



## Sub-atmospheric Gas Delivery Systems

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## Tony Kao



Tony Kao graduated from the National Tsing Hua University with a PhD degree in Engineering and System Science. He served Promos Technologies for 5 years and held different positions in diffusion and R&D departments. Tony specializes in selective epitaxial growth (SEG), spin on dielectrics (SOD), counter-doping for dual work function (DWF), and development of 3D IC memory.

In 2008, Tony joined Praxair Electronics as a Product Development Manager covering the Asia region. He's been immensely involved in the commercialization, technical development, and customer adoption of Praxair UpTime® Dopant Gas System. He is also now in charge of UpTime® sales in Asia.

Tony has more than 20 technical journal publications and holds 2 US and 4 TWN patents.

## Praxair Overview

- One of the world's largest industrial gas companies

- 2012A rev US\$11.2B
- Business in more 50 countries
- Over 26,000 employees

- US\$1.0B Electronics business

- Bulk and onsite gas plants
- Packaged process gases
- Gases analytical and delivery systems
- Sputter targets, ALD precursors

- Focused on growth in Taiwan

- UpTime™ manufacturing
- Precision mixture manufacturing
- Bulk and cylinder gases transfill
- Research and Development team



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## Source Material Requirement

Gas sources are desirable for implant because of ease of use relative to solid sources

- Productivity
- Handling

Hazardous nature of most source gases and location inside the tool and fab requires important consideration of their storage and delivery

- Need a storage and delivery system that provides:
  - Safety
  - Excellent product quality over life of package
  - Stable flow behavior
  - Good productivity, compatible tool integration
  - Low cost of ownership

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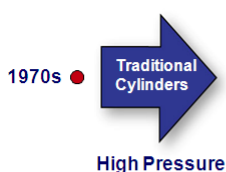
## Source Material Requirement

Dopant Species	Source Material*	Application	Toxicity (TLV-TWA)
As	AsH <sub>3</sub> , AsF <sub>5</sub>	N-type doping	AsH <sub>3</sub> - 50ppb
B	BF <sub>3</sub> , <sup>11</sup> BF <sub>3</sub> , B <sub>2</sub> H <sub>6</sub>	P-type doping	BF <sub>3</sub> – 1ppm, B <sub>2</sub> H <sub>6</sub> 0.1ppm
P	PH <sub>3</sub> , PF <sub>3</sub>	N-type doping	PH <sub>3</sub> – 0.3ppm, PF <sub>3</sub> 1ppm
Ge	GeF <sub>4</sub> , <sup>72</sup> GeF <sub>4</sub>	PAI	HF – 0.5ppm
C	CO, CO <sub>2</sub>	USJ	CO – 25ppm
Si	SiF <sub>4</sub>	RSD	HF – 0.5ppm

\*Includes only gaseous/liquefied gas source materials

## Evolution of Gas Delivery Systems

➤ Traditional cylinders initially used for delivery of source materials in implantation... inside the fab



➤ Displaced by “sub-atmospheric” gas delivery systems with improved safety and productivity benefits.



- Adsorbent type systems initially introduced in 1990s

- Mechanical type introduced in 2000s

- Generator and alternative adsorbent types also introduced in 2000s



## Sub-Atmospheric Gas Systems (SAGS)



### ◆ Overview

#### ➤ Adsorption Technology

- Based on adsorption/desorption of gas from a solid or liquid support/medium
  - Carbon and ionic liquids ("sponge"-like)
  - Reversible
  - Provides sub-atmospheric storage but may exhibit positive pressure due to temperature and pressure dependent nature

#### ➤ Mechanical Technology

- Based on mechanical regulator or check-valve inside cylinder that provide sub-atmospheric flow only when downstream vacuum applied
- Products stored at natural compressed state
- Temperature and pressure independent

