West Coast Junction Technology Group

Semicon West — San Francisco

July 14, 2005

Tom Horsky, Chief Technology Officer

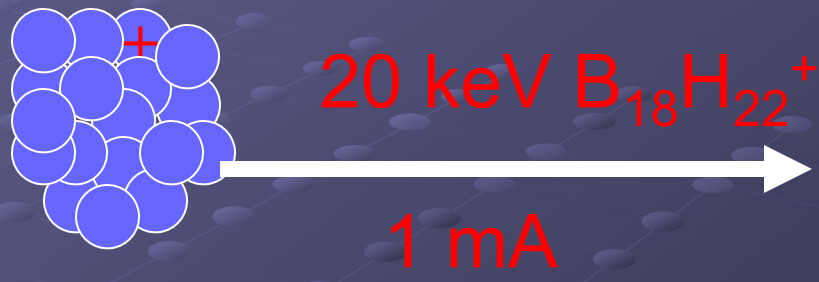
Company Mission

- SemEquip provides innovative technologies that enable the use of cluster beam ion implantation in manufacturing the world's most advanced IC's at the lowest cost and highest throughput.
  - We do this by enabling the rapid commercialization of cluster implantation in conventional high current and medium current implanter platforms.

new thinking SemEquip

Why Cluster Implantation?

- 18 dopant atoms per cluster
- Increases effective dose rate by 18X
- Extract and transport at 20X higher energy
- Reduces net current to wafer by 18X (reduced charging)
- Deceleration is *not* required, eliminating energy contamination
- Enables cost-effective *low energy, high dose* Implants

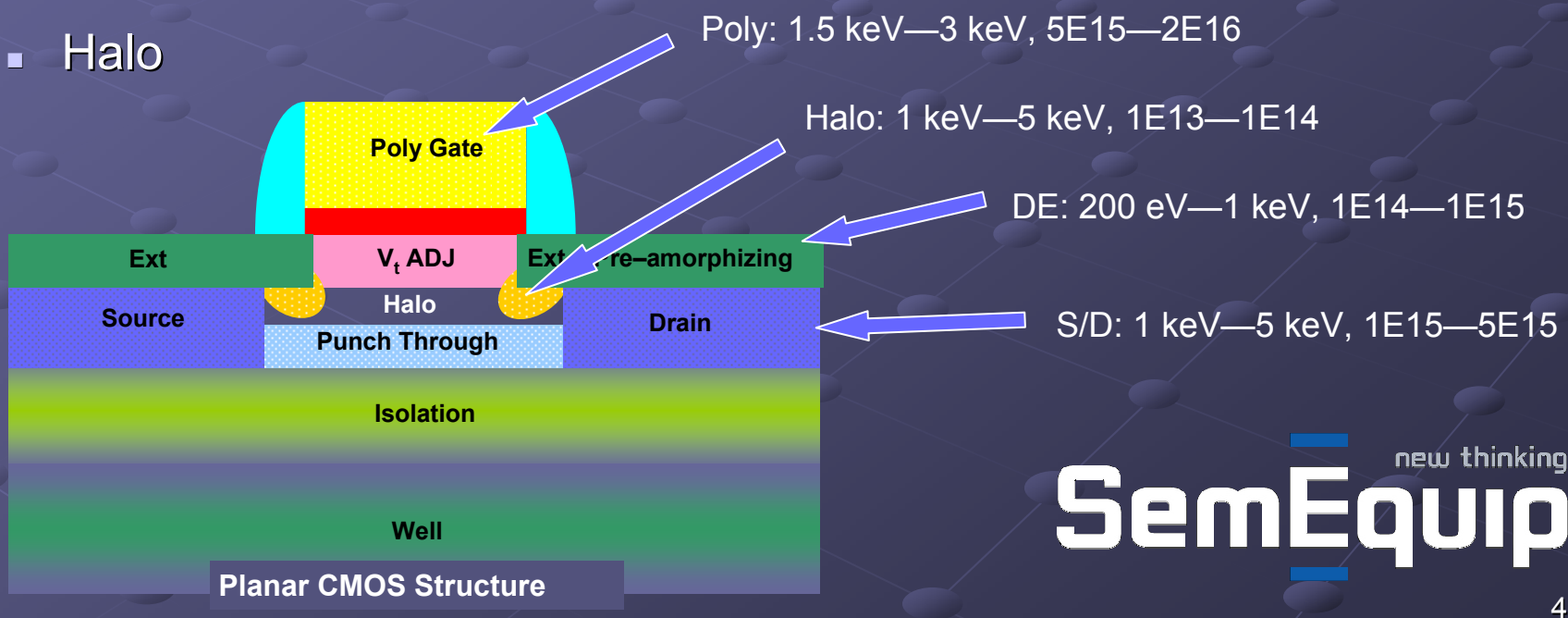


Is process equivalent to

new thinking SemEquip

What implants can be done with Clusters?

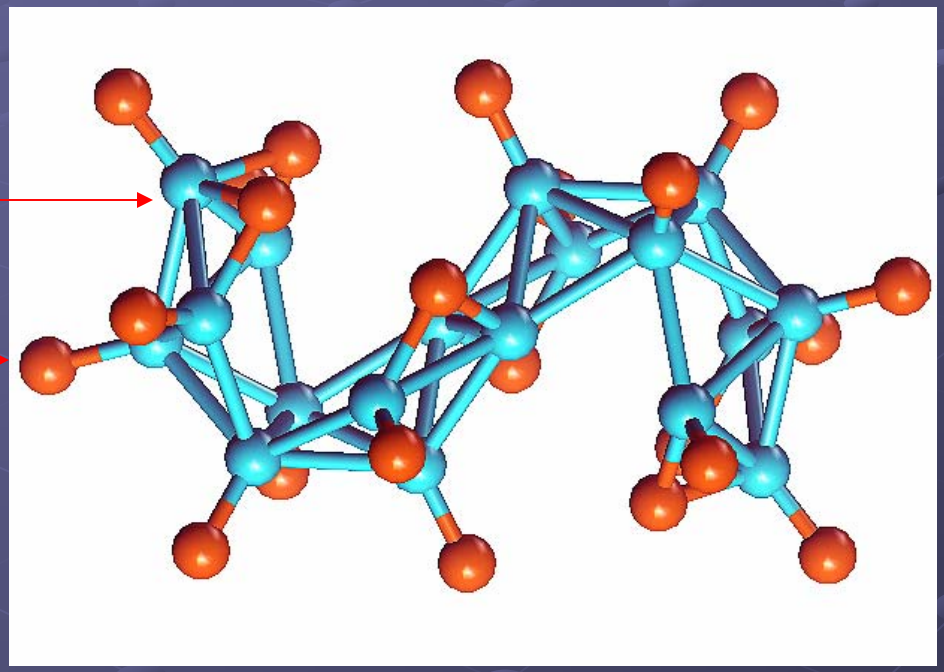
- **$B_{18}H_{22}$, $B_{10}H_{14}$** and **As_4** can be used for USJ n+ and p+:
  - Source/Drain Extensions
  - Deep Source/Drains
  - Poly Gate
  - Halo



new thinking SemEquip

ClusterBoron™

$B_{18}H_{22}$



new thinking
SemEquip

SemEquip Products

- ClusterIon® Source
- ClusterIon® Universal Ion Source™
- $B_{18}H_{22}$ and $B_{10}H_{14}$ (distributed by ATMI)
- Custom engineered systems

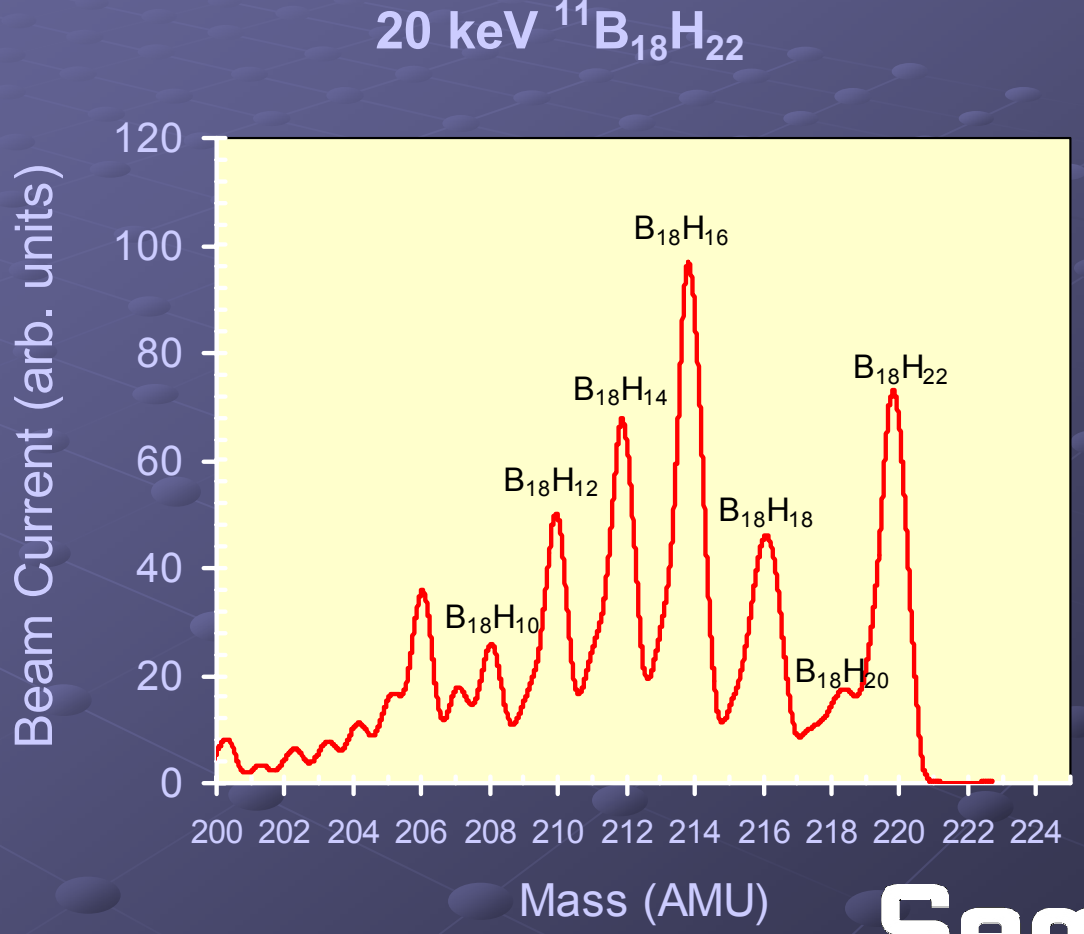
new thinking SemEquip

Universal Ion Source™

Ion Species	Analyzed Beam (emA)
$B_{18}H_{22}^{+}$	1.0
$B_{10}H_{14}^{+}$	1.0
B^{+}	8.0
B^{++}	0.25
BF_2^{+}	10
P^{+}	10
P^{++}	1.0
P^{+++}	0.25
P_2^{+}	1.0
P_4^{+}	1.0
As^{+}	10
As_2^{+}	1.0
As_4^{+}	1.0

