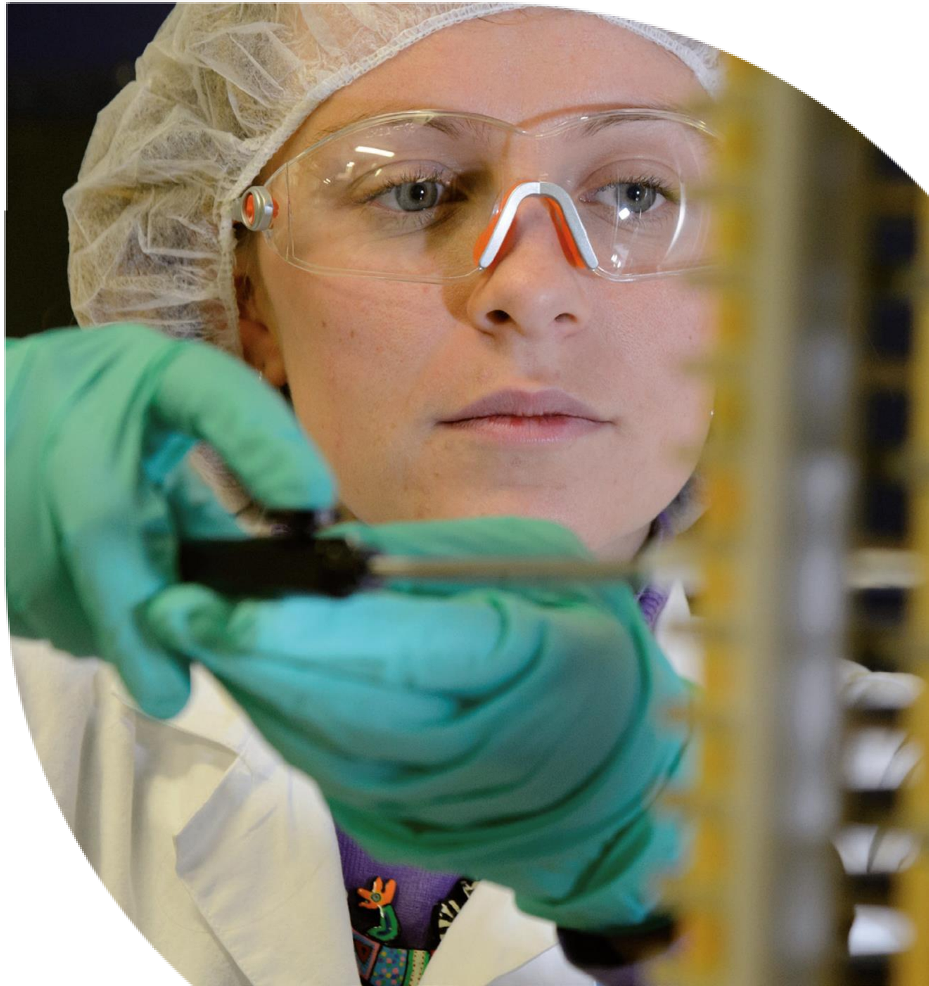
CMC Seminar 2019

Precursors and Specialty Gases: Greater Needs and Challenges on Characterization and Quality Control

Berry TSENG, Product Quality Director
17 Oct. 2019



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ELECTRONICS

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Major trends and challenges are shaping our materials

Growing **Novel Material** in flux

- **ALD/CVD precursors for advanced node development**
- New material learning cycle impact to ramp/HVM
- Classical metrology is inadequate to tell good/NG
- Product “in spec” is not necessarily “fit for use”