## Sub-Atmospheric Gas Systems (SAGS)



### ◆ Overview

#### ■ Sub-atmospheric Definitions (NFPA 2009):

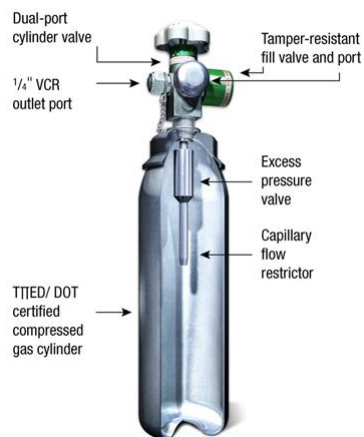
- Type 1: Gas source package that stores and delivers gas at sub-atmospheric pressure and includes a container (eg gas cylinder and outlet valve) that stores and delivers gas at a pressure of less than 14.7psia at NTP
- Type 2: Gas source package that stores compressed gas and delivers gas sub-atmospherically pressure and includes a container (eg gas cylinder and outlet valve) that stores gas at a pressure greater than 14.7psia at NTP and delivers gas at a pressure less than 14.7psia at NTP

#### ■ Facility Controls Requirements: essentially identical with minor differences

- SAGs provide significant improvement in overall safety for implant gas application
- However, SAGs still involve toxic gases so best industry EH&S practices and controls for risk mitigation to personnel and facility should apply

## A black and white photograph showing the silhouettes of several runners crossing a finish line. The runner in the foreground is celebrating with arms raised. The background is a bright, hazy sky.

## Mechanical “Type 2”



9.

## A black and white photograph showing the silhouettes of several runners crossing a finish line. The runner in the foreground is celebrating with arms raised. The background is a bright, hazy sky.

## Multiple safe reliable designs

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- Diagram illustrating the components of a DOT certified compressed gas cylinder:
- Dual-port cylinder valve
  - Tamper-resistant fill port
  - $1/2"$  =  $1/2"$  VCR outlet port
  - Excess pressure valve
  - Capillary flow restrictor
  - DOT certified compressed gas cylinder



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# UpTime® Overview



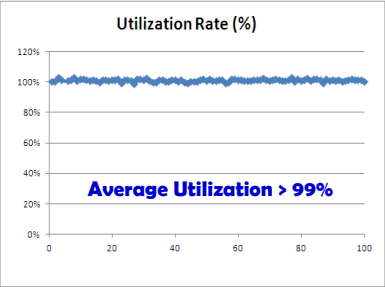
- How does it works?

# Utilization Rate

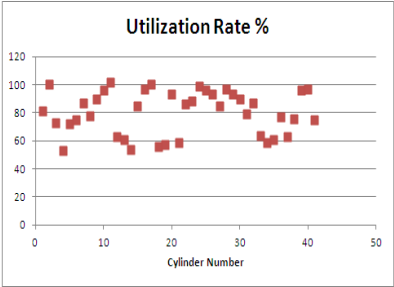


- What is the actual utilization rate of those packages?

## UpTime



## Adsorbent Technology



## Comparison of UpTime® and adsorbent system

Features	UpTime	Adsorbent
Delivery pressure	Sub-atmosphere	Sub-atmosphere
System type	Vacuum actuated bellow valve. One system for all dopant source	Vacuum carbon solid block absorbent.
Cylinder Type	2.2L DOT 3AA	2.2L cut in half
Cylinder Compliance Code	Full Compliance with DOT Specification, High Pressure Cylinders (DOT-49CFR, part 178, subpart C)	Cylinders have thin walls that are cut open & welded
Mechanism of gas storage	Mechanical	Adsorbent (Physical)
Capacity	High product capacity (~2X adsorbent) AsH3 1200g, PH3 520g, BF3 335g and 1100g <i>Reduces:</i> downtime, cylinder change outs, re-quals, risk <i>Increases:</i> tool availability, safety, tech availability	Adsorbent packages AsH3 655g, PH3 330g, BF3 295g
Thermal-independent	Yes	No (Super-Atmospheric above ~74 °F ~ 23.3°C)

## Comparison of UpTime® and adsorbent system

Features	UpTime	Adsorbent
Operation pressure	Steady operational pressure before EndOfLife(EOL)	Continuous pressure drop as gas depletes
Contamination Potential	Check valve with multiple frits can avoid gas back stream and particle contamination	Adsorbent material that will degrade and breakdown as a function of time, storage temperature, operation sequence
Process Performance	Stable Full Dopant Flow Through Entire Cylinder Life	Dopant Control and Delivery Issues at Lower Cylinder Pressures
	1. Eliminate beam "starvation" & process variability 2. Maintain high flow requirements without flow adjustments & re-tuning 3. Stable process until cylinder is depleted Maximize gas utilization	1. Potential beam current "starvation" & control loss 2. Challenge to sustain high dose recipe & robust process range 3. Inefficient removal of gas means loss of product & higher cost
Utilization	Higher product utilization > 95%	Depend on vacuum capability of tool
Certification	DOT cylinder, SEMI S2 and S8(GS3), FM & NFPA318	Unknown