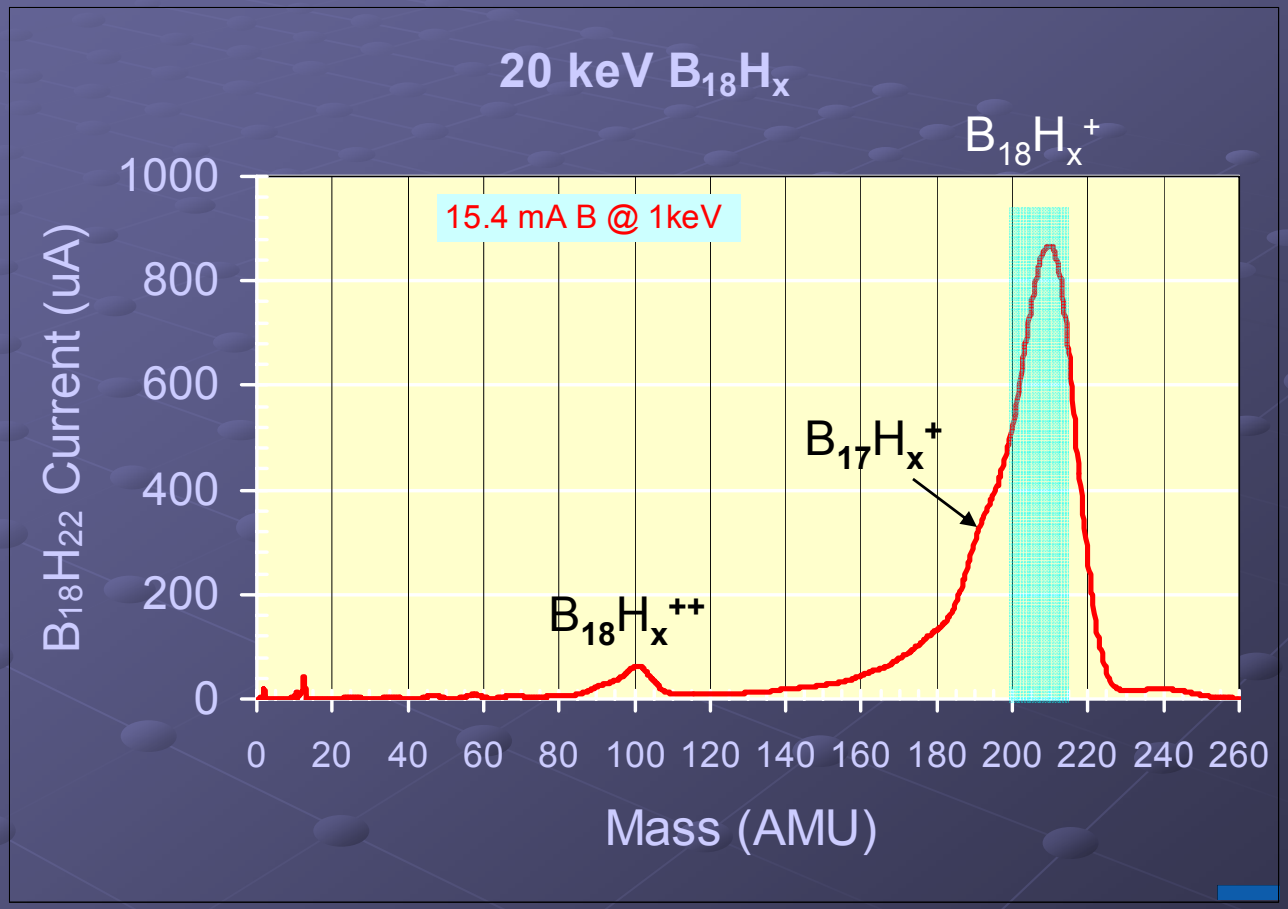
new thinking SemEquip

Isotopically Enriched $^{11}B_{18}H_{22}$



new thinking
SemEquip

$B_{18}H_{22}$ Mass Spectrum Passing 15amu



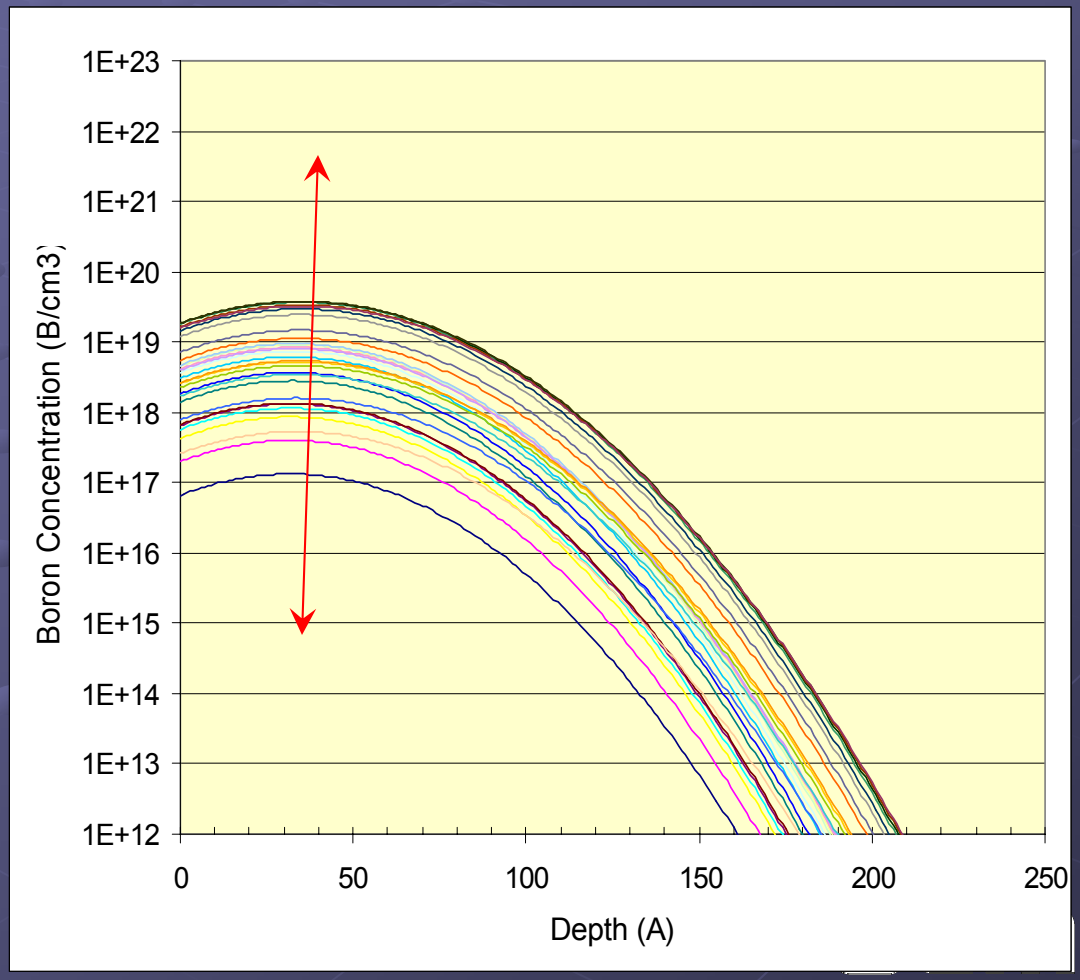
new thinking
SemEquip

Multiple Mass-Multiple Energy Analysis

- Simulation
  - 500 eV Equivalent Energy
  - $1x10^{15}$ B/cm^2
  - Assume Gaussian Profiles
  - Range and Straggle from SRIM
    - Linear Fit Over a few Hundred eV
    - Used Linear Regression to Calculate R_p and ΔR_p
- Used Measured & Calculated Distribution Functions (Binomial/Hydrogen/Mass Spectrum)
- 30 Unique Energies in the 15 AMU of Accepted Beam
- The Total distribution is the Sum of the 30 Mass Specific Depth Distributions
- Compare the Total Distribution to a Monomer Implant Distribution