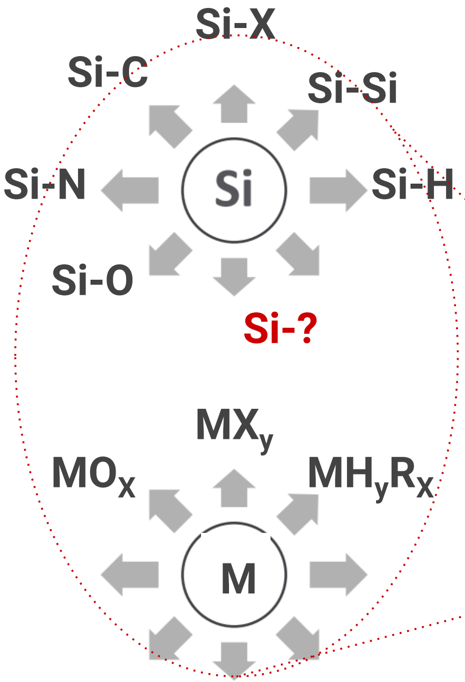
Zero Excursion - Lowest Defect Density

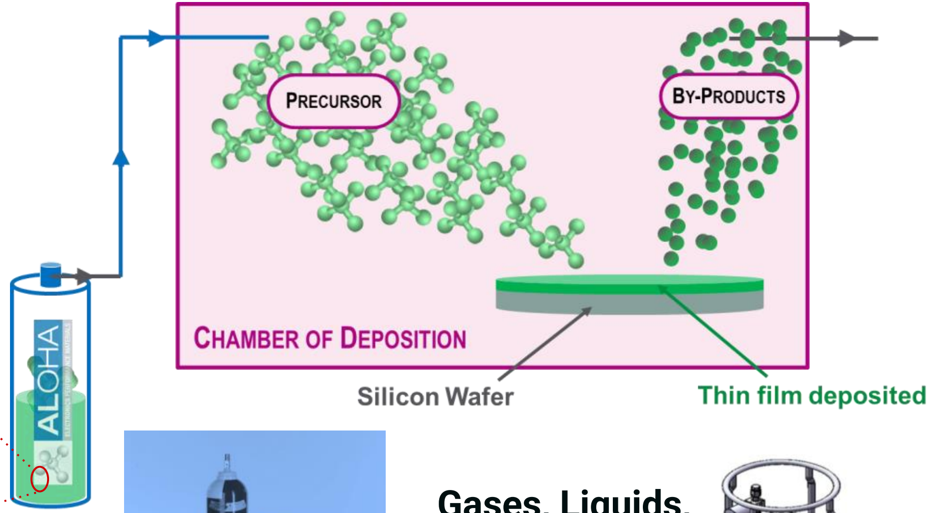
- **Unstable/sensitive material characterization** from POS to POU
- Killer defect detection vs. vast amount of nuisances
- Inline/offline correlation
- Increasing unwanted impurities

Product consistency and process stability

- **Dynamic control limit tightened** from the scope of material to run-to-run wafer
- Fast QC verification and real-time feedback for endpoint control, fault detection and drift control
- Baseline shift early detection and deviation control

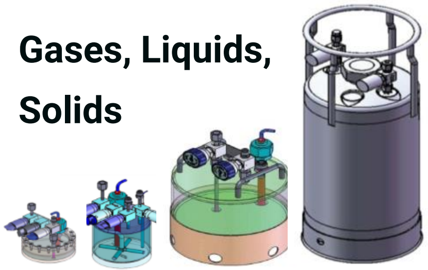
Precursor chemistries and difficulties





M: Al, Zr, Hf, Ti, Co, Mo, W, Ru…
L : multi ligand options

Gases, Liquids,
Solids



Precursor characterization challenge

- ❑ **Highly reactive**
- ❑ **Complex matrix**
- ❑ **Scarce information**

Analytical techniques and methods must be carefully selected and thoroughly studied.

No “One Technique” will do for all...

