current goes down by 5*
  - *If E goes down by factor of 10 Current goes down by 31*

Reduced Throughput

2002→2007

- Energy
  - Lower by a Factor of 2.5
  - Beam Current Down by factor of 4
  - Throughput Down by 4
- Dose
  - Higher by a Factor of 1.5
  - Throughput Down by 1.5
- Wafer Size
  - 200mm→300mm
  - Throughput Down by 2.25
- Net Throughput
  - Down by Factor of 14



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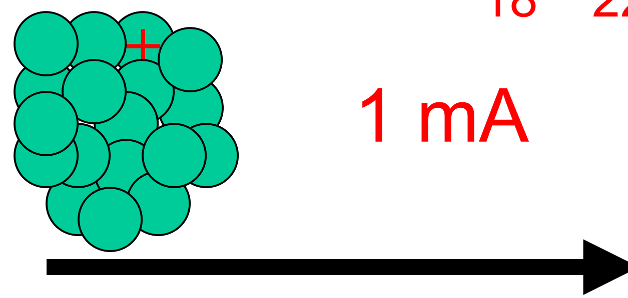
ClusterBoron™ Ion Implantation Is the Answer

- 18 Dopant Atoms per Cluster
- Extract and Transport at 20X Higher Energy
  - Enhanced Beam Transport
  - Less Over Scan Required
- Increase Effective Dose Rate by 18X
- Reduce Electrical Current by 18X
  - Reduced Beam Blow Up
  - Reduced Wafer Charging
- Deceleration is *not* required
  - Eliminating Energy Contamination
  - Reducing Beam Divergence
- Enables Cost-effective *Low Energy, High Dose* Boron Implants

20 keV $B_{18}H_{22}^{+}$



1 mA

Is process equivalent to

1 keV B^{+}

18 mA

The Physics

For Simple Clusters of n Dopant Atoms

- $V_n = nV_1$
- $m_n = nm_1$
- $J_n = nJ_1$
- But There Are n Atoms in the Cluster
- Therefore the Atomic Current Density is Proportional to n^2
- If the Geometry is Fixed the Extracted Atomic Current can be Enhanced by n^2

$$J = \frac{4\sqrt{2}\,\varepsilon_0}{9}\left(\frac{e}{m}\right)^{1/2}\frac{V^{3/2}}{d^2}$$

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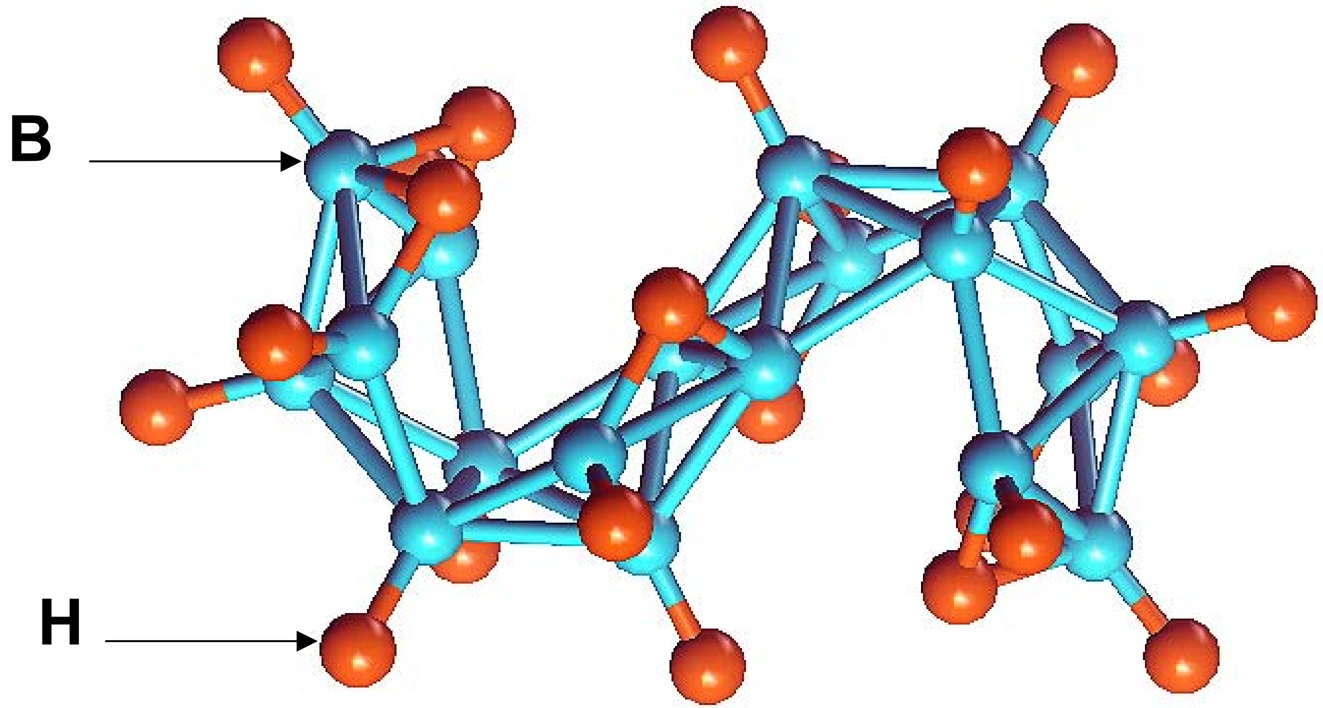
The Chemistry

