Engineering Research Center (ERC)
TeleSeminar, May 26, 2005

Novel Subatmospheric Pressure Gas Sources For Ion Implanters

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Novel Subatmospheric Pressure Gas Sources For Ion Implanters

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Sub-atmospheric Gas Delivery Options – SAGS recognized in US Fire Codes for increased Safety

Jan. 6, 2005

Gas adsorbed on a solid

- Gas is adsorbed onto a solid. It is able to be withdrawn when a vacuum (negative pressure relative to the surroundings) is applied to the cylinder

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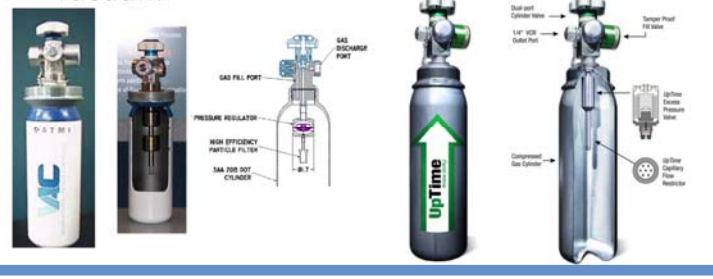
Jan. 6, 2005

Mechanical

- **Contained gas under pressure, able to be withdrawn only by the application of vacuum**



Jan. 6, 2005

Gas complexed with a liquid

- Gas is complexed (chemically bound) with a liquid. It is only able to be withdrawn by the application of vacuum. The system is analogous to one where gas is adsorbed onto a solid.

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Jan. 6, 2005

Gas Generator

- Generates gas to be delivered under vacuum on demand using an electric current.

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Introducing GASGUARD® Sub-Atmospheric Systems (SAS)

- **Program Goal: Develop alternate Ion Implant gas feed systems which meet or exceed current delivery methods and safety to provide customers with sourcing options**
- **GASGUARD® SAS - Complexed Gas Technology (CGT)**
  - **Ion Implant Grade PH_3, BF_3, and $^{11}BF_3$**
  - **Initial Ion Implant Grade PH_3 beta test successfully started on an Axcelis NV High Energy ion implanter**
  - **Customers actively qualifying this technology**
- **GASGUARD® SAS - Generated Gas Technology (GGT)**
  - **Ion Implant Grade AsH_3 has been successfully tested on an Applied Materials 9500 ion implanter for over 1 year**
  - **Customers actively qualifying this technology**

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GASGUARD® Sub-Atmospheric Systems (SAS) - Complexed Gas Technology

- **Gas is complexed (chemically bound) with a liquid. It is only able to be withdrawn by the application of vacuum. The system is analogous to one where gas is adsorbed onto a solid.**
- **Plug and Play for existing sub-atmospheric gas supply systems**

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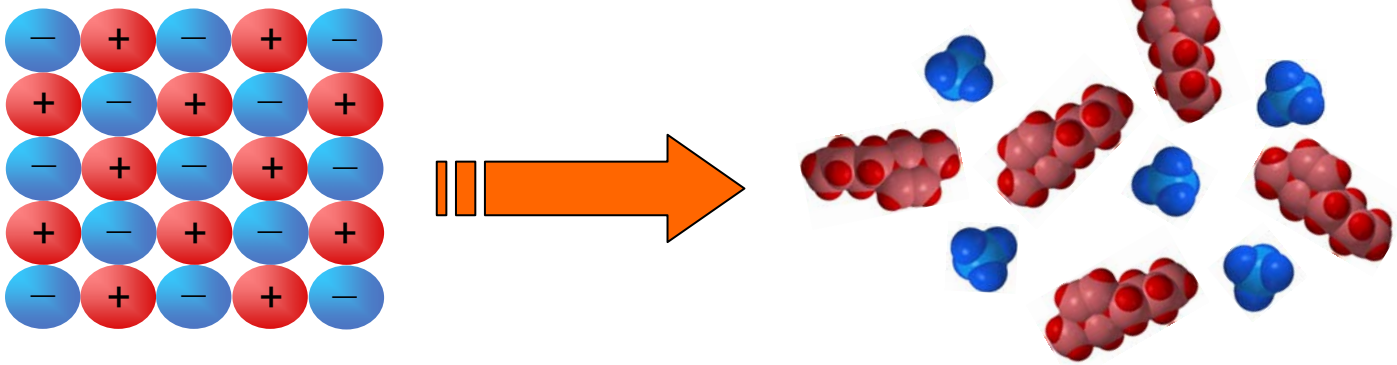
Complexed Gas Technology Unique Properties

Uses New Field of **Room Temperature IONIC LIQUIDS**

Pending US Patent, Publ.No.US# 2004/0206241 & Patents Pending



Like a conventional Salt (e.g. NaCl)…

- **No measurable vapor pressure**
- **Non-flammable**
- **Chemically and thermally stable**

but with unique benefits!

- **Customizable gas interaction**
- **Wide liquid temperature range**
- **Rapid gas and heat transport**

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Ionic liquids are a new and expanding technology

- **A new class of environmentally friendly solvents**
- **Exponential growth in research since late 1990s**
- **Recyclable "Green" solvents with essentially zero vapor pressure**
- **Limitless number of potential ion combinations**
- **Used as a solvent in chiral synthesis of pharmaceutical and fine chemicals**