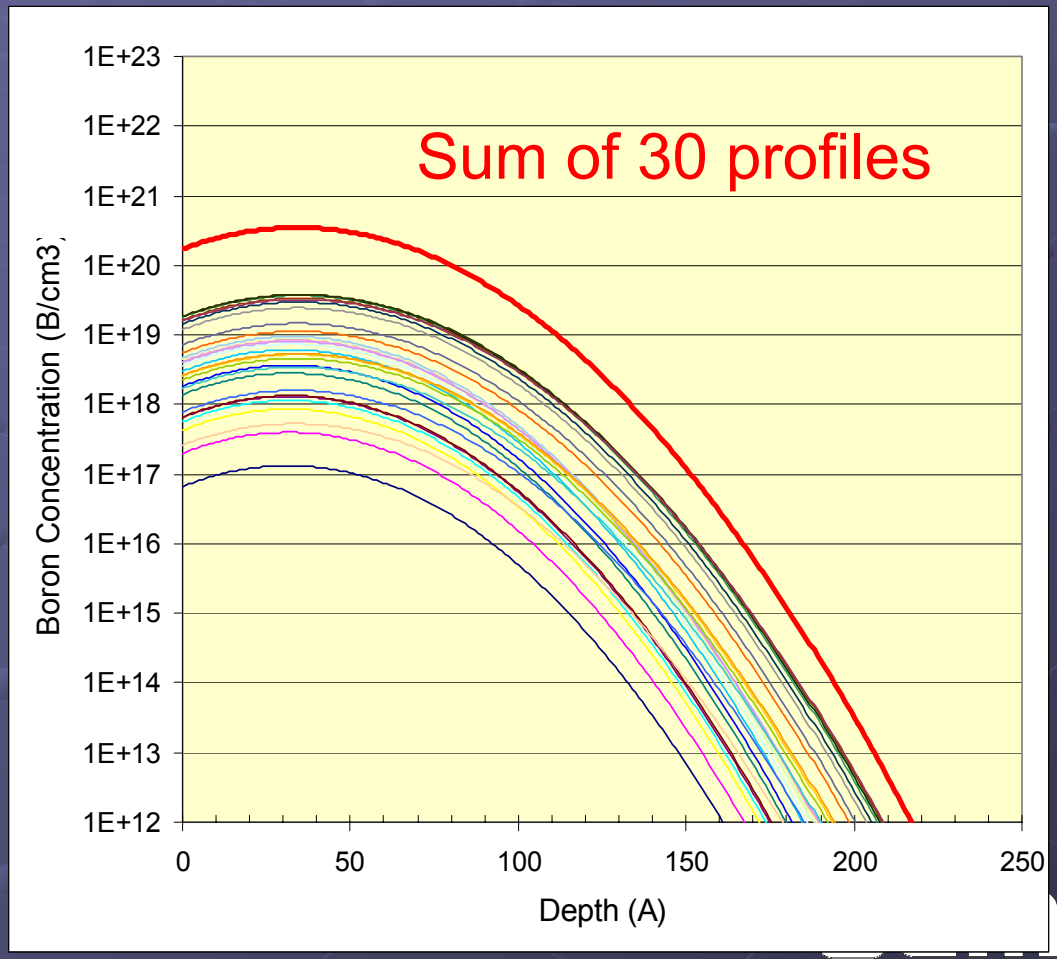
new thinking SemEquip

30 Energy Simulated Depth Profiles

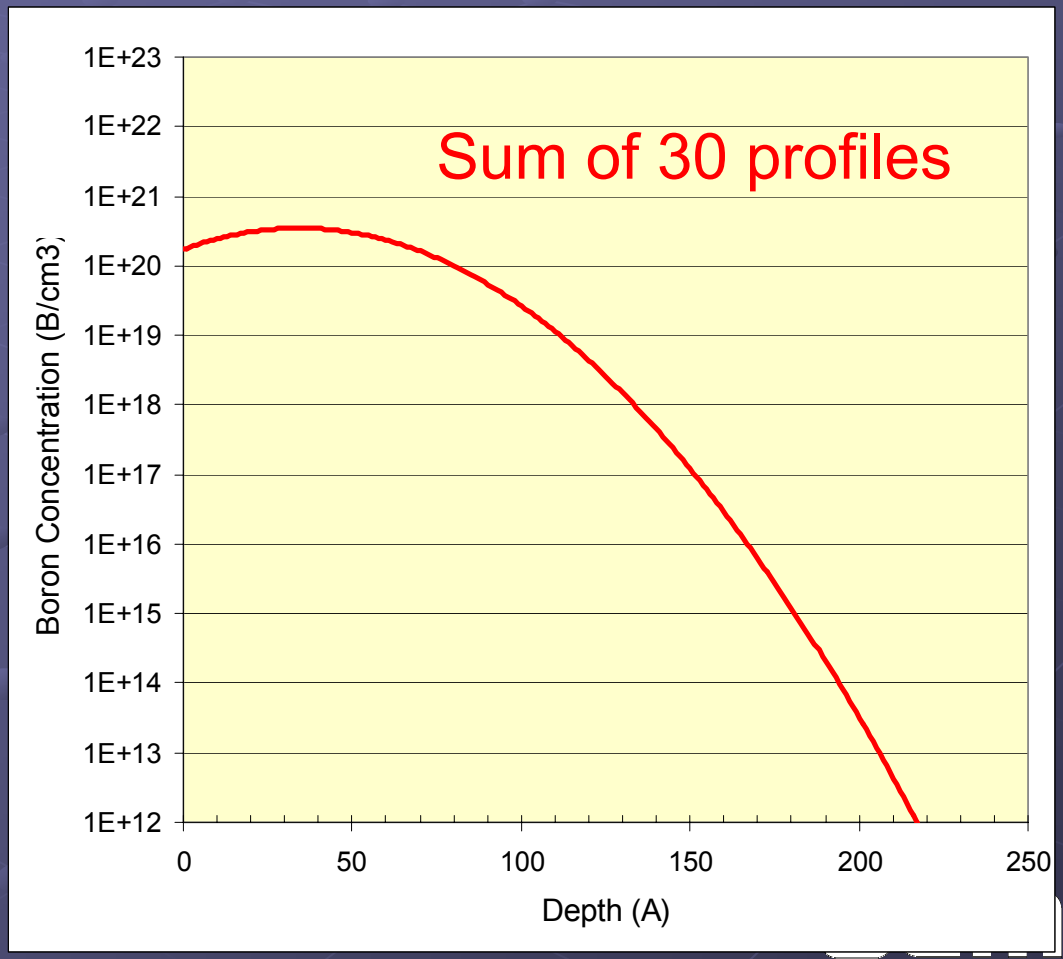


new thinking Equip

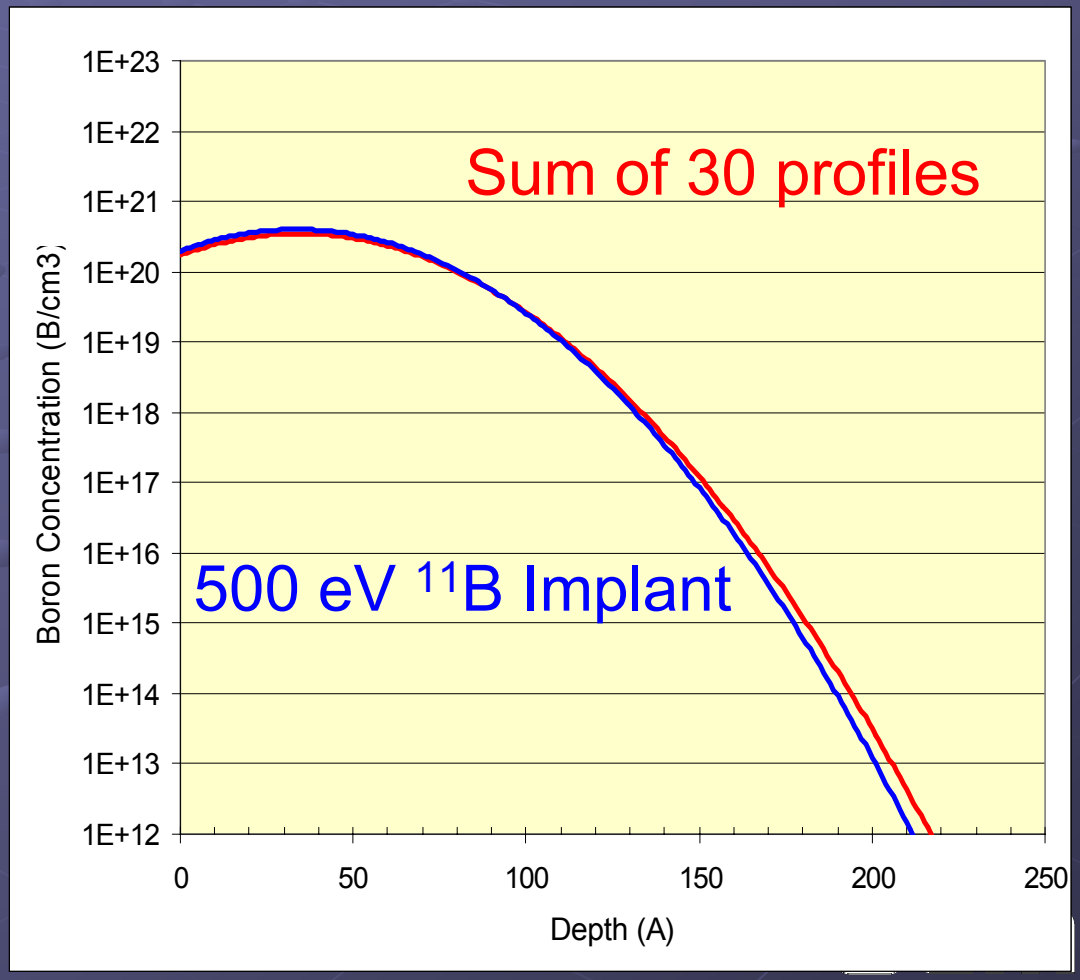
30 Energy Simulated Depth Profiles



30 Energy Simulated Depth Profiles

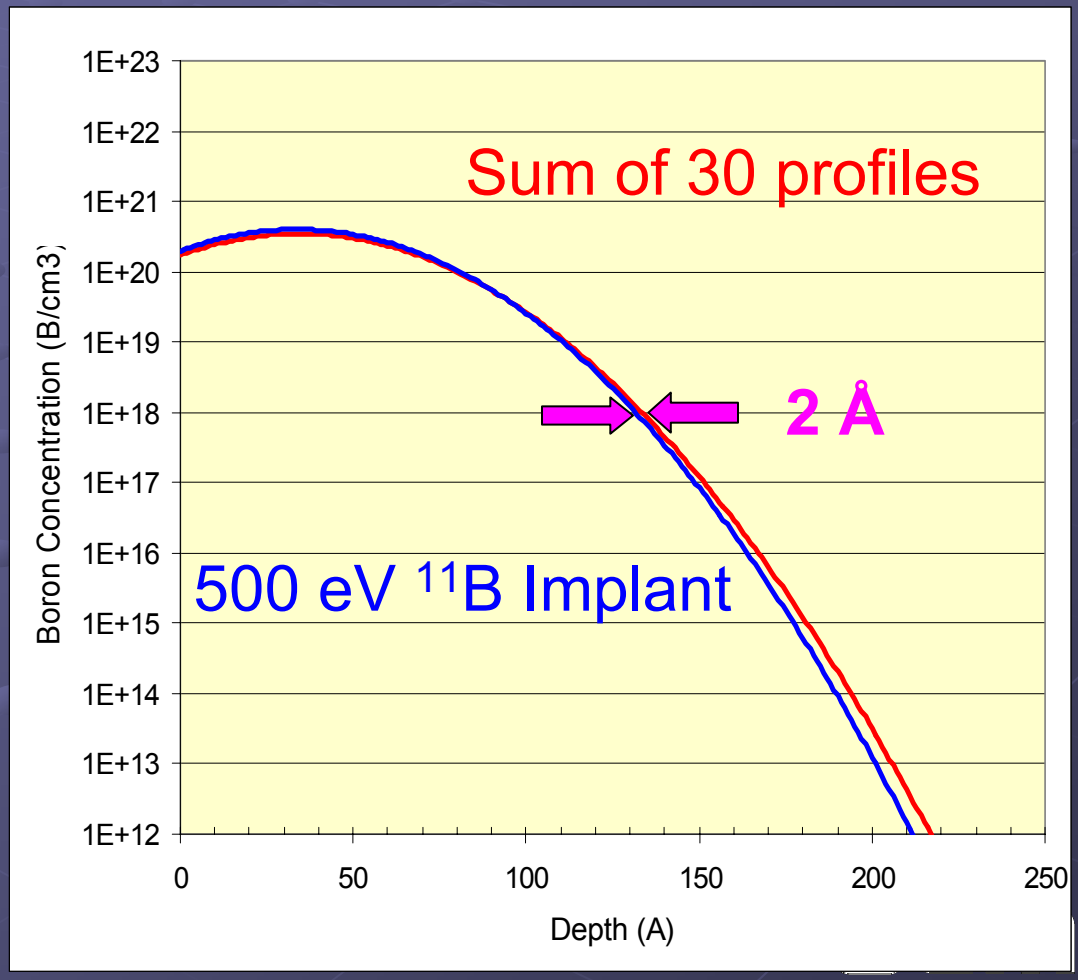


30 Energy Simulated Depth Profiles



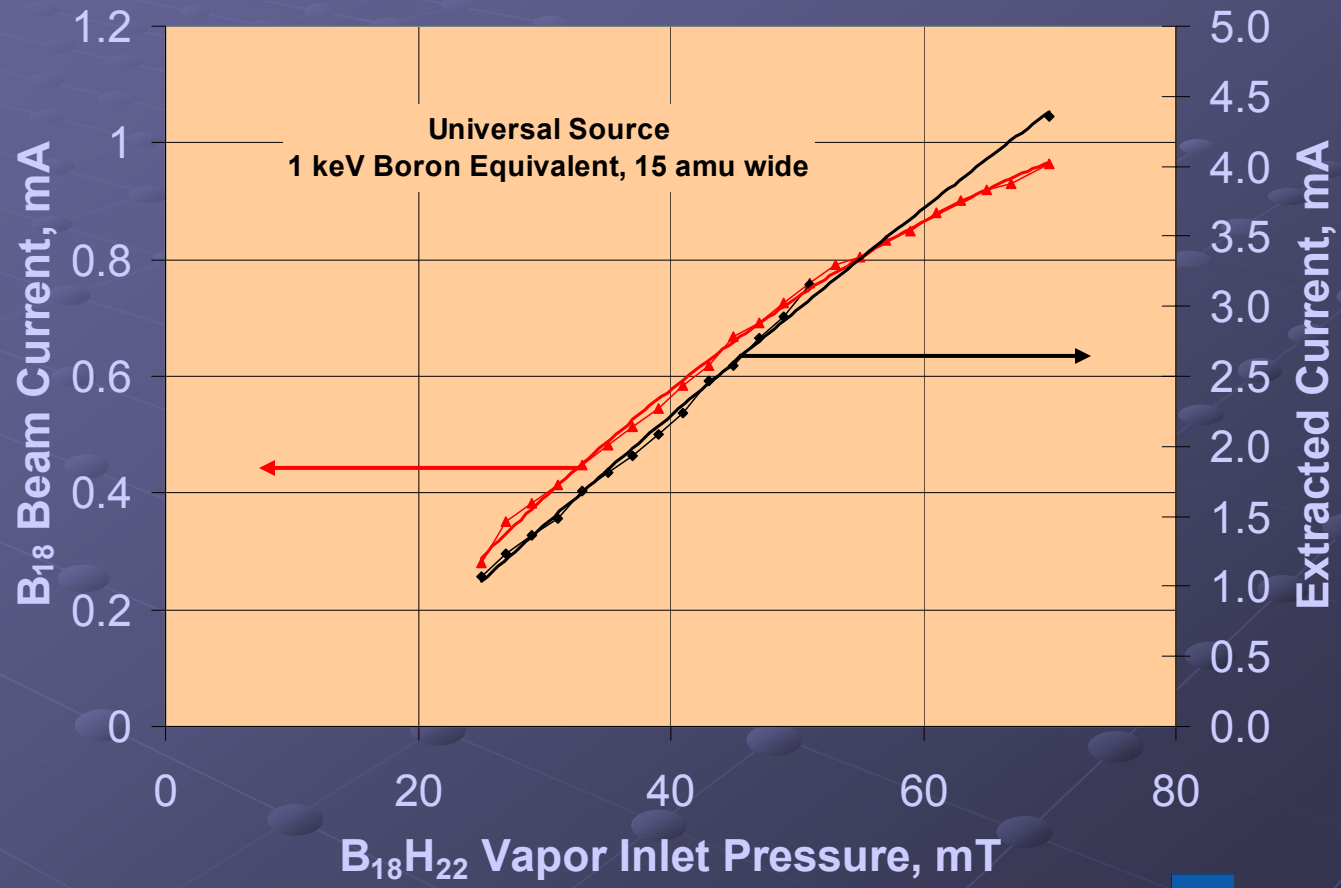
new thinking Equip

30 Energy Simulated Depth Profiles



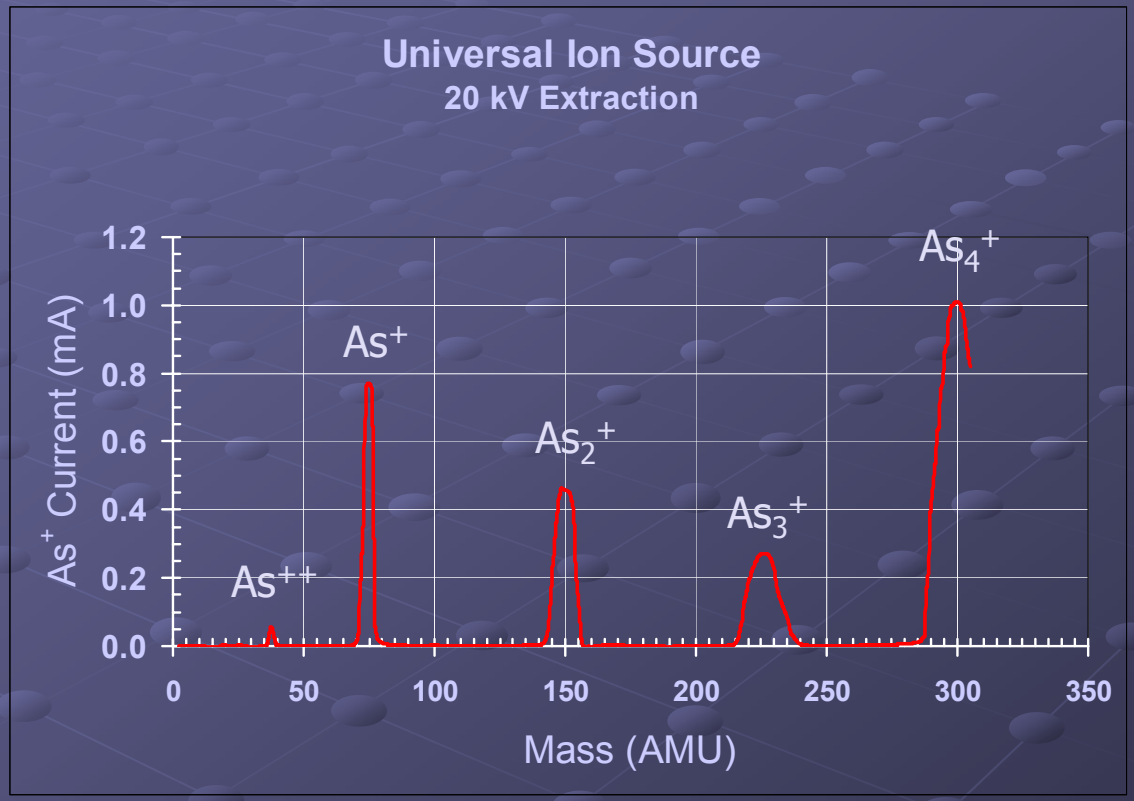
new thinking Equip

Universal Ion Source™ $B_{18}H_X^+$ Current

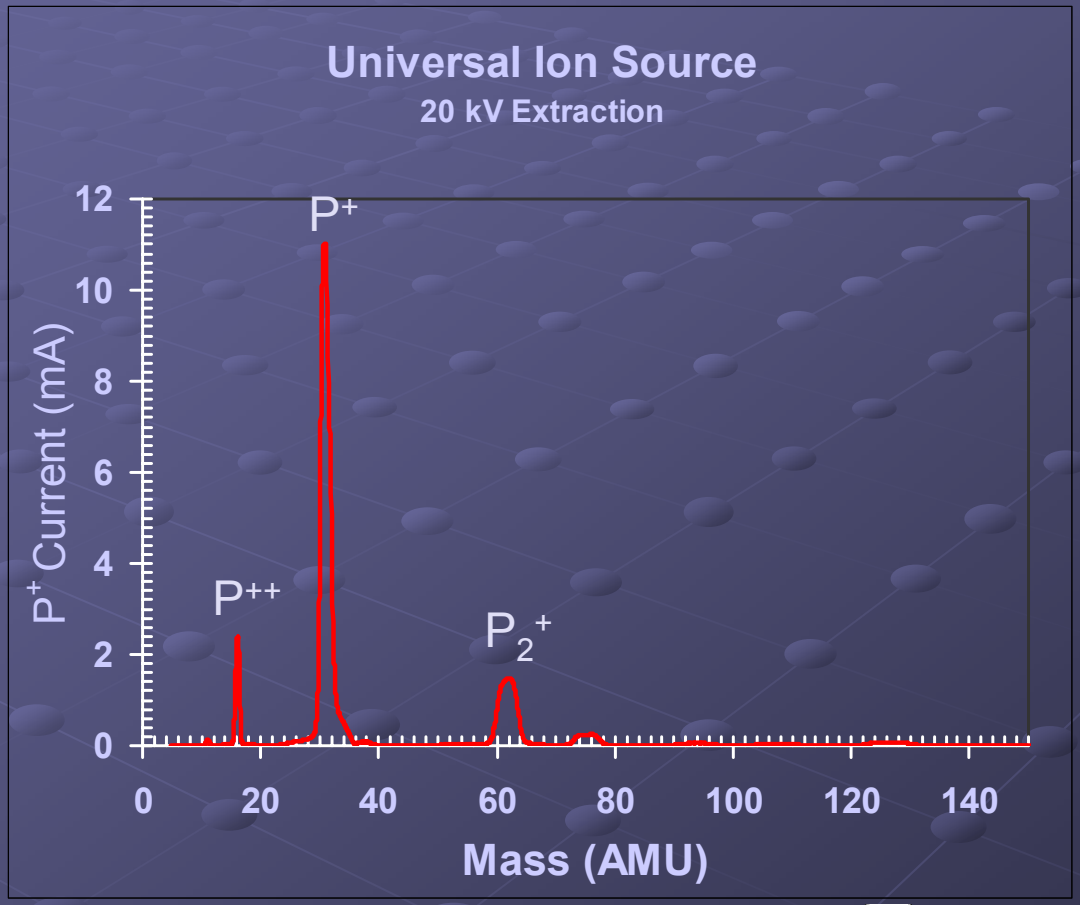


new thinking SemEquip

New n-type Cluster: As_4^+

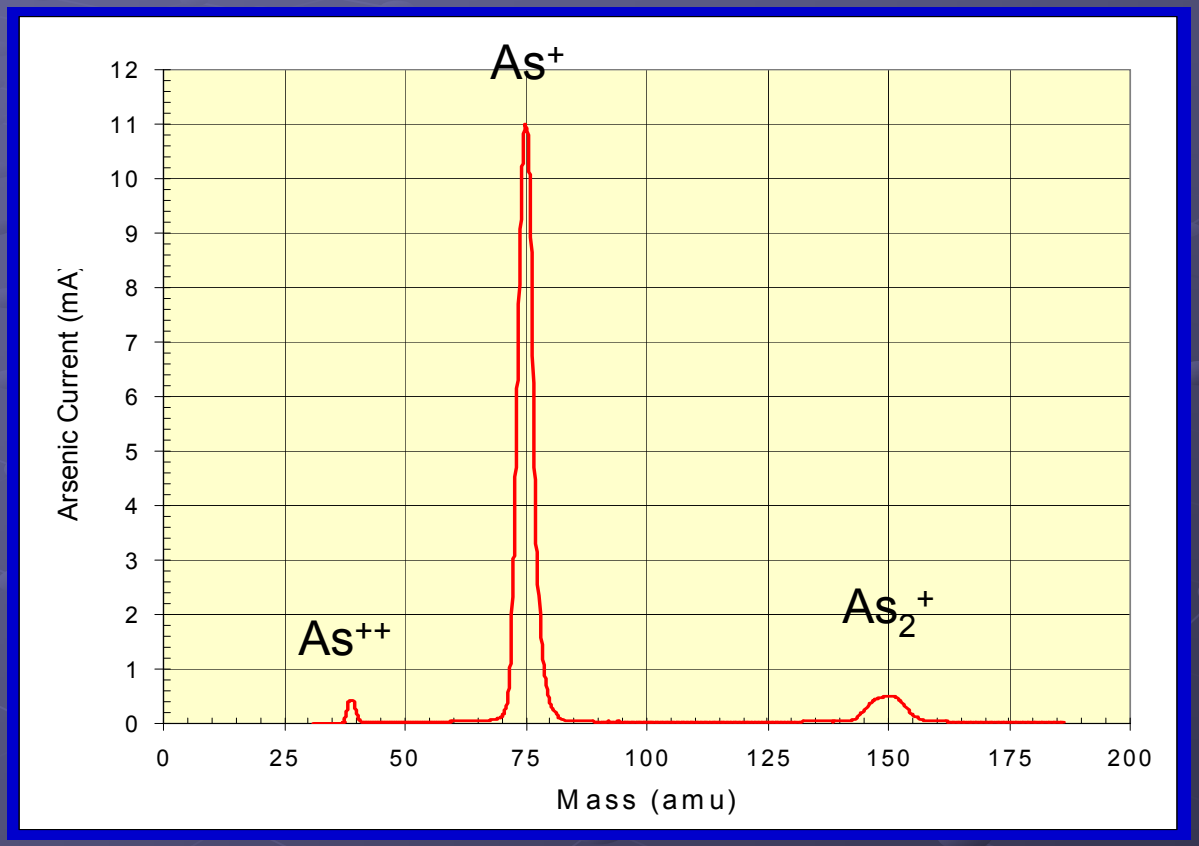


Phosphorus Mass Spectrum



new thinking
SemEquip

Arsenic Mass Spectrum



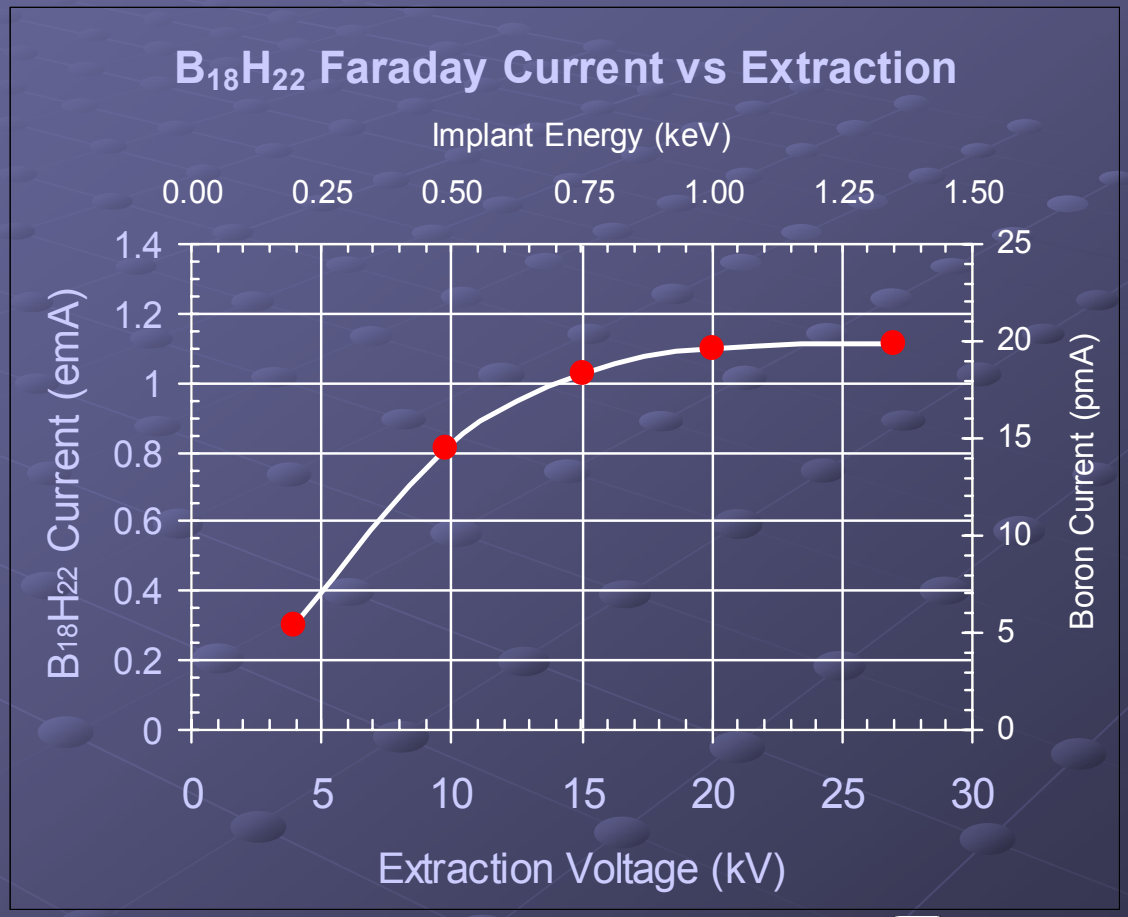
new thinking
SemEquip

Impact on HC Implanters

- Enables boron-equivalent drift currents of between 1-20 mA from 100 eV to 1.4 keV
- Provides very good spatial uniformity, angle control and small divergence even at sub-keV energies
- Maximum energy limitation can be ameliorated by increasing mass-energy product of analyzer magnet, or by adding a post-accel capability:
  - Minimal engineering since most HC implanters have a decel lens
  - Tests indicate very little high-energy contamination after post-accel
- Deceleration is also viable with clusters
  - Tests indicate level of energy contamination dependent on beam optics, not borohydride properties

new thinking SemEquip

ClusterIon® Currents on SemEquip HC Injector



new thinking
SemEquip

Impact on Medium Current Implanters

- Expands application space to high dose, low energy (S/D Ext, Halo, S/D)
- Enables under-the-gate USJ implants at high tilt
- Leverages the superior implant control which has always been a hallmark of MC Implanters
  - Single-wafer process
  - High tilt platten
  - Excellent angle control
  - Excellent energy purity
  - Large dose and energy range
- Magnetic rigidity of $B_{18}H_{22}$ and As_4 not an issue since MC implanters routinely operate in Accel & Decel mode