$B_{18}H_{22}$



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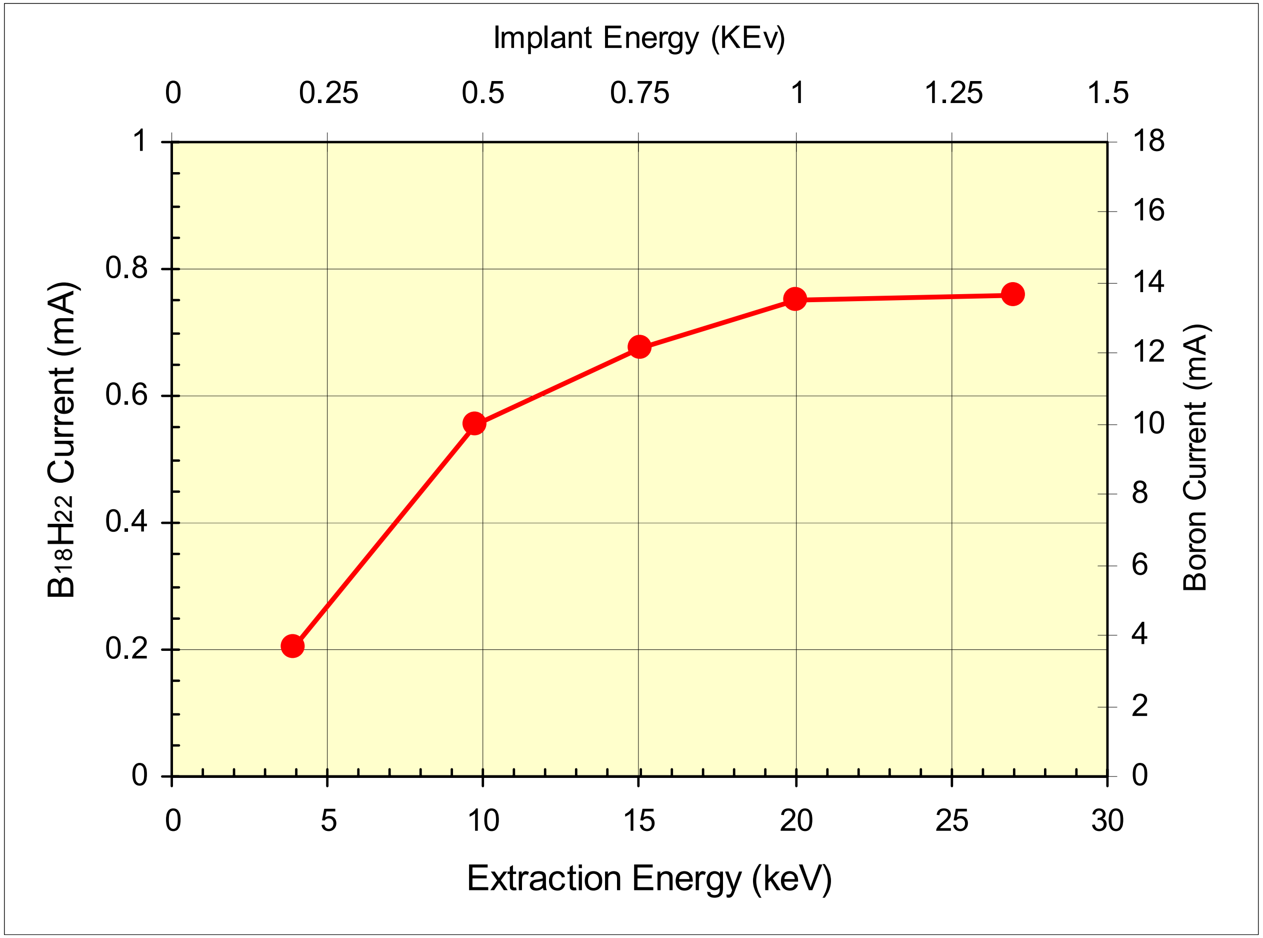
ClusterIon® Equivalent Boron Beam Current & Energy