Instrument	Applications
ICP-MS	trace metals
GC/MS	assay, impurity identification
IC	Anions (Fluoride, Chloride etc)
FTIR	functional group ID, impurity quantification
UV-Vis	impurity quantification
LC	impurity quantification
Karl Fischer	Water content
TGA	Thermal stability, weigh loss

Sophisticated techniques such as GC/MS, NMR, ICP-MS and FT-IR can provide essential information about trace-level contaminants

Precursor characterization challenge (cont./)

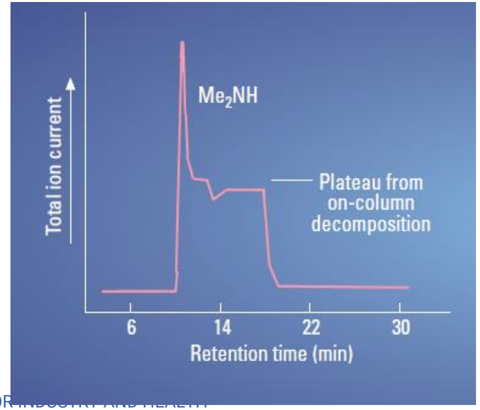
The reactive nature of the precursors is the major challenge for sample preparation and assay analysis

Sample handling/Preparation:

- Glove box is required for sample handling
- Great care needed to prevent sample from decomposing: dry solvents, dry sample vials etc.

Instrumentation difficulties:

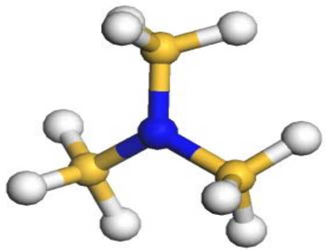
- Syringe clog
- Strong interact with GC column stationary phase damages the column
- Corrosive or non-volatile residues contaminate/destroy detectors: SiO2 coating, HCl Corrosion
- Frequent maintenance required to ensure instrument functionality



Precursor quality control plan - greater needs

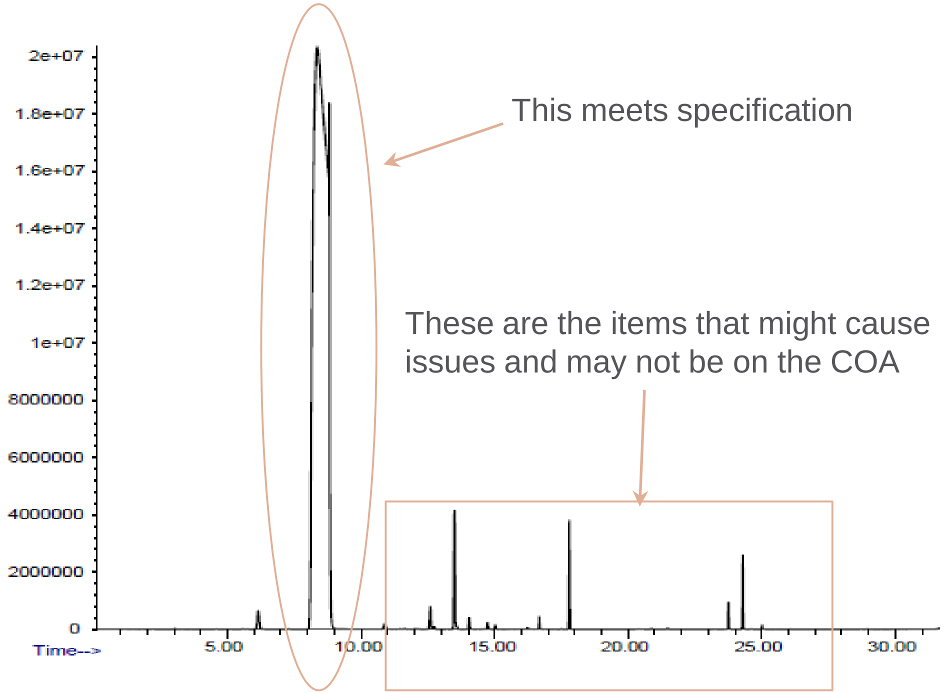
- **Starting Material + Compound(s) = Final Material (Purification/Synthesis)**
  - "Fingerprint (beyond CoA)" final material and critical starting material
  - Active batch variation to validate spec limits for CoA parameters
  - Complete baseline to comprehend variability

- **Final Material + Container(s) = Intermediate/Final Product(s)**
  - Packaging is as important as chemical itself
  - decon/clean, integrity leak/moisture check