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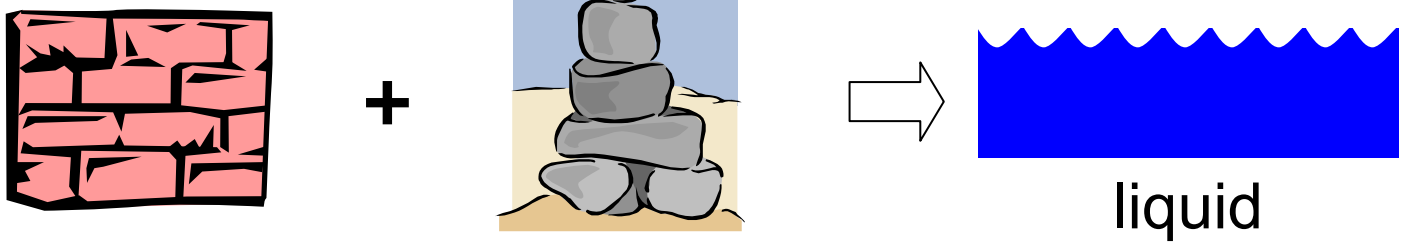
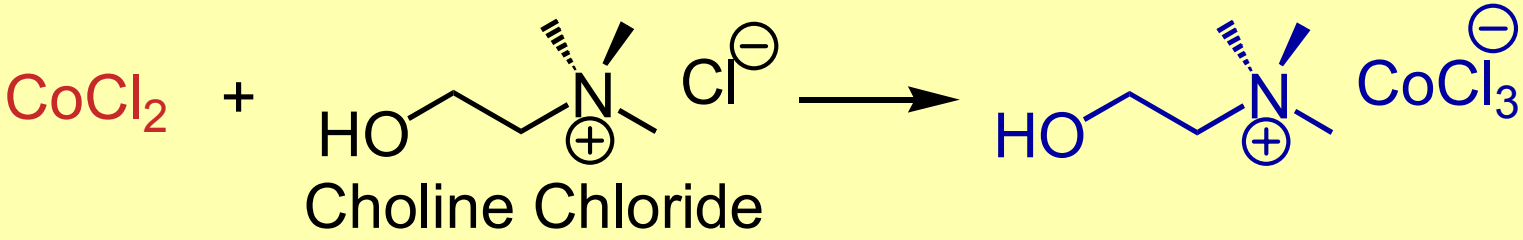
Typical example of an ionic liquid





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Complexed Gas Technology Safety Design Features

- **Intrinsic safety of sub-atmospheric pressure**
  - **Passive system, no moving parts**
  - **Pressure <650 torr at 25 °C**
- **MAWP = 2015 psig**
  - **> purge gases**
- **Membrane eliminates liquid passage**
- **Ionic liquid adds no other hazards**
  - **Non-flammable**
  - **Not-reactive with other gases**
  - **No measurable vapor pressure**
- **Complies to SEMI S-2 and SEMI S-10 standards**

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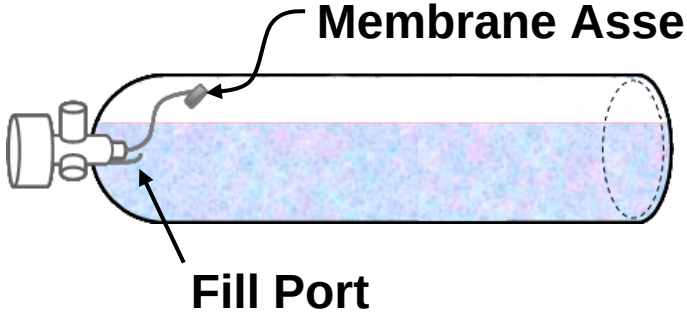
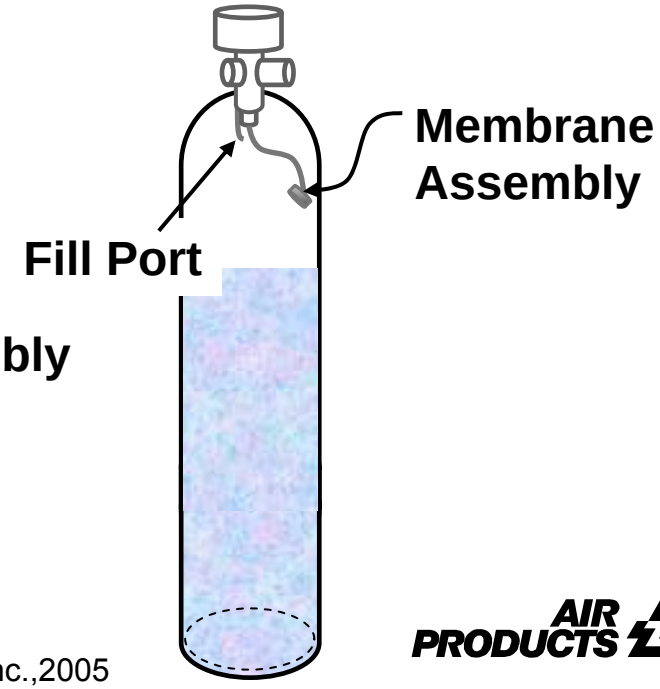
Complexed Gas Technology Unique Mechanical Design

- **Only desired gas is delivered**
  - **A liquid separator prevents reactive ionic liquid from escaping, submerged or entrained droplets**
  - **Short, curved dip tube**
  - **Works with vertical or horizontal orientation**