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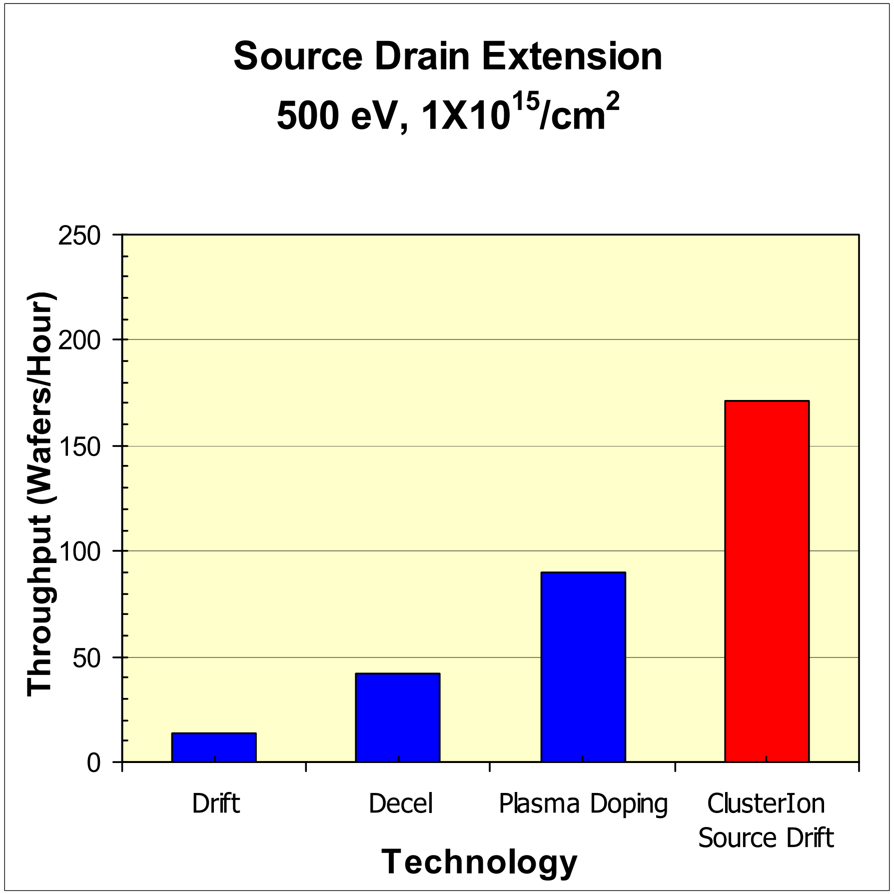
Throughput Enhancement
Source/Drain Extension Implant

SemEquip's ClusterIon® Source with ClusterBoron™ Provides Higher Throughput than <u>any</u> Available Implant Technology.