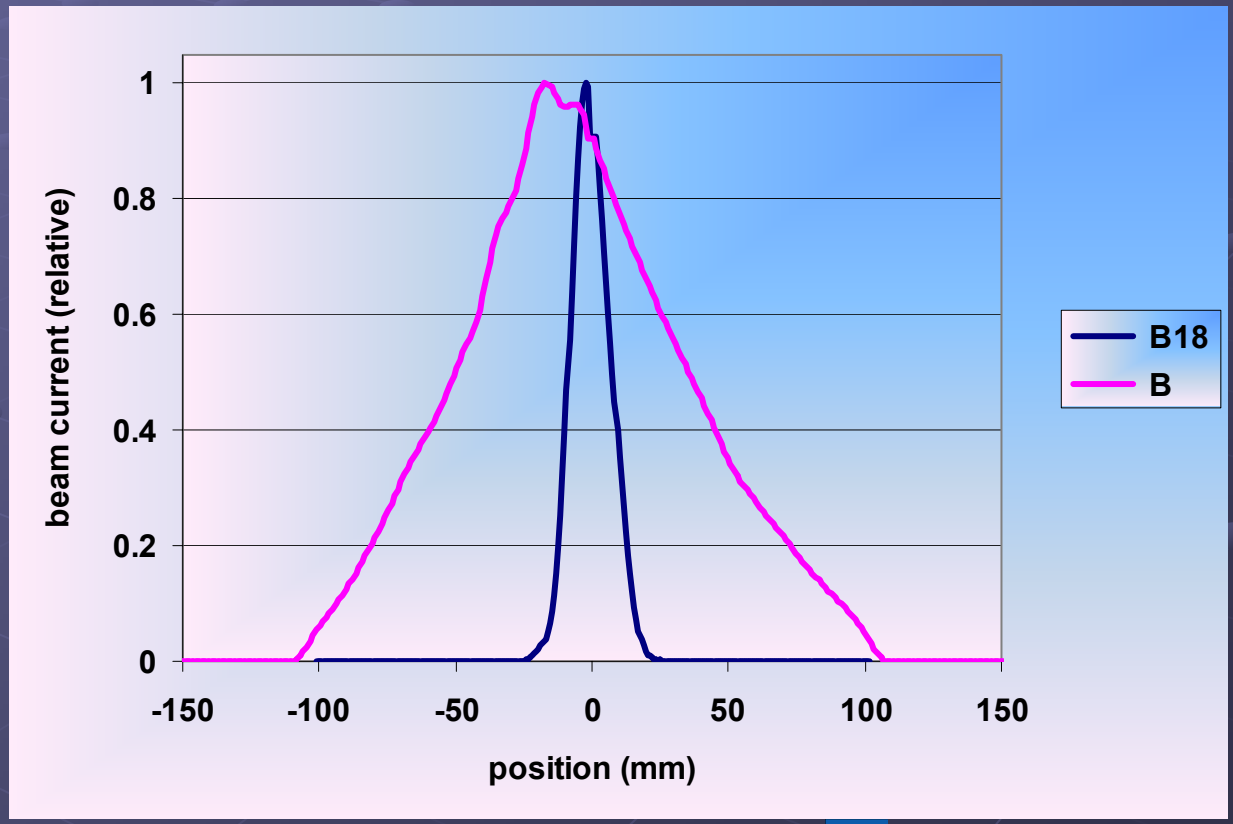
new thinking SemEquip

Reduced space charge with borane molecules results in beam size improvement – experimental evidence on MC Implanter

Lower space charge can result in a much narrower beam profile at the wafer

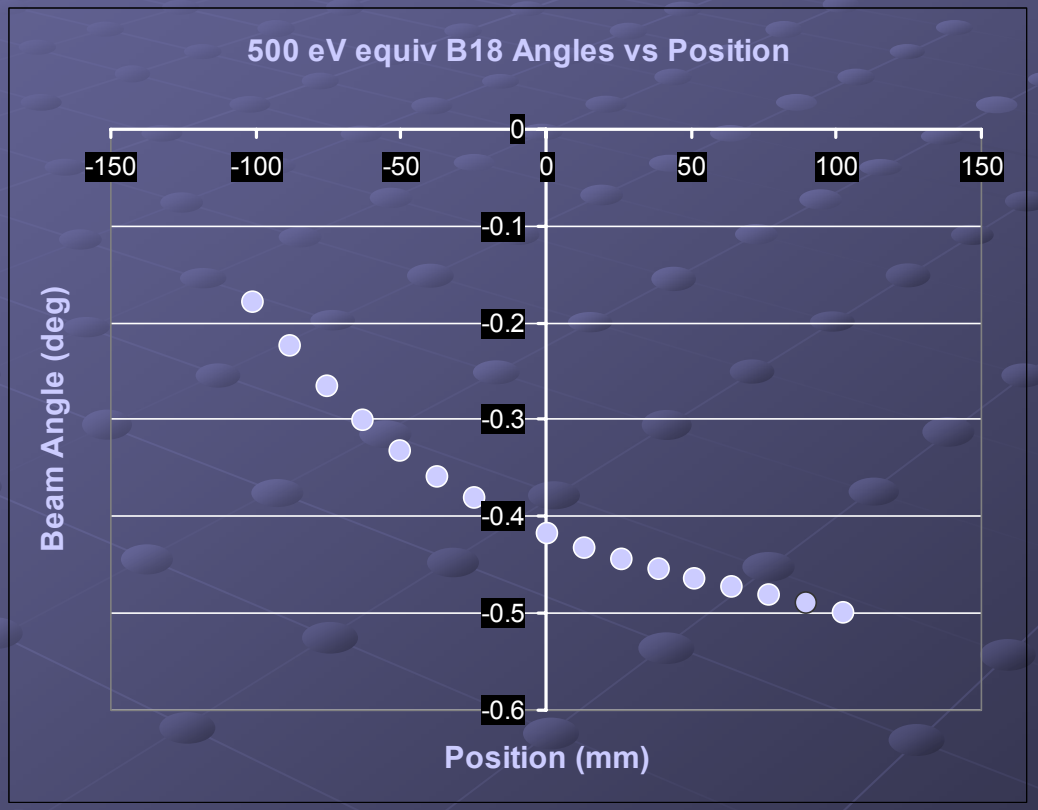
A smaller beam can:

Increase beam utilization efficiency on multi-wafer and scanned platforms



new thinking SemEquip

10 keV $B_{18}H_x^+$ Angular Profile on MC Implanter



new thinking
SemEquip

Process Benefits 1

- ClusterIon process is regular ion implantation
  - Dosimetry is based on counting charged ions
  - Implanted ions are mass analyzed
  - Energy of implanted dopant is well defined
  - Excellent contamination/particle control
- Improved annealing behavior
  - Damage structure is different with cluster implantation
  - Implants with ClusterBoron ions exhibit self-amorphization
  - Data show that junctions made with ClusterBoron
    - Are shallower compared with monomer implants
    - Have same dopant activation (sheet resistance) as B

new thinking SemEquip

Process Benefits 2

- Reduced angular spread in the ion beam
  - ClusterIon source has very low emittance
  - Angle errors due to low energy beam space charge blow-up are greatly reduced due to increased transport energy and reduced space charge in the beam
- Reduced wafer charging
  - Charge per boron dopant atom is 18x less

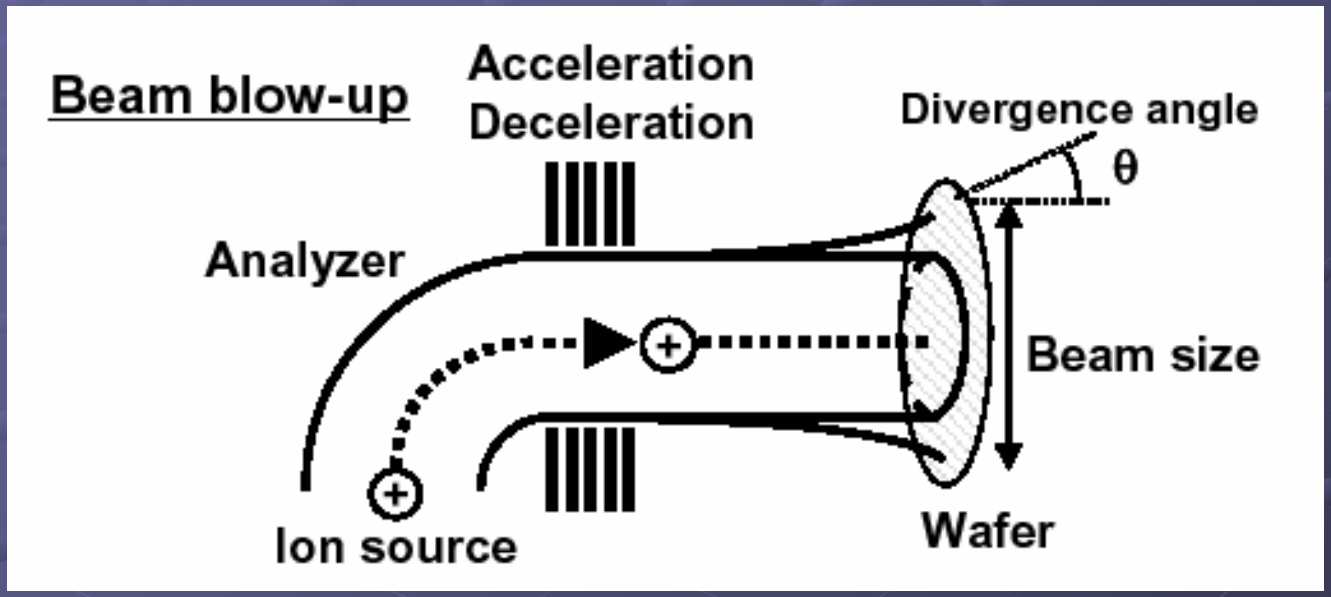
new thinking SemEquip

Device Data Review: Fujitsu

- Very early investigator of clusters for USJ
  - We will focus on recent results from IWJT2005