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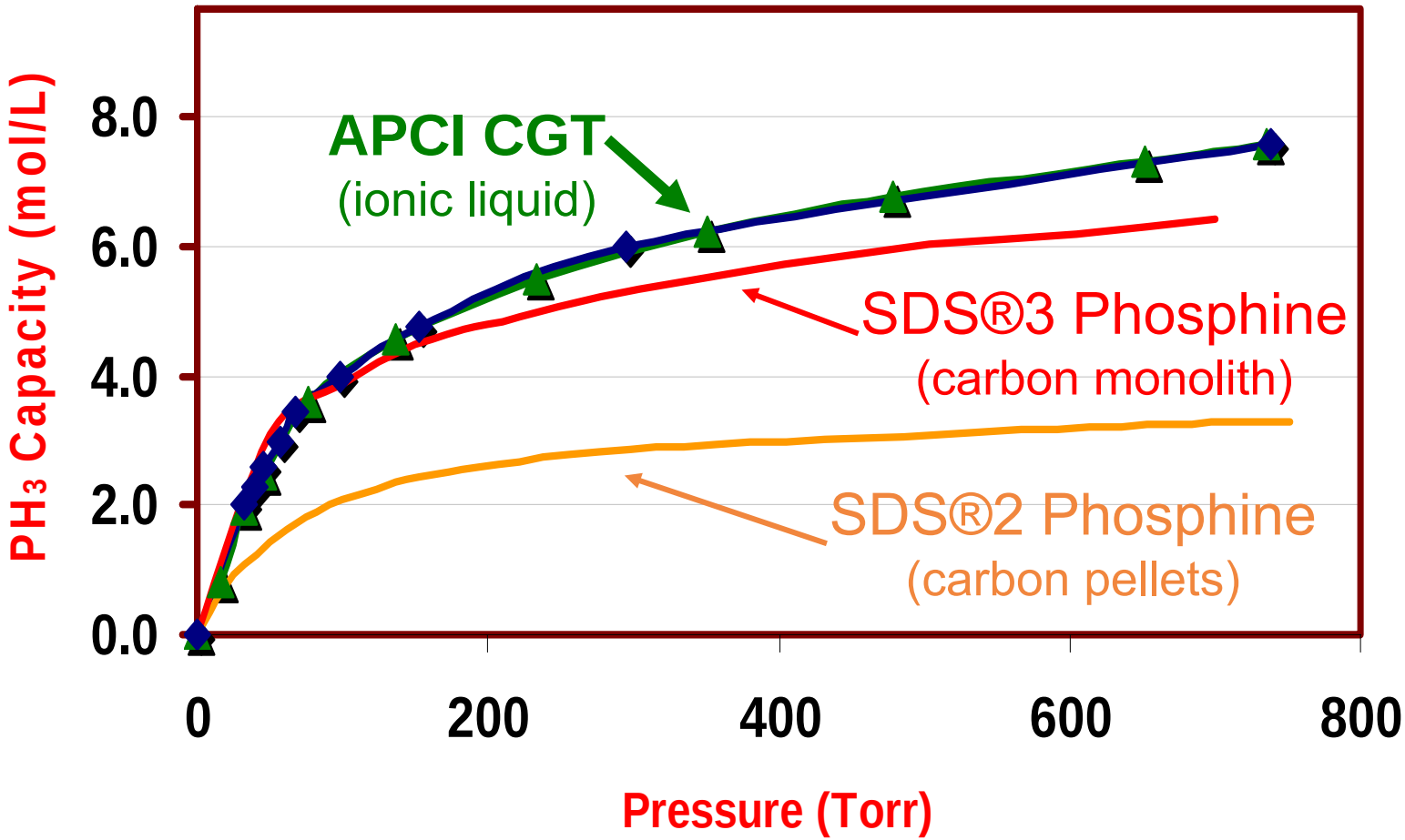
Complexed Gas Technology PH_3 Equilibrium Capacity



***SDS®2 Phosphine and SDS®2 Phosphine are registered trademarks of Matheson Tri-Gas and ATMI. Capacity data for SDS®2 Phosphine and SDS®2 Phosphine are from US Pat. No. 5,518,528 and US Pat. No. 6,743,278B1.**

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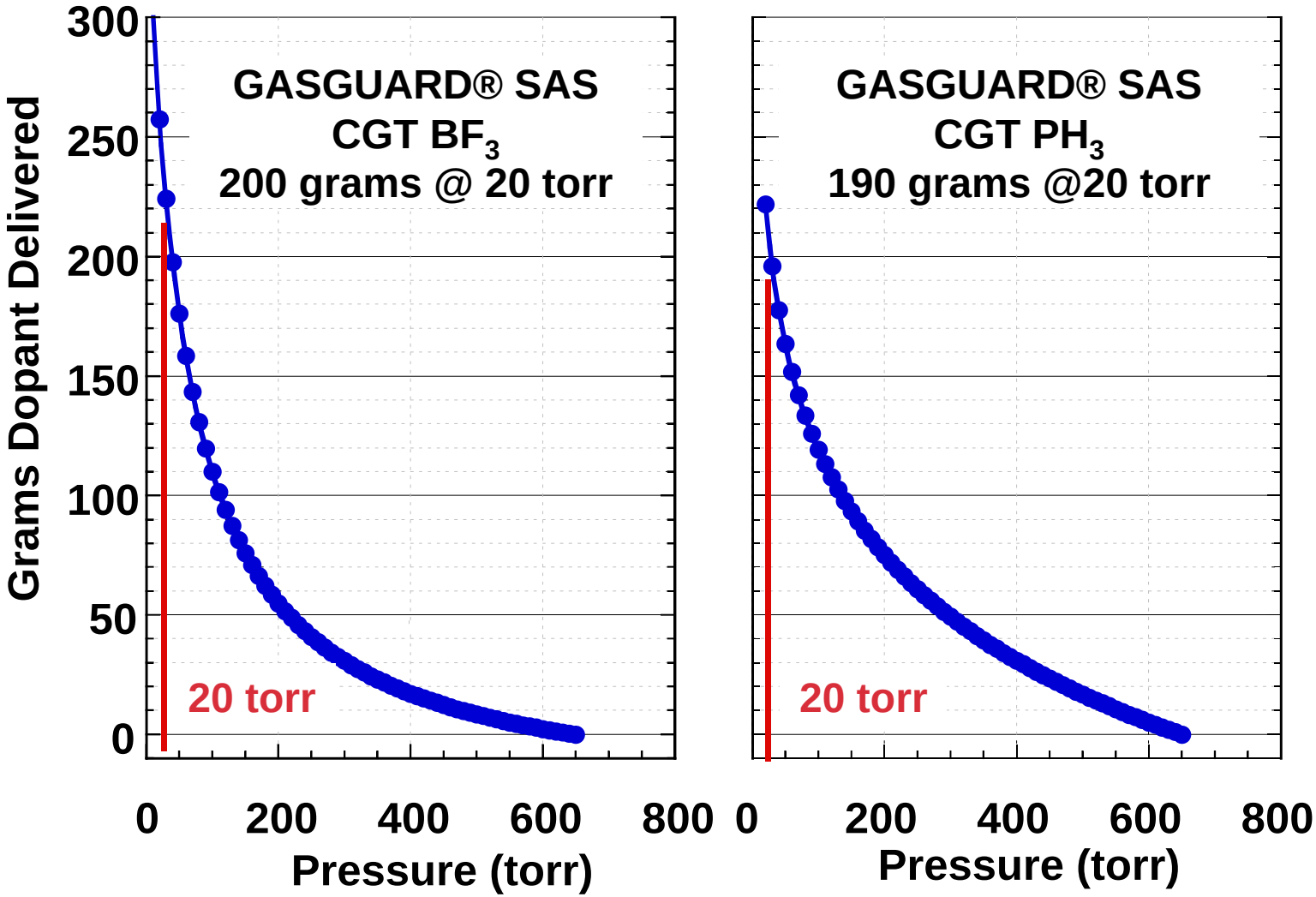
Complexed Gas Capacity profiles for an X2S – 2.2 liter cylinder