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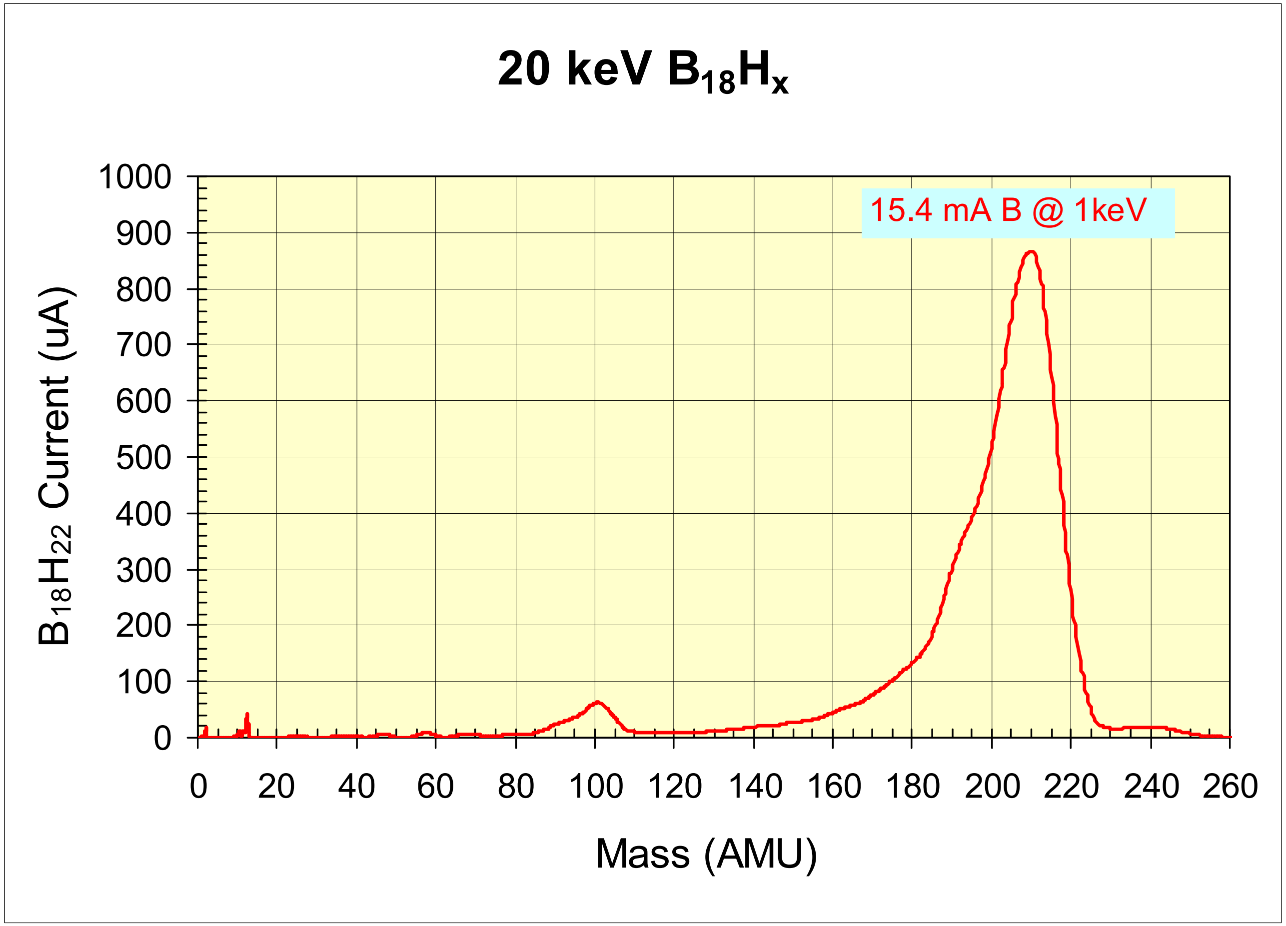
Mass Spectrum