Beam Blow-up at Low Energies

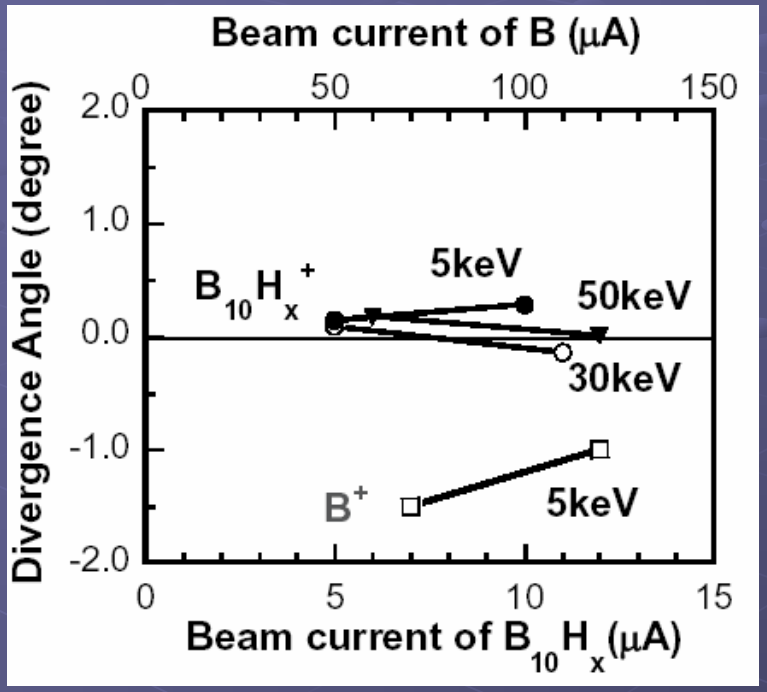
Fujitsu, IWJT2005

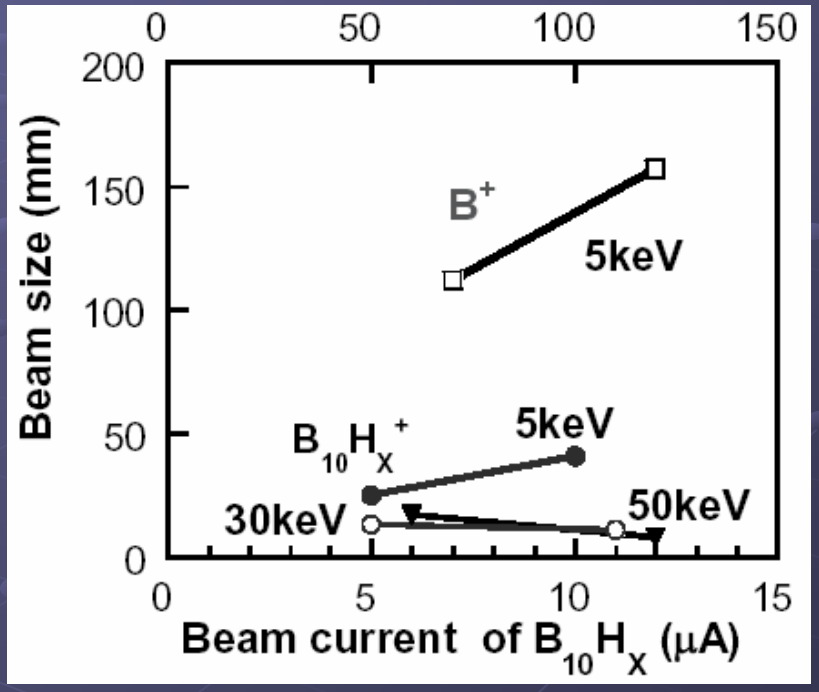


new thinking
SemEquip

Beam Divergence Angle and Beam size

Fujitsu, IWJT2005



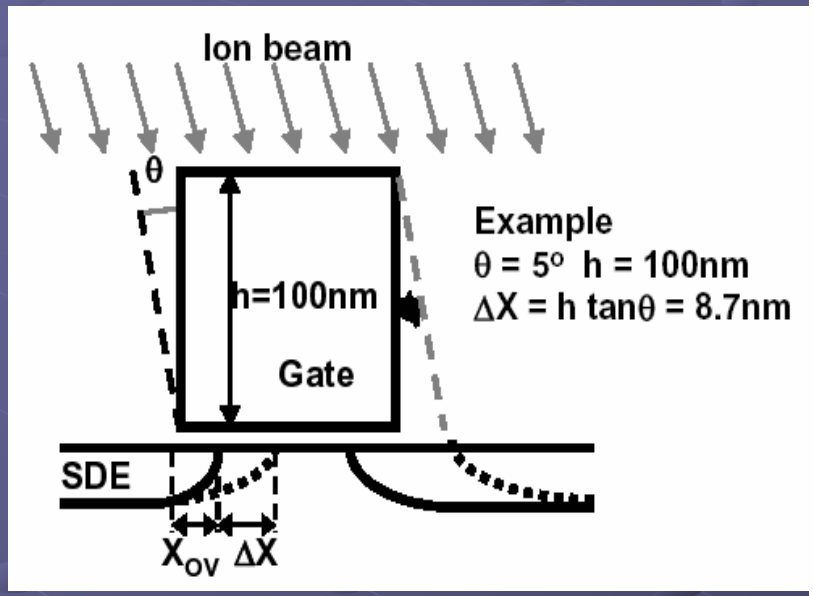


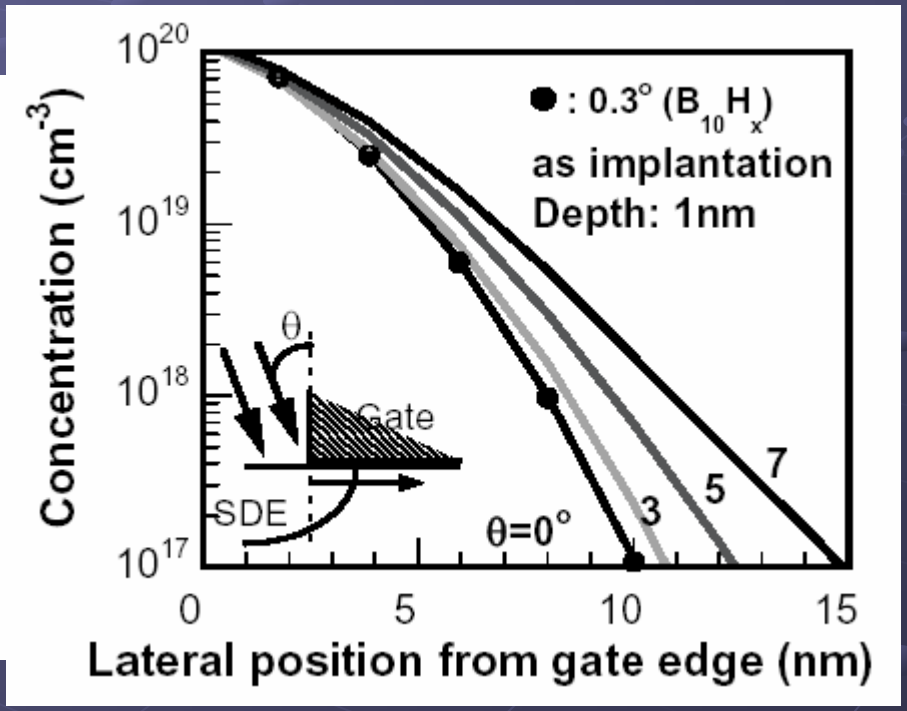
$B_{10}H_x^+$ beam is much smaller divergence angle and beam size than low energy B^+

new thinking SemEquip

Transistor Impact by Beam divergence

Fujitsu, IWJT2005

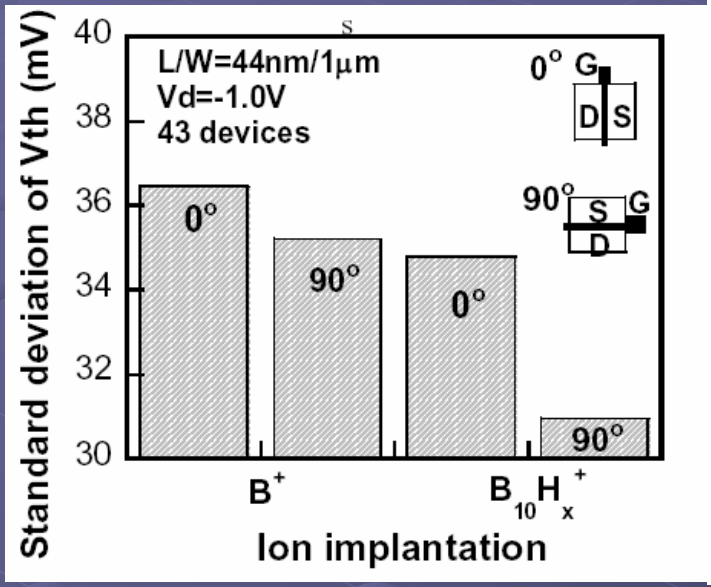


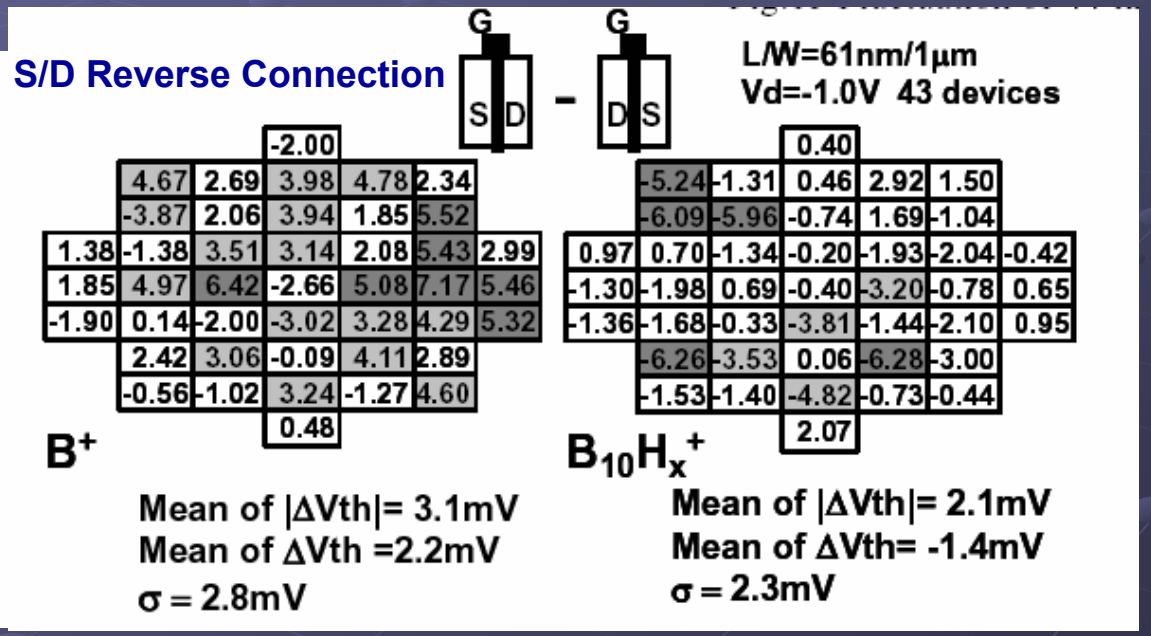


new thinking SemEquip

V_{th} Fluctuations Due to Beam Divergence

Fujitsu, IWJT2005



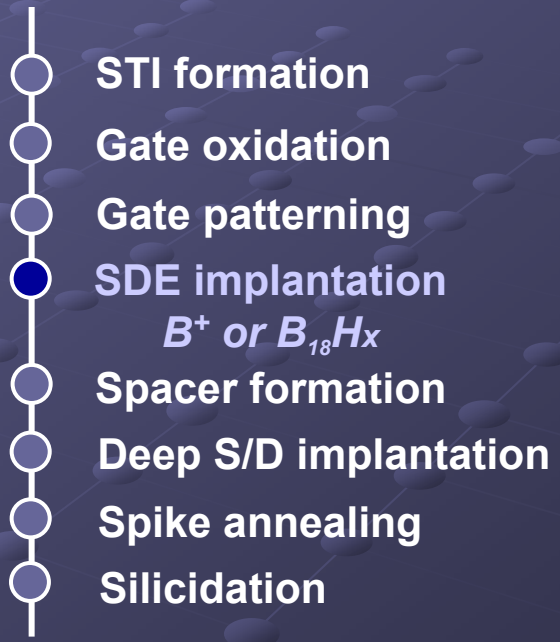


14% Improved Vth fluctuations,
that will be more pronounced in 300mm wafers

new thinking
SemEquip

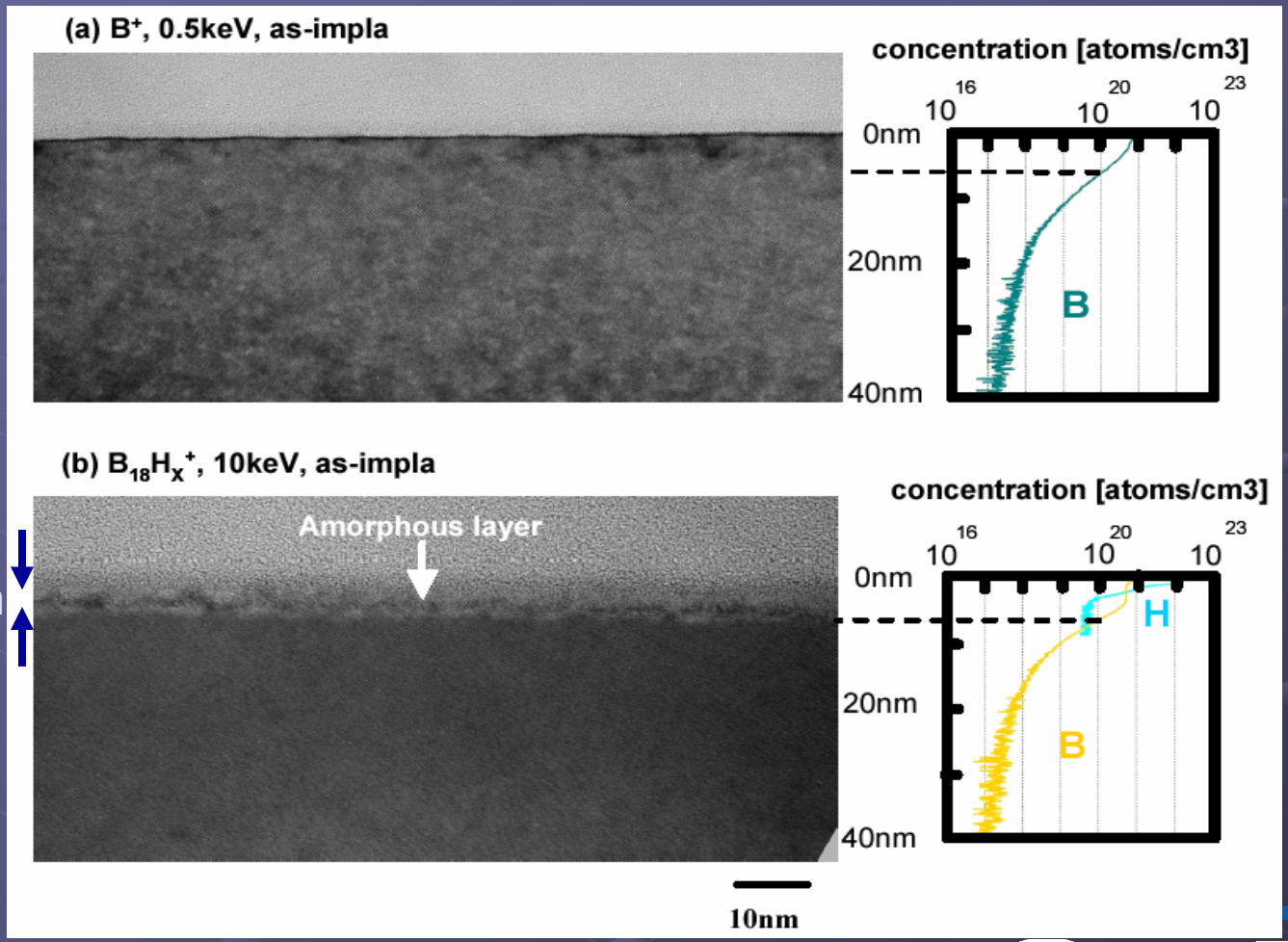
Device Data Review: Renesas

- Devices fabricated at Renesas, Itami, Japan
- ClusterBoron implant used for PMOS Drain Extension
- ClusterBoron implant performed on SemEquip demo tool: GSD112
- **Results show ClusterBoron as good or better than the Process of Record**
- Results presented at IIT 2004 & IWJT 2005