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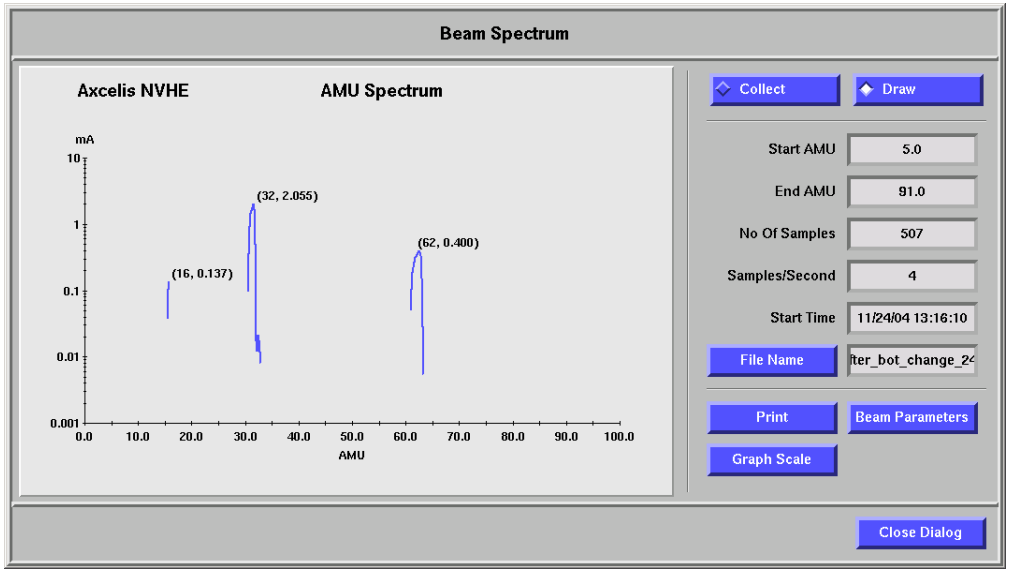
Complexed Gas Performance Validated on an Axcelis NV High Energy Ion Implanter



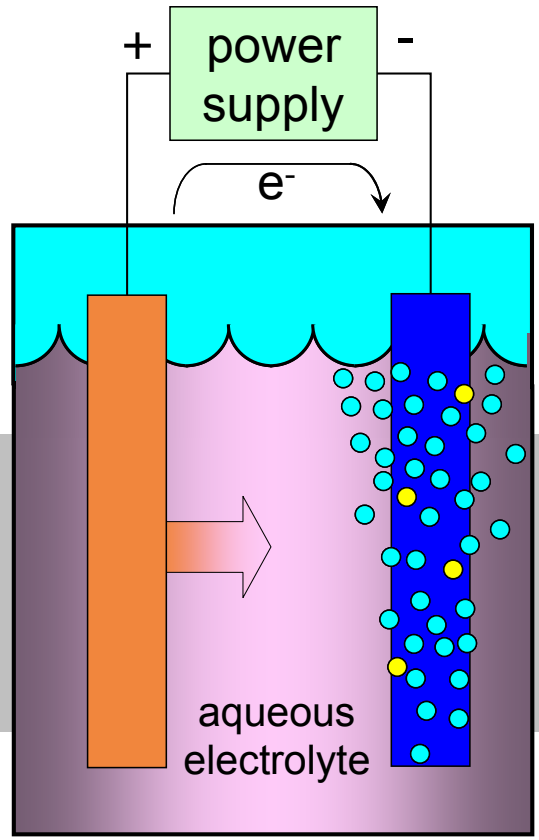
Contaminant	GASGUARD® SAS Phosphine	SDS®2 Phosphine Control
Fe	$<1.0 \times 10^{10}$ cm^{-2}	$<1.0 \times 10^{10}$ cm^{-2}
Cu	$<1.5 \times 10^{10}$ cm^{-2}	$<1.5 \times 10^{10}$ cm^{-2}
Ni	$<1.0 \times 10^{10}$ cm^{-2}	$<1.0 \times 10^{10}$ cm^{-2}
Cr	$<2.0 \times 10^{10}$ cm^{-2}	$<2.0 \times 10^{10}$ cm^{-2}
Na	3.6×10^{10} cm^{-2}	3.2×10^{10} cm^{-2}
Zn	0.5×10^{10} cm^{-2}	5.4×10^{10} cm^{-2}
Ca	$<2.0 \times 10^{10}$ cm^{-2}	10.5×10^{10} cm^{-2}
Al	$<1.5 \times 10^{10}$ cm^{-2}	9.9×10^{10} cm^{-2}
Fe	0.5×10^{10} cm^{-3}	1.0×10^{10} cm^{-3}
Diffusion length	472 μ	430 μ

VPD-ICP-AAS Vapor Phase Decomposition Inductively Plasma Coupled Atomic Absorption Spectrometry data

SPV Surface Photo Voltage

GASGUARD® Sub-Atmospheric Systems (SAS) - Generated Gas Technology

- **Generates gas under vacuum on-demand using an electric current**
- **US Patent No. 5,158,656 and Patents Pending**