- **Final Product + Process = Deposition**
  - Co-process optimization to validate material in use consistency

Specialty gases characterization challenge

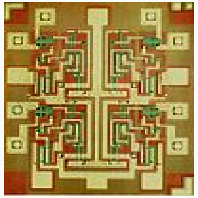


- What happened?
  - Decomposed over time (ex. B2H6 -> B4H10)
  - Product rearrangement over time (ex. DCS -> MCS, TCS)
  - Unknown peaks, phase change impurities...etc
- What to do?
  - Revisit unstable, sensitive SG
  - Obtain data over the shelf life
  - Understand and control "material" and "material in use"
  - Make a "correlation" with process

Specialty gases characterization challenge (cont./)

- Detect and eliminate **trace metallic particles (killer defect)** in critical etch materials
  - New flavor of ICP-MS: GED-sp-ICP-MS application under developing
  - Nanoparticle extraction and characterization by ICP-MS complements traditional particle technique by providing additional info of elemental composition plus particle size/concentration
- Characterize **unwanted decomposed byproducts** in critical materials (ex. B2H6)
  - Traditional FTIR to semi-quantitatively determine higher boranes
  - Inline sensor complements critical material in use (ex. hydrides)

Semiconductor manufacturing processes



10 µm – 1971
6 µm – 1974
3 µm – 1977
1.5 µm – 1982
1 µm – 1985
800 nm – 1989
600 nm – 1994
350 nm – 1995
250 nm – 1997
180 nm – 1999
130 nm – 2001
90 nm – 2004
65 nm – 2006
45 nm – 2008
32 nm – 2010
22 nm – 2012
14 nm – 2014
10 nm – 2017
7 nm – *~2019*
5 nm – *~2021*

- Major trends and challenges of materials (#3)
- Characterization needs for ALD precursors and specialty materials (#4-9)
- Quality control requirement: yesterday vs. today, and tomorrow? (#10-14)
- Air Liquide solutions (#15-17)
- Q&A

Quality control requirements - yesterday vs. today

Yesterday

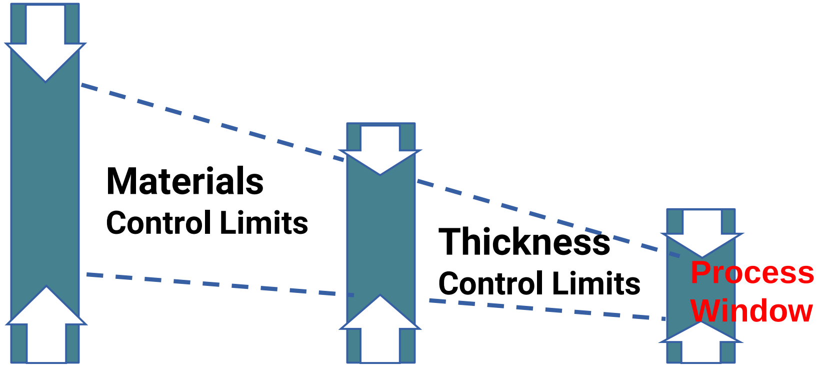
- √"In Spec" product (STS)
- √Historical quality data review (SQC)
- √Few key parameters
- √Metrology calibrated
- √Just in Time Supply (JIT)
- √Casual PCN at major change
- √Raw material non conformity management
- √CofC or CofA (paper format)

Today

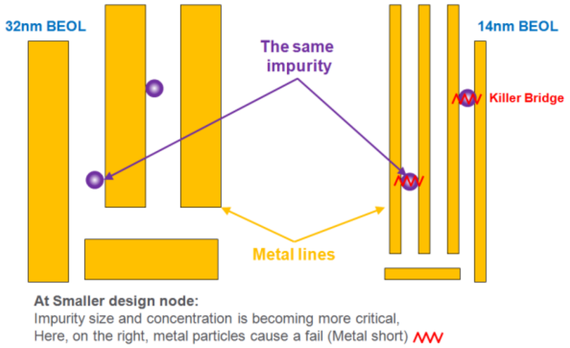
- √"<u>In Control</u>" product (STC)
- √Real-time process control wi/ OCAP(SPC)
- √Dynamic key parameters
- capability analysis (IDL,
  , gage R&R, LTS)
- inuity Plan (BCP)
- √"Copy Exact" (Management of Change from R&D to HVM)
- √CoA reliance/upstream supplier management/lot traceability
- √CofA (e-CoA pre-upload review)

Tomorrow?