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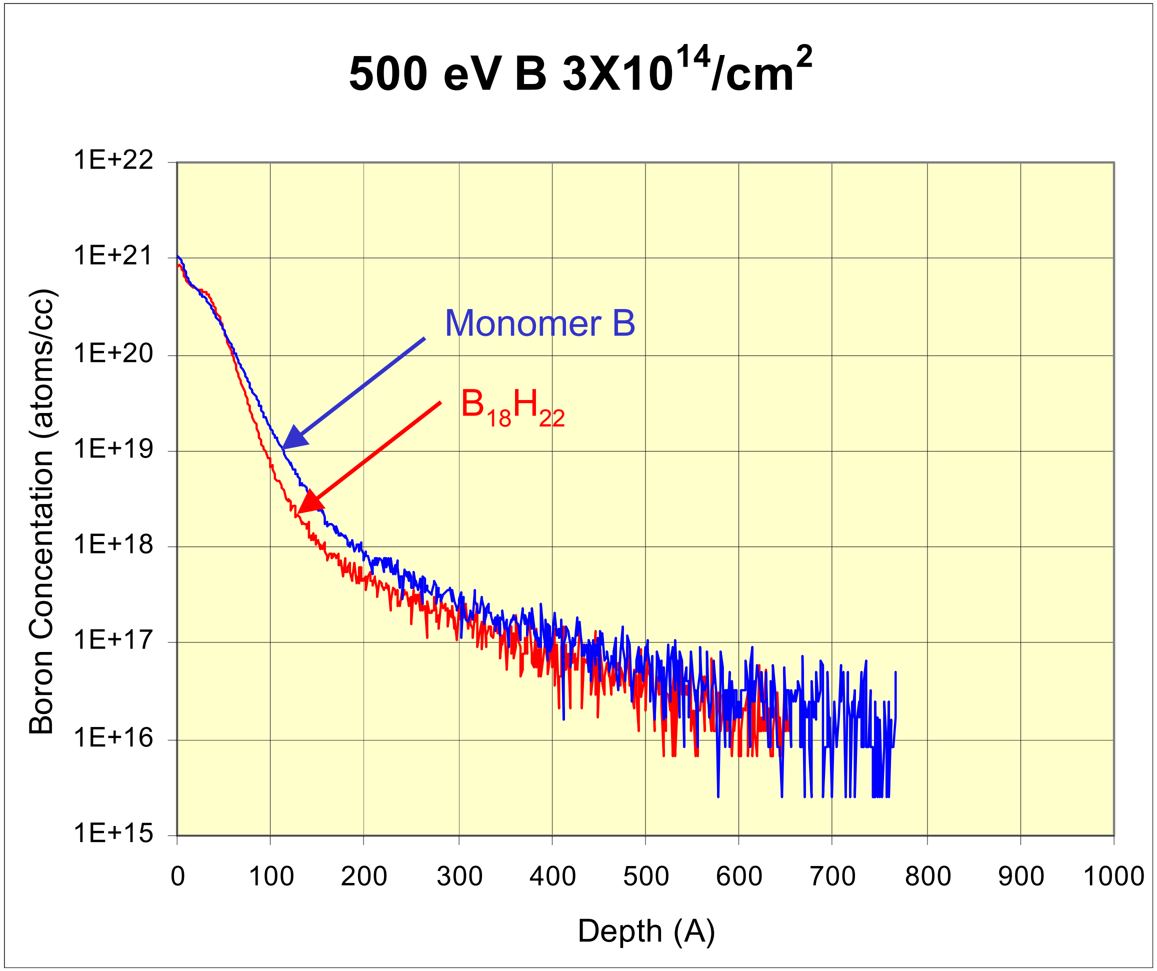
SIMS 500eV $B_{18}H_{22}$ vs B