new thinking SemEquip

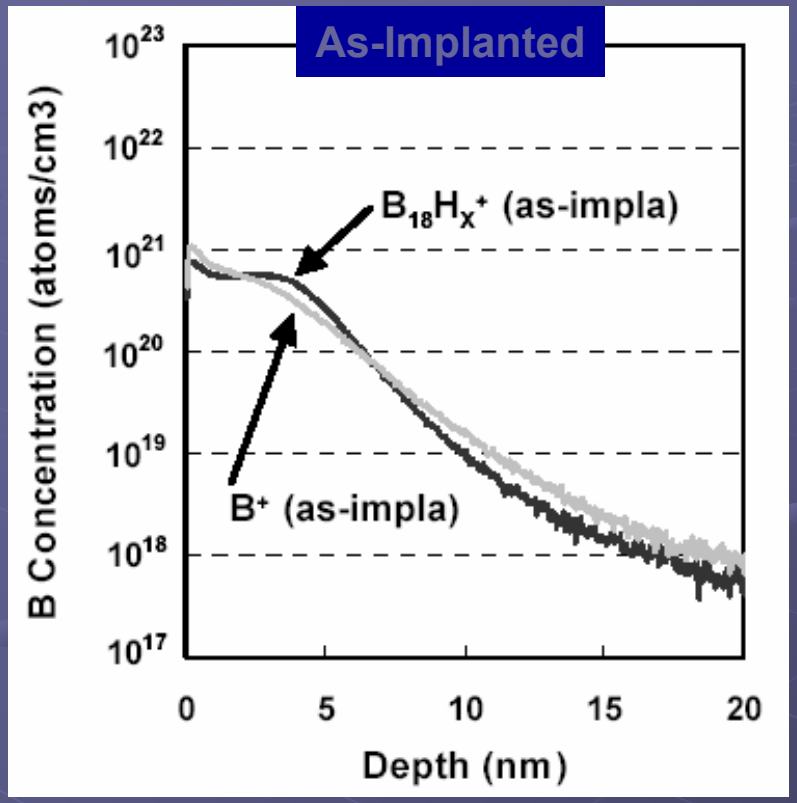
TEM of Self Amorphization with $B_{18}H_{22}$

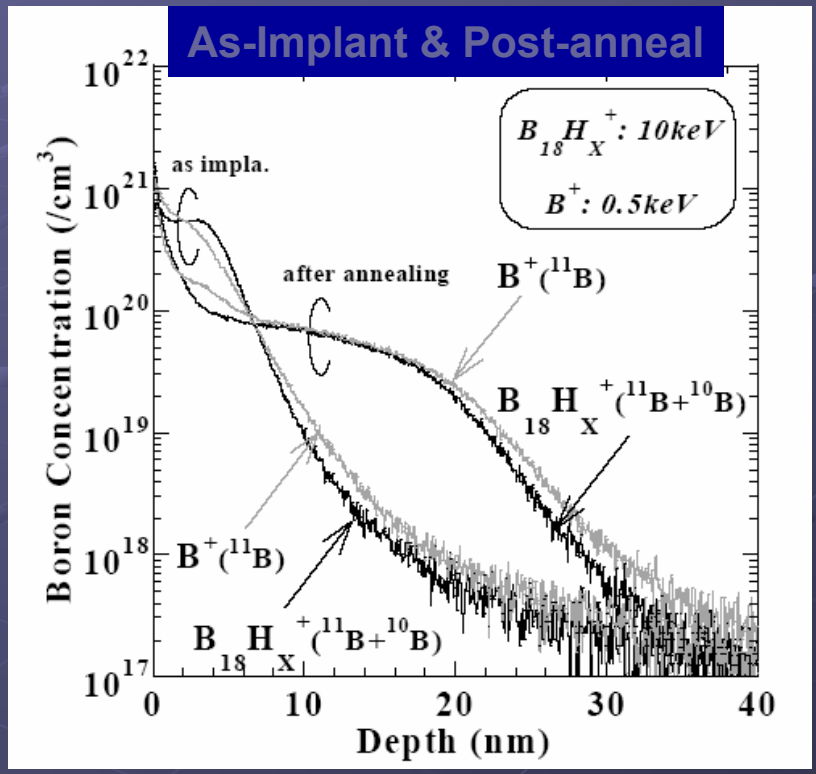


Renesas, IWJT2005

new thinking
SemEquip

SIMS 500eV ClusterBoron *vs.* B^+



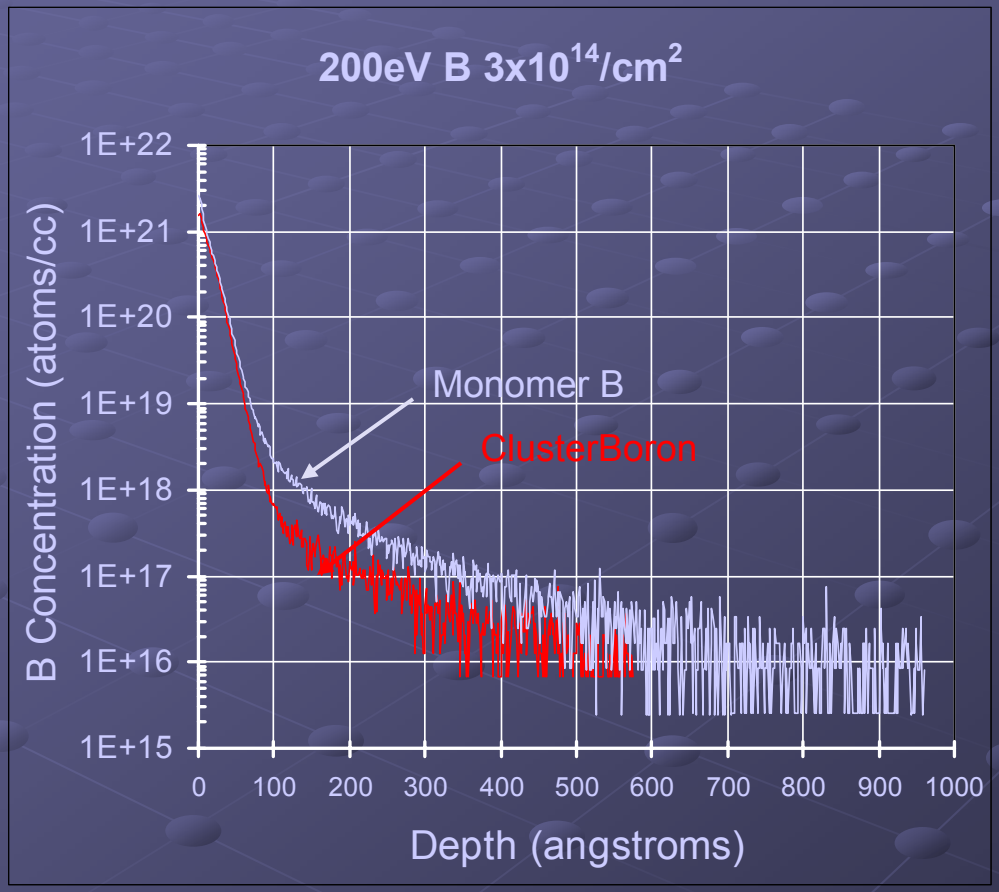


Steeper and Shallower profile achieved by Self-Amorphization

Renesas, IIT2004 & IWJT2005

new thinking SemEquip

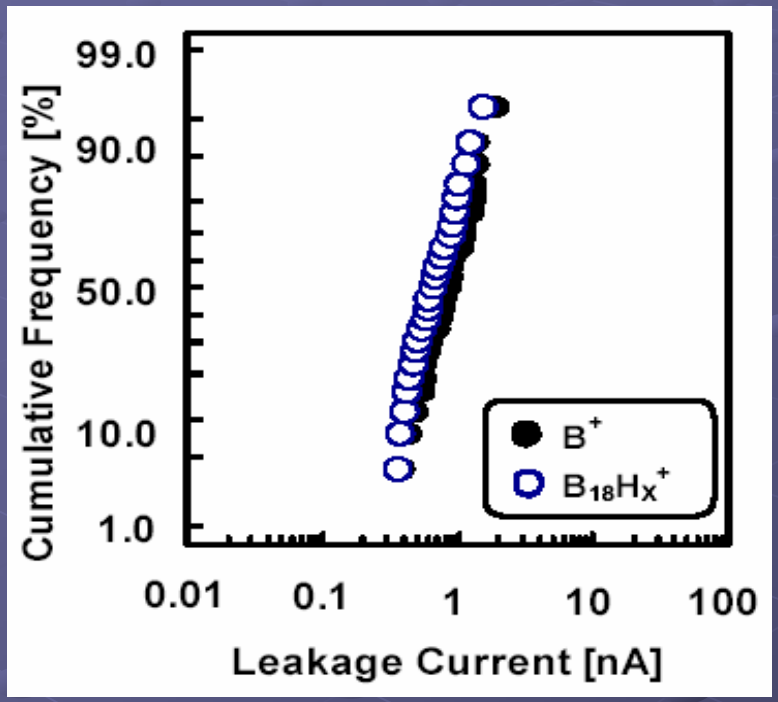
SIMS 200eV ClusterBoron *vs.* B

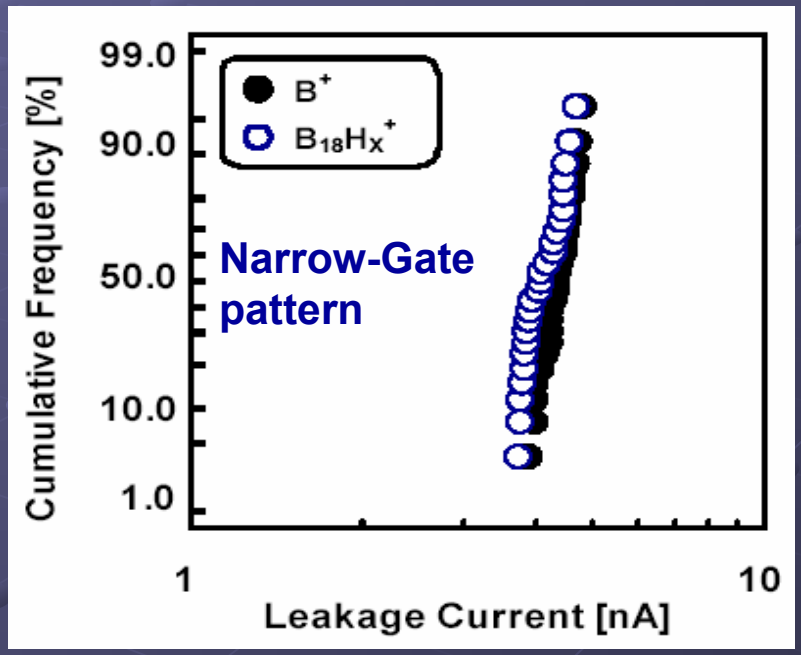


new thinking
SemEquip

Junction Leakage Current

Renesas, IWJT2005





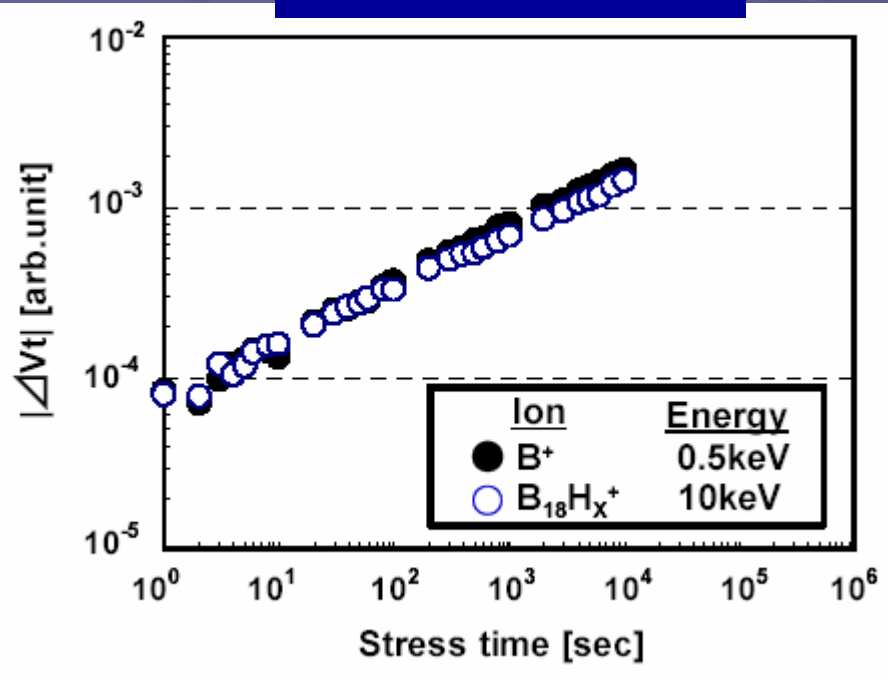
No Adverse effects in both Si Crystal junctions and Gate oxide edge