Shrinking of process window leading to stringent QC

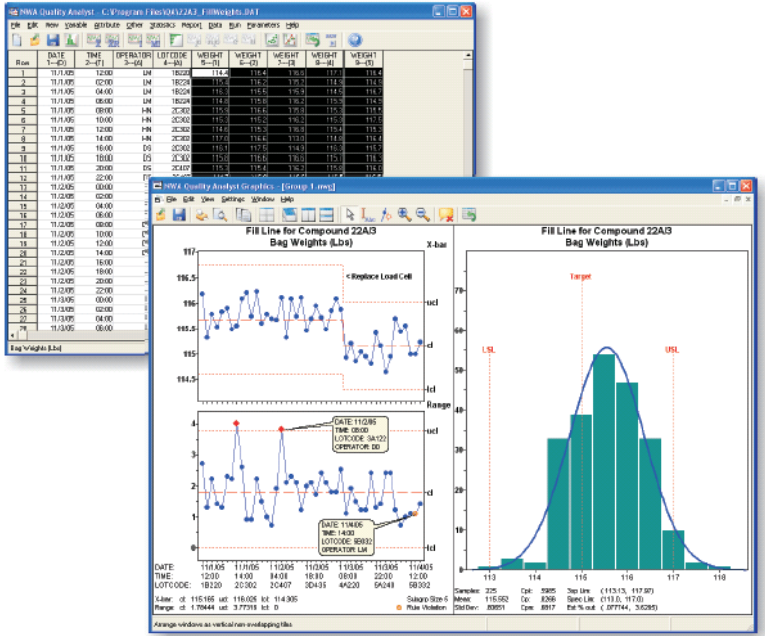


Point of Supply (Materials)	Point of Delivery (Facility)	Point of Use (Tool)



- As customer process window is shrinking to <u>smaller nodes</u> and <u>zero defect</u>, "materials window" requires tighter acceptance limits adjusted dynamically with higher frequency than in the past.
- "<u>Co-process control</u>" to beat down process variability.

Quality control requirement - tomorrow?

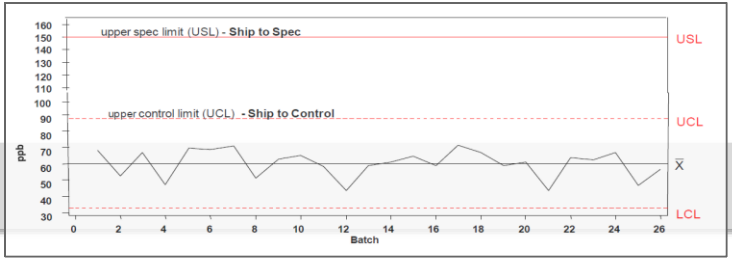


- Process parameter trending in CoA
- Production-like pre-conditioning
- Enhanced sub-supplier defence line
- Baseline management (technology, application, factory-specific)
- Selective for cost-effective quality
- Predictive data analytics - advanced process control by real-time SPC + correlation (from corrective to predictive)
- …….

QMS focusing on entire supply chain control

Quality Incident Free can only be achieved in a sustainable manner by exercising proper control on products and processes and cultivating quality mindset over the entire supply chain.

