

## Innovative Etch Technologies

Solving etching and environmental challenges with new materials → Focus on silicon material etch

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## Air Liquide's new enScribe<sup>™</sup> brand of etching gases

Product family of new, innovative etch molecules with an eye on <u>en</u>vironmentally friendly properties

- $\rightarrow$  Design to function
- $\rightarrow$  Solving Technology challenges

✓ Quality

- Environmental friendly
- ✓ Leading edge technology
- ✓ Customer driven



Air Liquide is leading the way to develop next generation etching processes with leading edge OEMs, device manufacturers, universities and technology consortiums



# Development timeline - A long vision....

Solving semiconductor process challenges, especially etch with new materials requires a long vision

- $\rightarrow$  Development of new materials
- $\rightarrow$  Process development and integration
- $\rightarrow$  Tool development
- $\rightarrow$  Time to bring the product from R&D to HVM
  - $\rightarrow$  Scale up of production equipment
  - $\rightarrow$  Hazards testing, chemical registration, HSE requirements,

## Looking towards regulatory issues is prudent early in the development

etc



## Outline

- > A historical perspective the ozone layer to global warming
- Emissions in the semiconductor industry which products contribute?
- > What are governments doing about it?
- What causes a molecule to have high GWP and how can we design around it?
- Some examples of technology challenges solved with new environmentally friendly gases



# The past and the present for fluoride gases

## Ozone depletion

## **Global Warming**

1970s-1980s concern about ozone layer 1987 - Montreal Protocol Phaseout of halons (BrCFC), CFCs, **HCFCs** Other rules -Clean Air Act (US) -Class I and II ODS



1990 - GWP concept 1992 - UN Framework **Convention** on Climate Change (UNFCCC) 1997 - Kyoto protocol 2012 - Doha amendment Carbon tax implementation BrCFC, CFC, HCFC, HFC, FC

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# Last 10 years – highest growth for GHG Emissions

Total Annual Anthropogenic GHG Emissions by Groups of Gases 1970-2010



## GHG emissions are increasing and accelerating



## **Electronics Manufacturing Emissions**



Even though Electronics manufacturing is a small percentage of total GHG emissions, many of the chemicals used are also used in other industries (SF<sub>6</sub>, CHF<sub>3</sub>, ....)

IPCC, 2014



## All GHGs are not equivalent



• SF<sub>6</sub>, NF<sub>3</sub> and CHF<sub>3</sub> have the highest GWP



# **Electronics Manufacturing Emissions**

Emissions by source (US fabs) (MMT CO<sub>2</sub>e)

PFC and other F gases are used in chamber cleaning and etching



## Perfluorocarbons 81%

US EPA, GHGRP WSC 2016

- Perfluorocarbons are the most concerning GHG for Electronics industry
- PFC molecules are potent GHGs with high GWP



## An example of a country implementing carbon tax

By 2019, the Singapore will charge a Carbon Tax of between\$7-\$15 for every ton of CO2e per year emitted by a company.

 $\rightarrow$  target CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>

Other countries not far behind?

## SINGAPORE'S CLIMATE ACTION PLAN



HOW A CARBON TAX WORKS

#### INTRODUCE A TAX ON EMISSIONS

- Carbon tax will generally be applied upstream, for example, on power stations and other large direct emitters.
- Businesses can choose to reduce emissions or pay a carbon tax.

#### 2 ENCOURAGE ENERGY EFFICIENCY & SUPPORT MORE GREEN ACTIONS

- Businesses are motivated to improve their energy efficiency.
- Consumers are encouraged to use less
  electricity and save energy.
- Carbon tax revenue will help to fund measures by industry to reduce emissions and provide appropriate measures to ease the transition.

#### LOWER CARBON, GREENER ECONOMY

- · Lower emissions lead to a greener planet.
- Businesses become more resource-efficient and sustainable.
- More opportunities in green growth sectors, such as clean technology.

https://www.nccs.gov.sg/sites/nccs/files/How\_A\_Carbon\_Tax\_Works.pdf



## Need for Innovative Etch solutions

Traditional molecules have insufficient performance for new high end applications New etch materials are needed for many key applications



## **Environmental issues :**



High gas consumption

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Traditional fluorocarbons have high GWP

### **Double Challenge :**

Solve technical problems with low GWP chemistries

enScribe innovative etch materials

## Understanding GHG effect to design low GWP solutions





# Designing new performance molecules for etch





## **Balancing Process & Environmental Impact**





# A number of etching challenges face the industry







Air Liquide is currently developing new etch gases for a wide variety of applications and challenges





## 3D devices

...

# TSV (3DIC)

App: 3D memory, Logic 2.5D cowos, CMOS, RF

# MEMS

App: Inkjet, Accelerometers, Microphones, Lab-on-chip

...

These devices are primarily created by etching of Silicon



# One issue with TSV etch involves RIE lag

- RIE lag, also called aspect ratio dependent etching (ARDE).
  - One of the technical challenges for TSV process. It is the difference in etching rate of different trench sizes. Normally the wider trench the higher etch rate.



## Can this be achieved by a new gas?



# TSV etch process and redesigning " $C_4F_8$ "





## New TSV Etch Gas - Tonga<sup>™</sup>



2 um

20 um



	C <sub>4</sub> F <sub>8</sub>	Tonga™
Si Etch <b>rate</b> (2µm feature)	Equivalent	Equivalent
RIE <b>lag</b> : 2µm vs 20µm	33%	~0
GWP100	8700	30
Gas consumption decrease		50%

•<u>Technology performance :</u> •<u>Environmental aspect :</u> Significant RIE lag reduction Low GWP gas Reduced gas consumption in the process

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## Another Critical industry etch challenges – 3DNAND



• Etch process is complex involving mixture of multiple fluorocarbon gases to get the etch performance just right

Can include high GWP gas like C<sub>4</sub>F<sub>8</sub>, CHF<sub>3</sub>, etc
 Etch chemistry plays a strong role in the performance of the process
 New chemistries are coming......



## Conclusions

- New environmental regulations may be coming in the near future that can affect the GWP emitting gases used in the Semiconductor industry....
  - □ HFC's, PFC's, etc
- The etching application is facing a number of technological challenges that may be solved with new gas design
- Solving both environmental and technological challenge with new gas design may be possible
  - □ TSV etch
  - □ 3DNAND etch

Design small.

Think bia