Anode = sacrificial metal

Cathode = arsenic containing electrode

$M \rightarrow M^{n+} + n\ e^-$

$As + 3\ H_2O + 3e^- \rightarrow AsH_3 + 3\ OH^-$

$2\ H_2O + 2e^- \rightarrow H_2 + 2\ OH^-$

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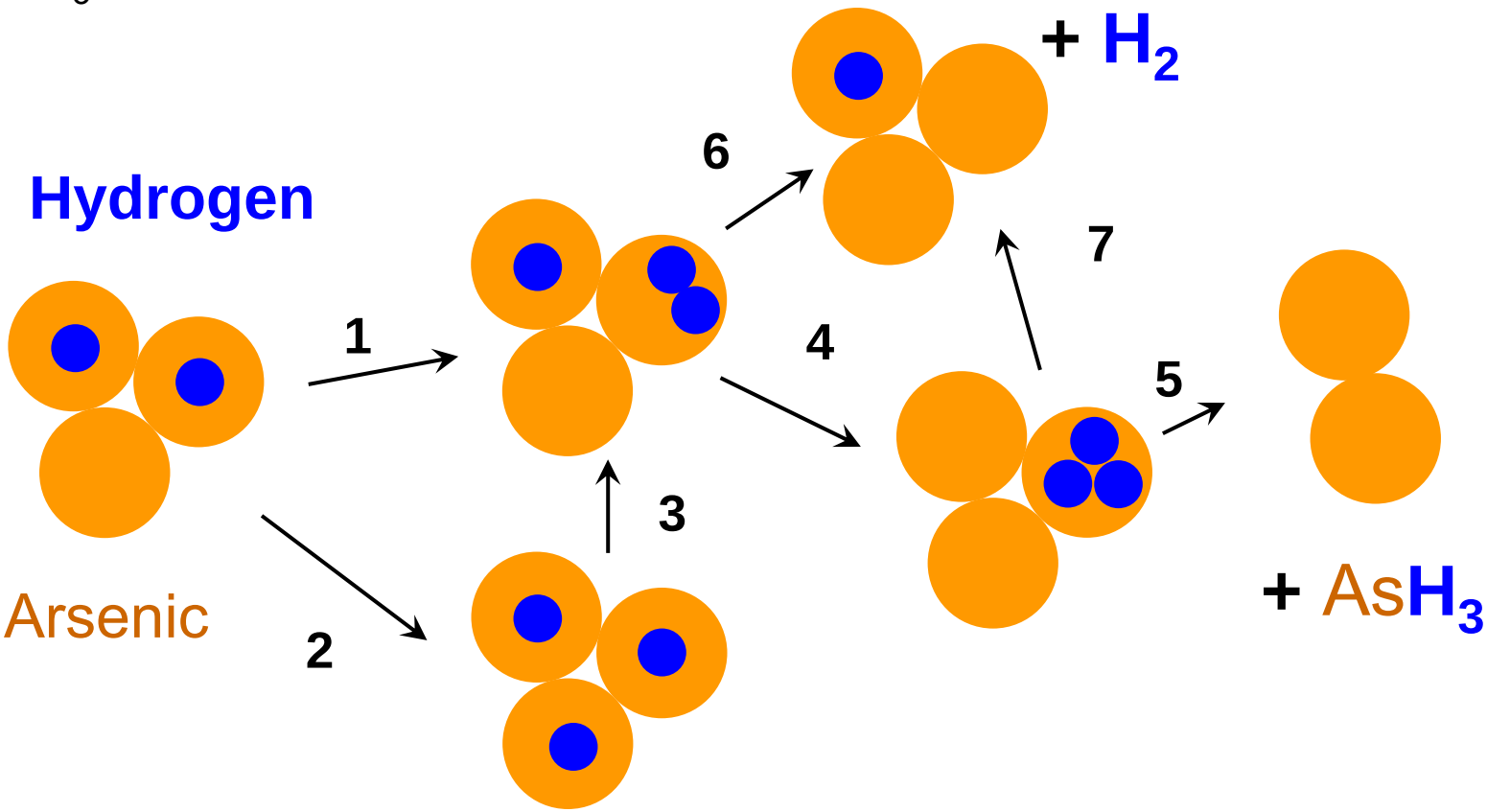
Arsenic hydride disproportionation is key to high arsine yields

H_2 is the thermodynamically favored but
AsH_3 can be made >90% if kinetics are controlled



J. Elect. Soc. Vol 107, pg. 348-353 April 1960

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Generated Gas Technology Intrinsic Safety Design features

- **Arsine inventory is minimized**
  - **0 grams during shipping**
    - **Can be air freighted**
    - **No AsH_3 volume restrictions during storage**
  - **1 gram AsH_3during operation**
    - **Produced on-demand at a constant 400 torr with rates between 0 and 10 sccm**
- **Generator sub-atmospheric during storage and operation**
  - **Minimizes exposure and accidental release**
  - **Subatmospheric at elevated temperatures**
  - **Subatmospheric in high-elevation Fabs**
- **Reduced change-outs: high capacity and robust design**
  - **2 liter generator delivers 660 grams AsH_3**
  - **Capacity gauged to avoid early change-out**
  - **If contaminated with purge gas, generator can be evacuated and restarted with out change-out**
  - **MAWP = 160 psig > purge gas supply**

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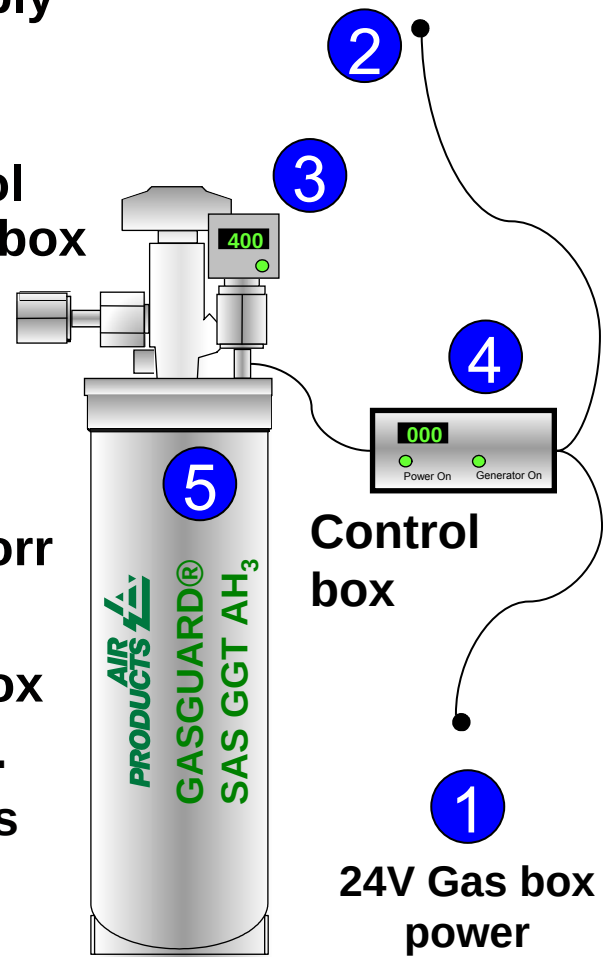
5 levels of instrumented safety

1. **Operating power interface**: Control box tied into available gas box 24VDC supply
   - Interfaces with implanter safety systems
2. **Pneumatic interface**: Pneumatic control line from the gas feed valve to control box
   - Power off when gas demand stops
   - Interfaces with implanter safety systems
3. **Pressure controller**: On generator maintains pressure between 405-410 torr
   - Power off if P > 410 torr
4. **Watch-dog timer**: Located in control box
   - Power off if current is “on” >90 min.
   - Typical operation for 2 sccm AsH_3 is 1-2 min.“on” and 6-12 min. “off”
5. **Over-pressure switch**: Built into generator
   - Power off if P > 1 barg