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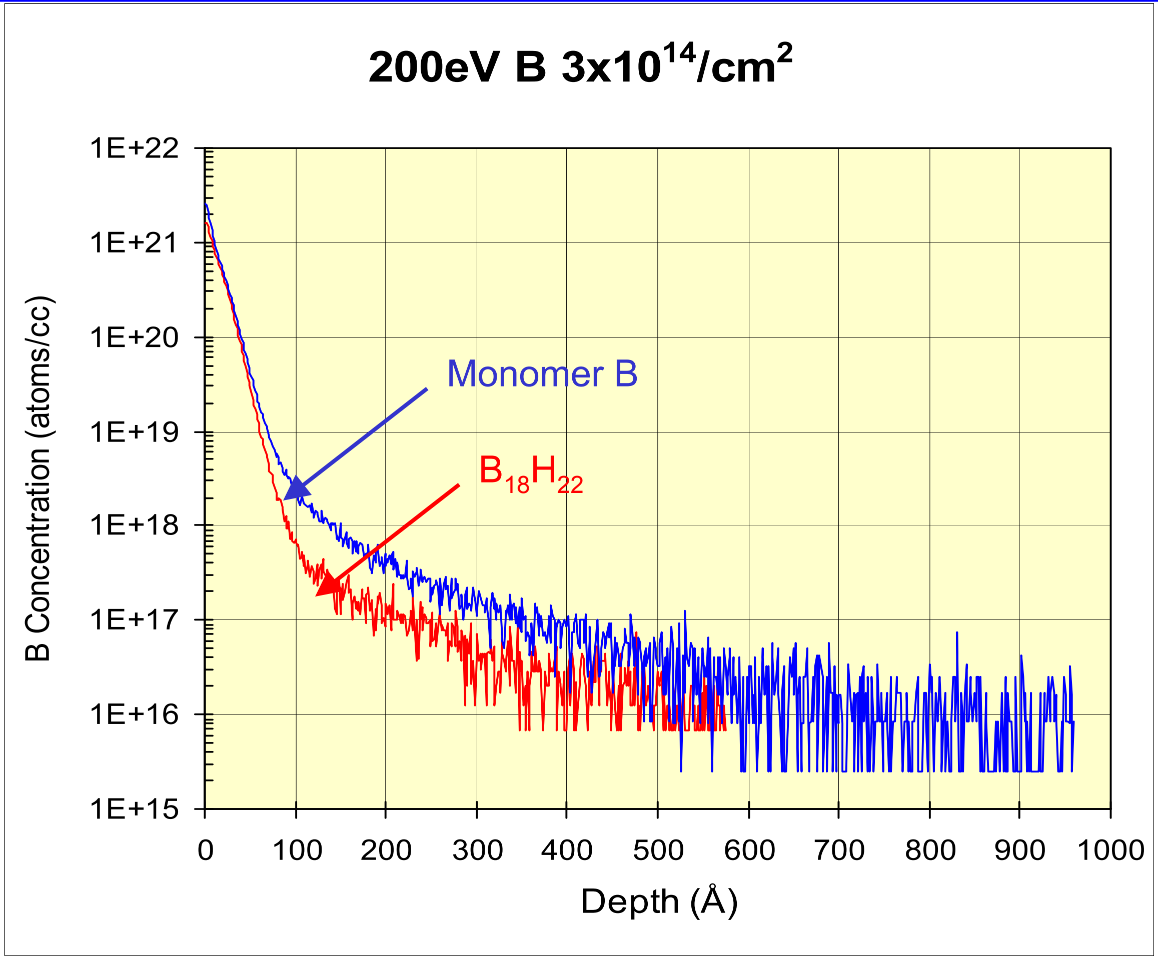

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Axcelis GSD100 Retrofit

- Ten Year Old GSD100
- Retrofitted with SemEquip ClusterIon® Source and Vaporizer
- Running $B_{18}H_{22}$ ClusterBoron™ Source Material
- World Class Low Energy Boron Beam Current
- Device Wafers Processed
  - Equal or Better Device Performance
- Exceptional Throughput