new thinking SemEquip

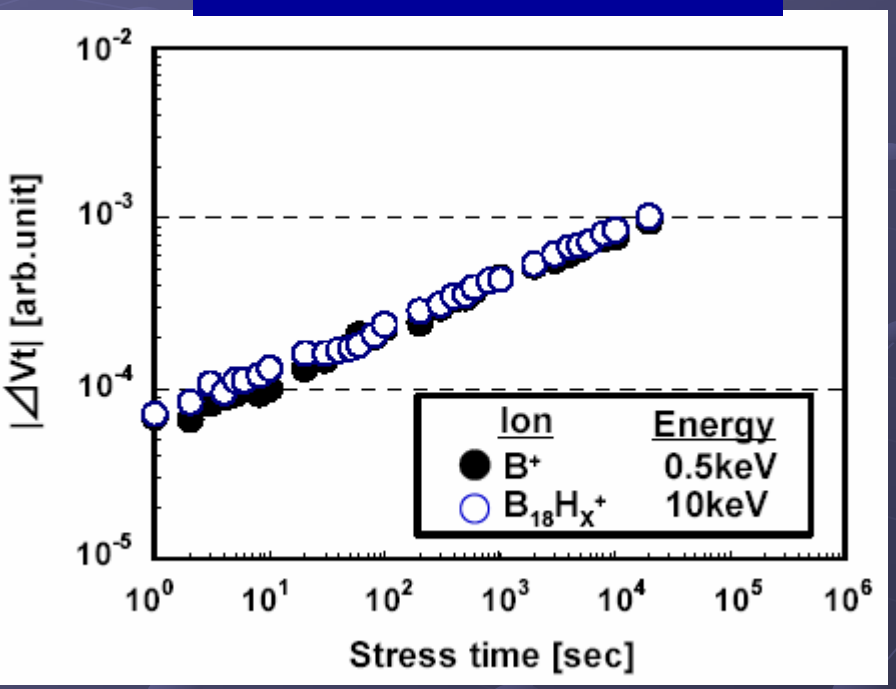
Gate Oxide and Hot Carrier Reliability

Renesas, IWJT2005

NBTI induced Vt shift



Hot carrier-induced Vt shift

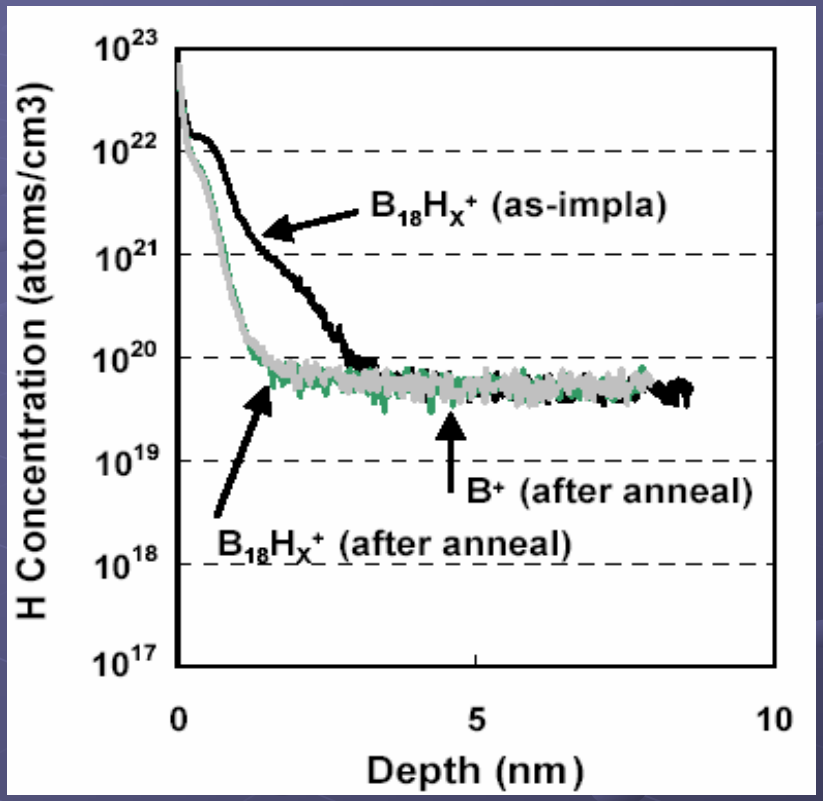


No degradation found in PMOS reliability by hydrogen in $B_{18}H_{22}$

new thinking SemEquip

Hydrogen Profile

Renesas, IWJT2005



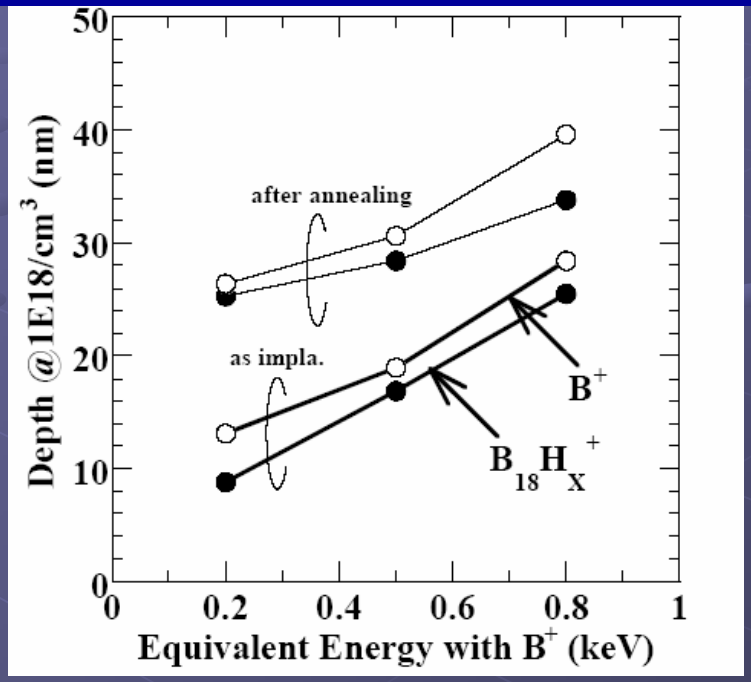
Hydrogen completely diffuses out at annealing

new thinking SemEquip

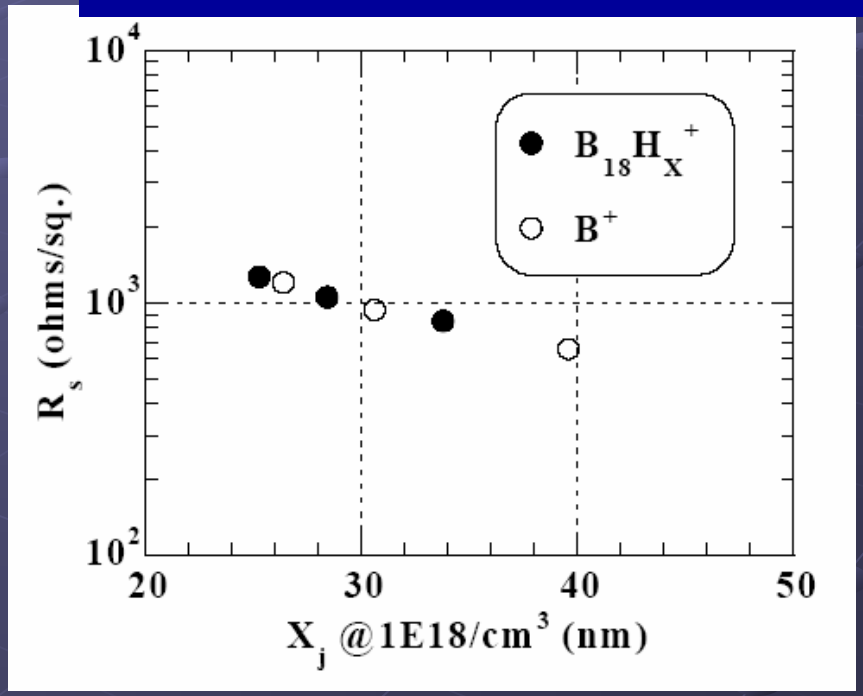
Junction Depth & Sheet Resistance

Renesas, IIT2004

Implant depth, showing shallower profile from ClusterBoron



Junction depth *vs* sheet resistance, annealed ClusterBoron *vs*. B

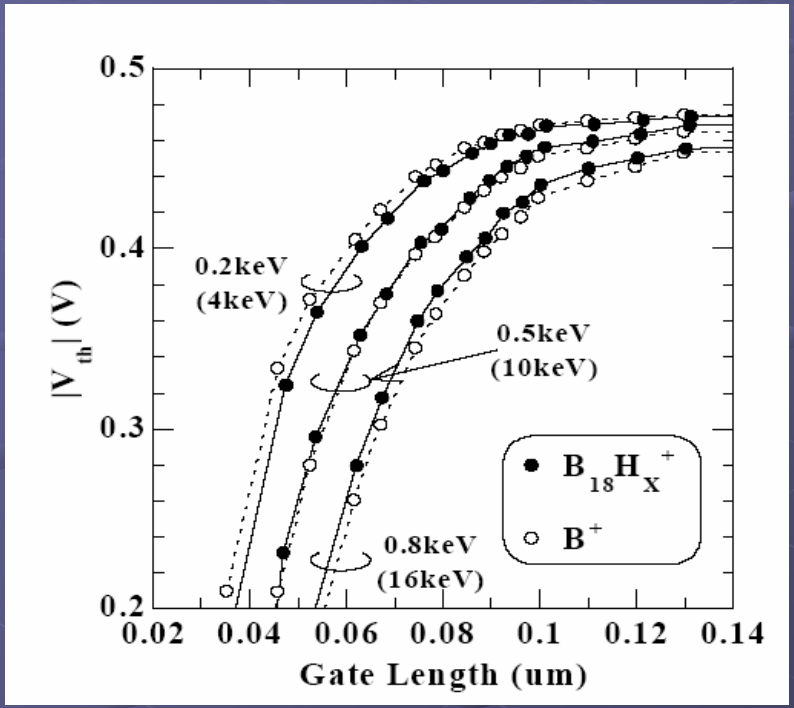


new thinking SemEquip

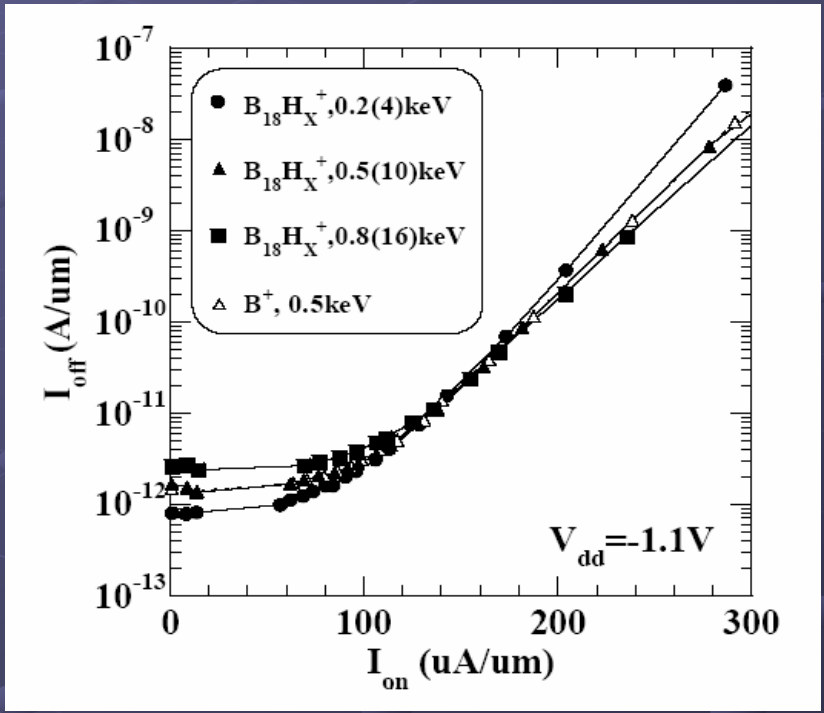
pMOSFET Transistor Characteristics

Renesas, IIT2004

V_{th} roll-off characteristics



I_{on} - I_{off} characteristics



new thinking SemEquip

Summary

- The use of $B_{18}H_{22}$ and $B_{10}H_{14}$ in conventional implanters dramatically increases throughput for p+ USJ process
  - Reduces cost per implanted wafer
  - Dramatically improves beam quality at wafer
  - Reduces Vth variation due to non-uniform device shadowing effects caused by poor beam angular profiles
  - Self-amorphization obviates the need for the pre-amorphization implant, further reducing processing costs
- ClusterIon® technology is fully compatible with existing HC and MC tool architectures
  - Front end process remains unchanged
  - Enables MC platforms to “cross over” to HC recipes as single-wafer HC implanter
  - New Universal Ion Source™ delivers ClusterBoron™ and As_4 process as well as traditional HC and MC beams

new thinking SemEquip