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Safety Design and Documentation

- **GASGUARD® SAS GGT adheres to the requirements set by the European Pressure Equipment Directive 97/23/EC**
  - **Designed in accordance with SOUND ENGINEERING PRACTICE (ASME BPV code Section VIII, division 1, July 2001 Edition with Addenda; supplemented by PD5500:2003 Amendment 1 ; ASME BPV code case 2211)**
- **Electronics system is CE marked**
- **Complies to SEMI S-2 and SEMI S-10 standards**

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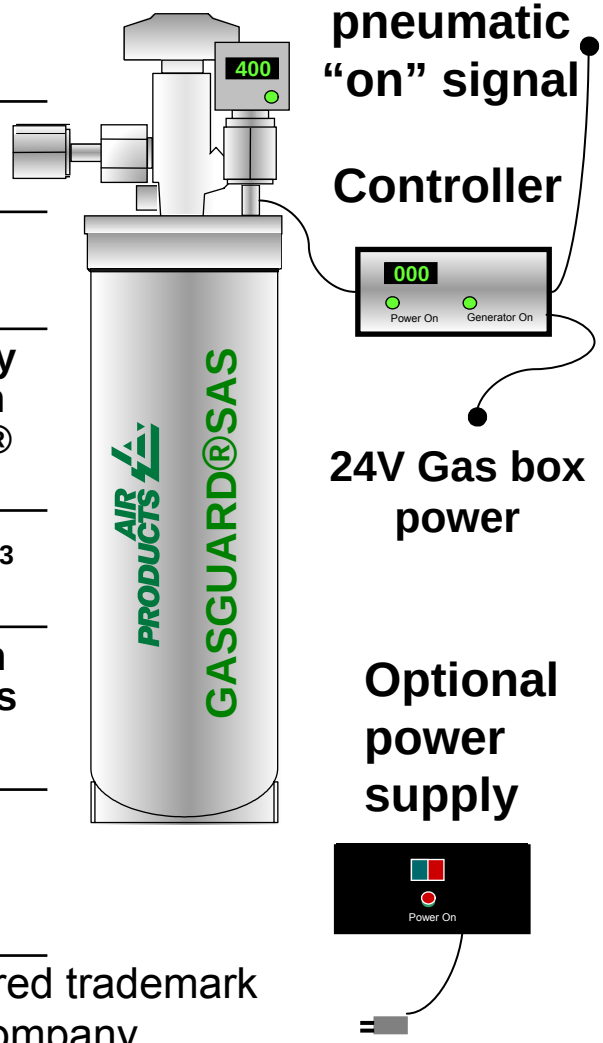
Generator specifications

Generator

size	2.2 liters
diameter	114.5 mm
height to valve	449 mm
valve	Proprietary valve with ½" *VCR ® Fitting
capacity	660 g AsH_3
rate	0-10 sccm continuous
AsH_3 mole %	93-95% (make-up H_2)

*VCR® Fitting is a registered trademark of the Swagelok Company



Controller

location	gas box
size	105 mm x 60 mm x 105 mm
input	18-36 VDC
"on" signal	air >60 psig

Optional power supply

location	transformer rack
size	105 mm x 60 mm x 125 mm
input	120-220 VAC
output	24 VDC, 2.5 A

Generated Gas Technology (GGT) Performance Validated on an Applied Materials 9500 Ion Implanter

- **Operating since February 2004**
- **Reliable service to supply 660 grams AsH_3**
- **Wafer product quality comparable to other AsH_3 sources**
  - **Stable beam currents**
  - **Successful at various recipes**
  - **No wafer or tool contamination identified**
- **No change in ion source life or operation**

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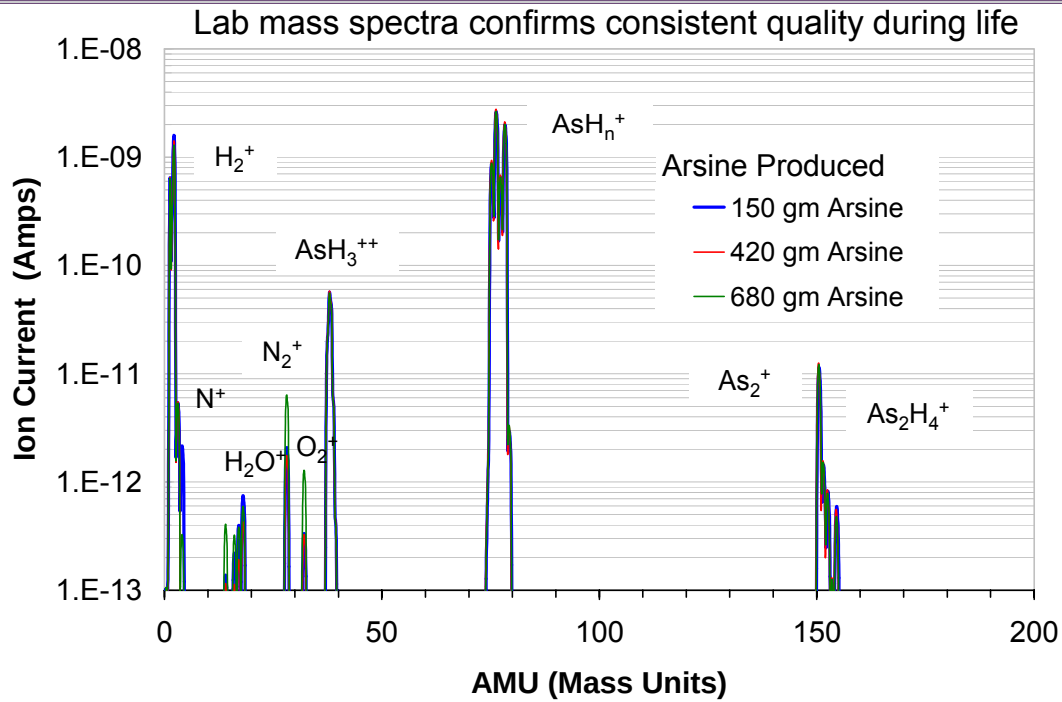
Comparisons for Generated Gas Performance and Quality