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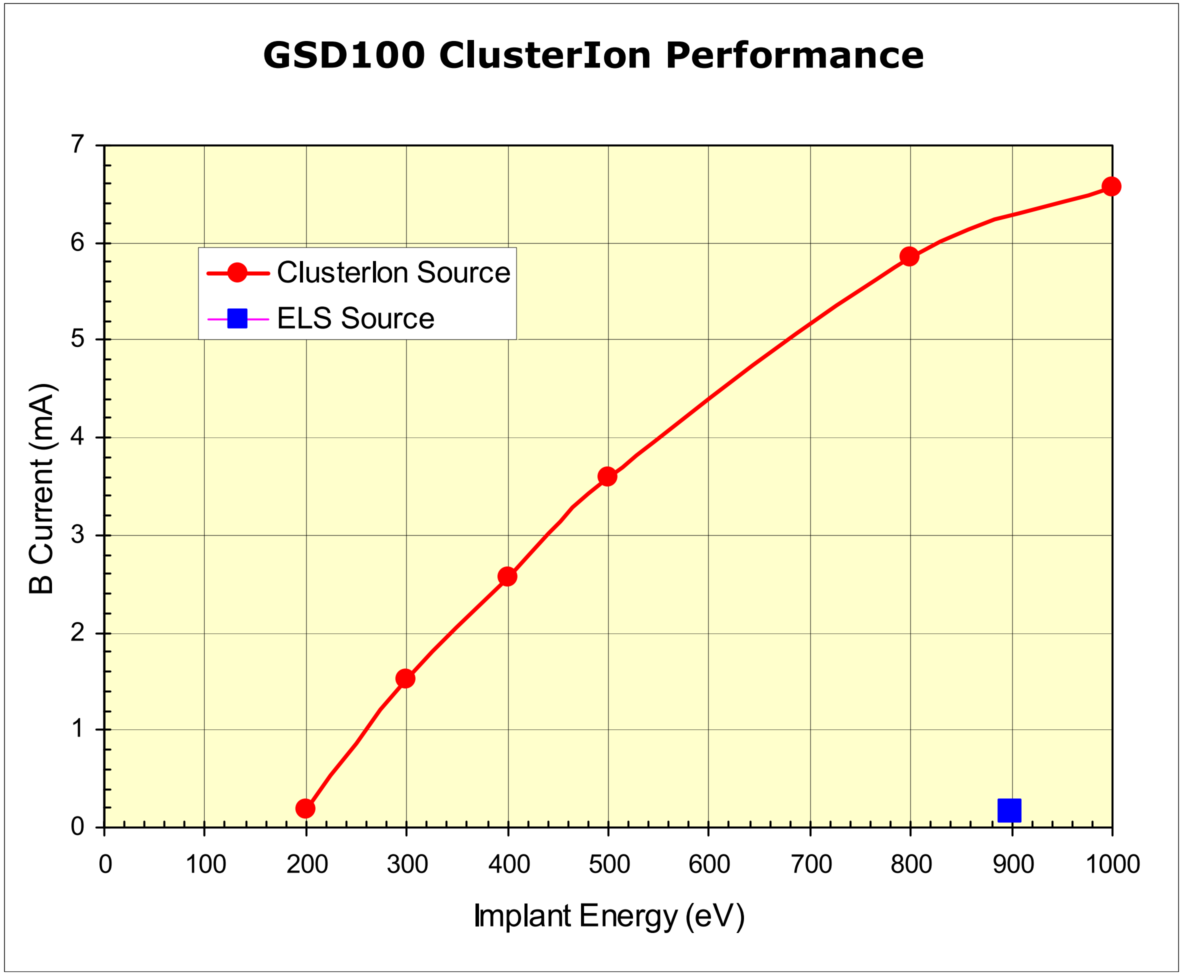
GSD100 Performance

- Original Spec (1994):
  - B and BF_2 1 mA at 10 keV
- Performance: (Pre-retrofit Q3-04)
  - BF_2 1mA at 10 keV =2.25 keV B
  - BF_2 0.16 mA at 4 keV = 900 eV B
- Retrofit Performance (Drift Mode):
  - B_{18} 5.85 mA at 800 eV (36X improvement)
  - B_{18} 4.23 mA at 500 eV (Impossible Pre-retrofit)

GSD100 Performance with $B_{18}H_{22}$ Drift Mode Boron Current



ClusterBoron™ Summary

- $B_{18}H_{22}$ Enables sub-keV Boron Implantation with High Productivity and High Quality
- Relaxes the Child-Langmuir Limits
- No Decel Required
  - No Energy Contamination
  - Shallower Junctions Demonstrated
- Applicable to High Current and Medium Current Implanters
- Capability to 100 eV B^+ Equivalent

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