## UpTime Leadership in new implant gases

### 1. Leadership in new implant gases since mixture gases

#### a. UpTime Clean solution

- Xe/H<sub>2</sub> for Ge and B implant process



Heavy W growth on ion source without Xe/H<sub>2</sub>

Minimized W growth on source with Xe/H<sub>2</sub>

#### b. UpTime Carbon source

- CO and Mixture Gas

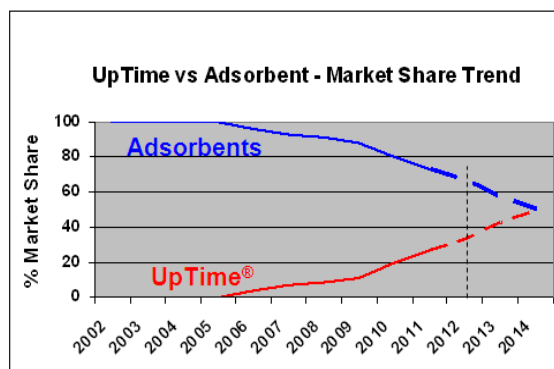
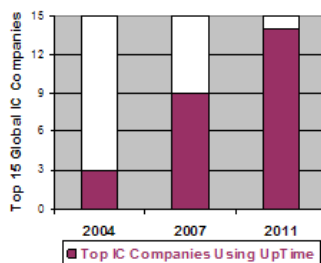
#### Commercial Landscape

Molecule	Beam Current	Source Life
CO <sub>2</sub>	✗	✗
CO (currently being marketed)	✓	✗
PH <sub>3</sub> /CO <sub>2</sub> mix	✗	✓
CO <sub>2</sub> /H <sub>2</sub> mix	✗	✓
UpTime Mixture Gas	✓	✓

## UpTime Leadership in new implant gases

### 2. UpTime market share growth via new implant gases

- Enters market ~2003
- Wins legal challenge
- Stronger value proposition



Source: Techcet; Company Reports

UpTime market share accelerates rapidly especially in new implant gases



## Varian Press Release - 2/14/2012



### PRAXAIR SUPPORTS INDUSTRY'S LEADING ION IMPLANT PLATFORM WITH ADVANCED GAS DELIVERY SYSTEM

DANBURY, Conn., February 14, 2012 – Praxair Electronics, a division of Praxair, Inc. (NYSE: PX), announced today that its UpTime® sub-atmospheric dopant gas delivery system has been selected to be the factory default standard for Applied Materials' flagship Varian VIISta® ion implant platform.

"We are pleased to offer customers Praxair's UpTime system on our VIISta platform," said Matt Gaucher, general manager of high current implantation at Varian Semiconductor Equipment, a division of Applied Materials, Inc. "Compared to other available options, the UpTime system has demonstrated significantly improved operational productivity on our platform."

Ion implantation is a process used in the fabrication of microchips in which ions, created from highly specialized gases, are accelerated and implanted into silicon wafers to modify the properties of a film. With over 1,500 tools installed worldwide, the VIISta system is the industry's leading ion implant platform.

"We look forward to continuing our work with Applied in identifying and jointly bringing to market additional productivity enhancements to customers in the implant space," added Lisa Fanti, director of electronics product commercialization at Praxair. "Applied's adoption of UpTime for their market-leading implant platform is a validation of its advanced and cost-effective capabilities."

Praxair is also the preferred sub-atmospheric dopant supplier for the Solion™ implant tool developed by Varian Semiconductor Equipment for the solar photovoltaic market.

Praxair, Inc. is the largest industrial gases company in North and South America and one of the largest worldwide, with 2011 sales of \$11 billion. The company produces, sells and distributes atmospheric and process gases and high-performance surface coatings. Praxair products, services and technologies are making our planet more productive by bringing efficiency and environmental benefits to a wide variety of industries, including aerospace, chemicals, food and beverage, electronics, energy, healthcare, manufacturing, metals and others. More information on Praxair is available on the Internet at [www.praxair.com](http://www.praxair.com).