	GASGUARD® SAS AsH_3	SDS®2 AsH_3
Arsine, volume %	> 93%	≥ 99.9995%
Arsine (H_2 free basis) vol%	≥ 99.9995%	NA
Hydrogen, volume%	< 7%	NA
Oxygen, ppmv	<1.0	< 1.0
Nitrogen, ppmv	<2.0	<2.0
Carbon dioxide, ppmv	<0.5	<0.5
Carbon monoxide, ppmv	<0.1	<0.1
Methane, ppmv	<0.1	<0.5
Water , ppmv	<2.0	<2.0

SDS®2 AsH_3 specifications are from Matheson Tri-gas Product Brochure 4/03

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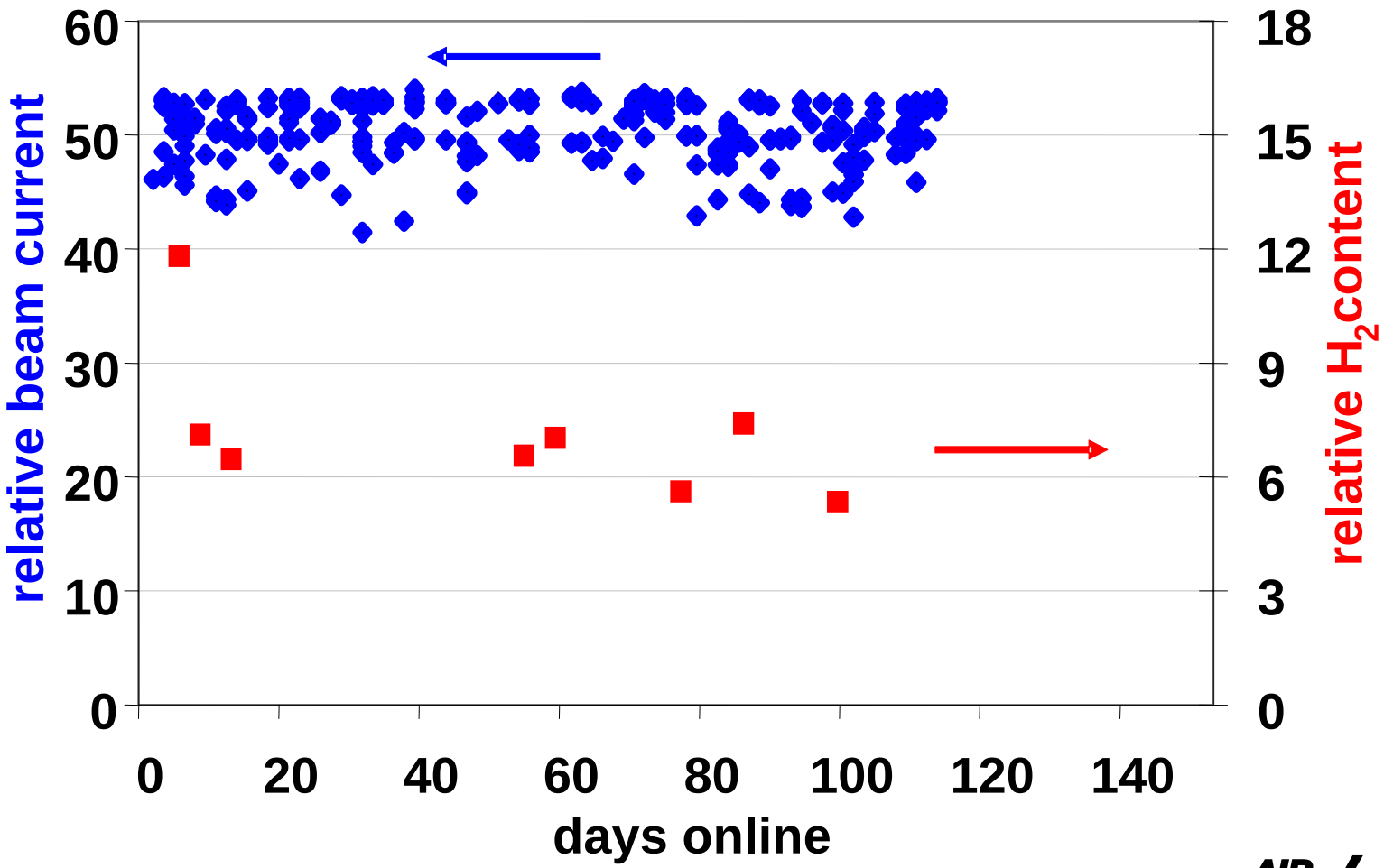
Generated AsH_3 produces stable ion beam currents comparable to other commercial AsH_3 sources



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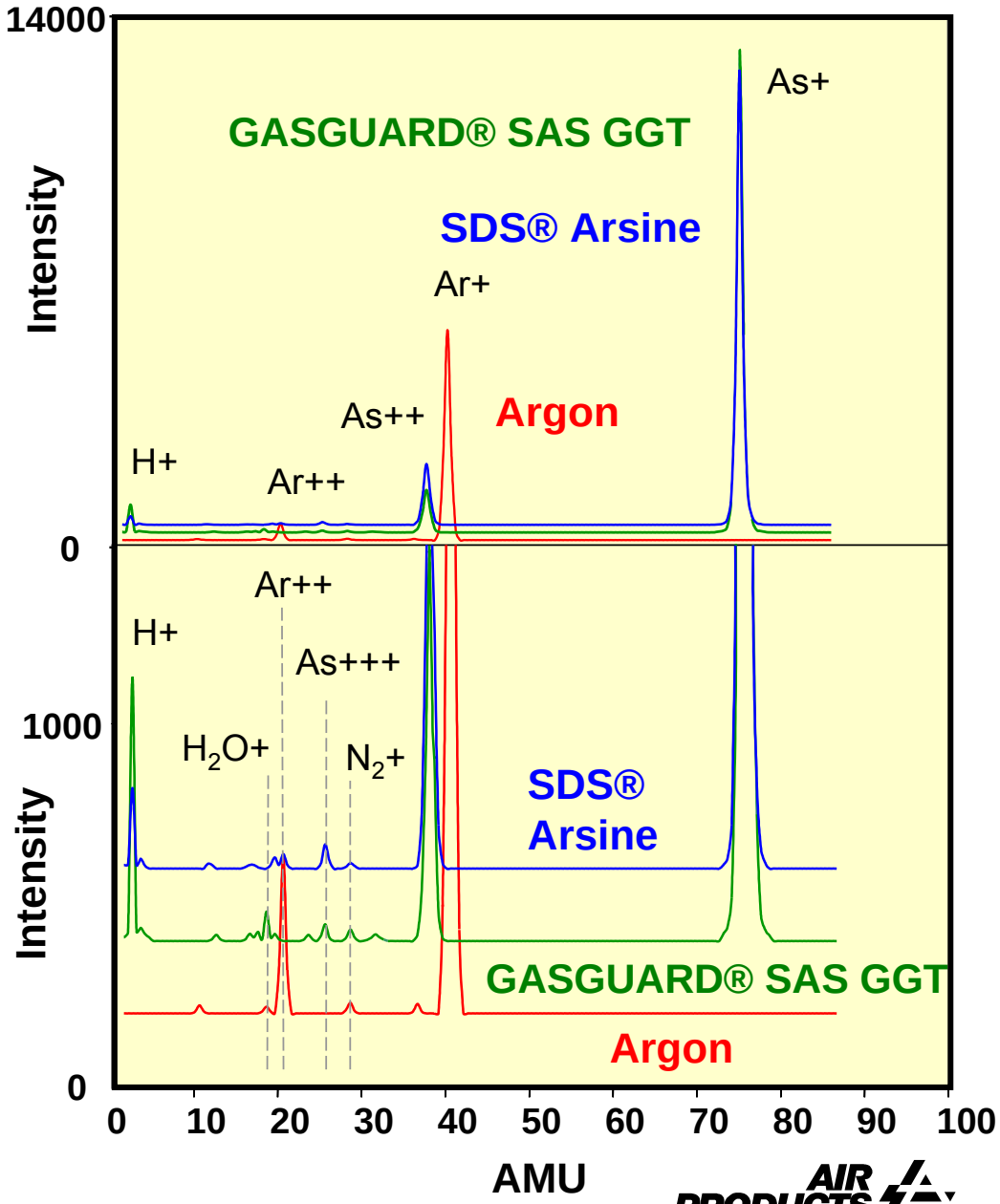
GGT Arsine mass spectra on an Applied Materials 9500 Ion Implanter compares to SDS® Arsine



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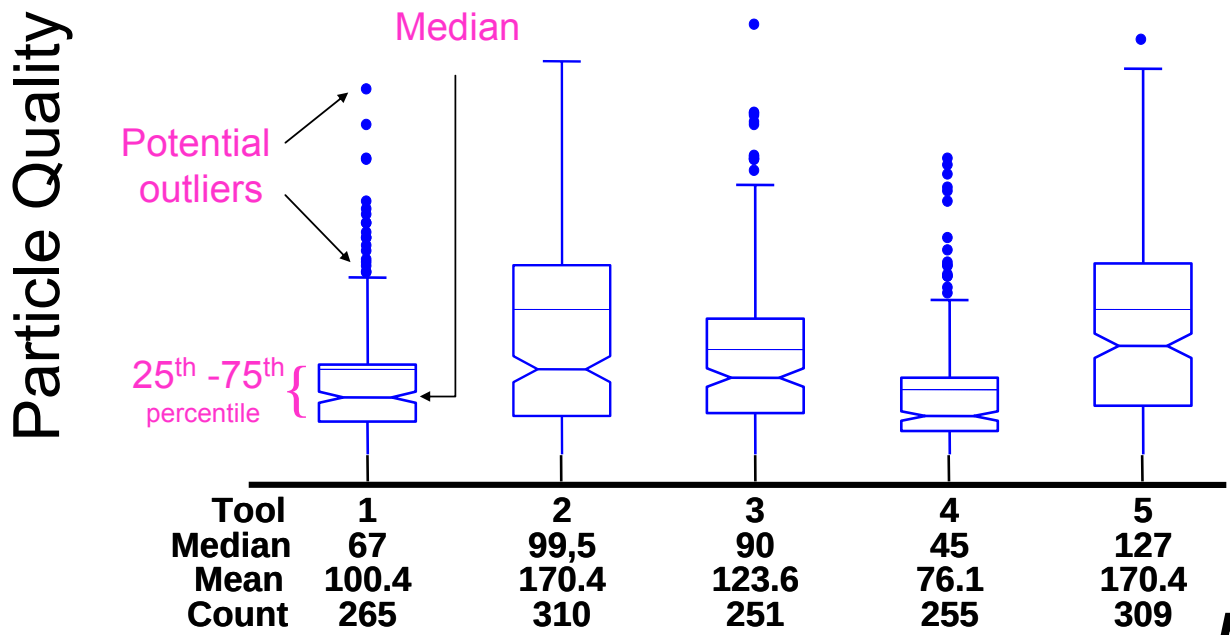
Generated Gas Technology Wafer and Particle Quality

VPD-ICP-MS Vapor Phase Decomposition
Inductively Plasma Coupled Mass Spectrometry data

Values in 1E10 atoms/cm^2	K	Na	Al	Fe	Cu	Ni	Cr	Zn
GGT Arsine	**<0.1**	**31**	**54**	**2.3**	**1.5**	**<0.4**	**0.3**	**1.4**
SDS® Arsine	**<0.1**	**42**	**160**	**2.9**	**2.8**	**<0.4**	**0.2**	**2.4**
Reference	**<0.1**	**27**	**13**	**1.5**	**<0.1**	**<0.4**	**<0.1**	**3.3**

Tool 1 running with GGT Arsine others on SDS® Arsine



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GASGUARD® Sub-Atmospheric Systems (SAS) - Available Now

- **Complexed Gas Technology:**
  - **PH_3, $^{11}BF_3$, BF_3 available as Plug and Play replacements for existing sub-atmospheric gas supply systems**
    - **2.2 L size containers**
    - **Horizontal or vertical orientation**
    - **Face-seal VCR® Fitting -compatible connections**
- **Generated Gas Technology:**
  - **AsH_3 available as replacement for existing sub-atmospheric gas supply systems**
    - **2.2 L size containers**
    - **Vertical orientation**
    - **Face-seal VCR® Fitting -compatible connections**
    - **Requires minor modifications for first time electrical installation connections**

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