Over the entire material supply chain



Process Control System - SPC, STC, Baseline Management

Supplier Quality Management

Validation of specifications

Metrology Control

Material Deviation Review

Change Management

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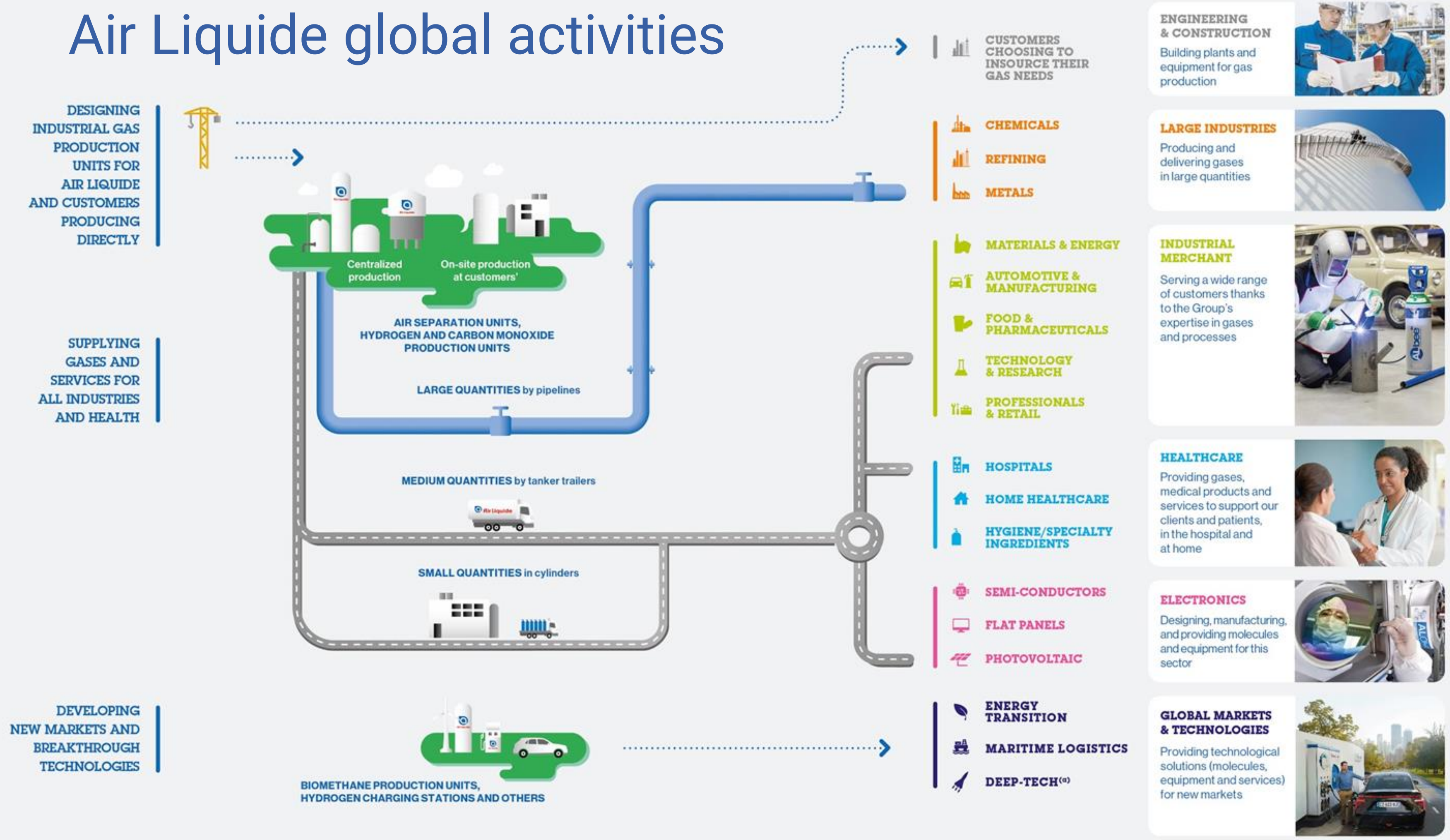
Air Liquide global activities



Air Liquide Electronics: a total solution provider for IC leaders

SAM 24

B_2H_6

DCS

TSA

ZyALD

C_xF_y

Material

- ALD Precursor (AM)
- Etch, doping gases
- Deposition gas
- Carrier Gas

CO_2

Ar

N_2

O_2

SiH_4

He

H_2

Analytical

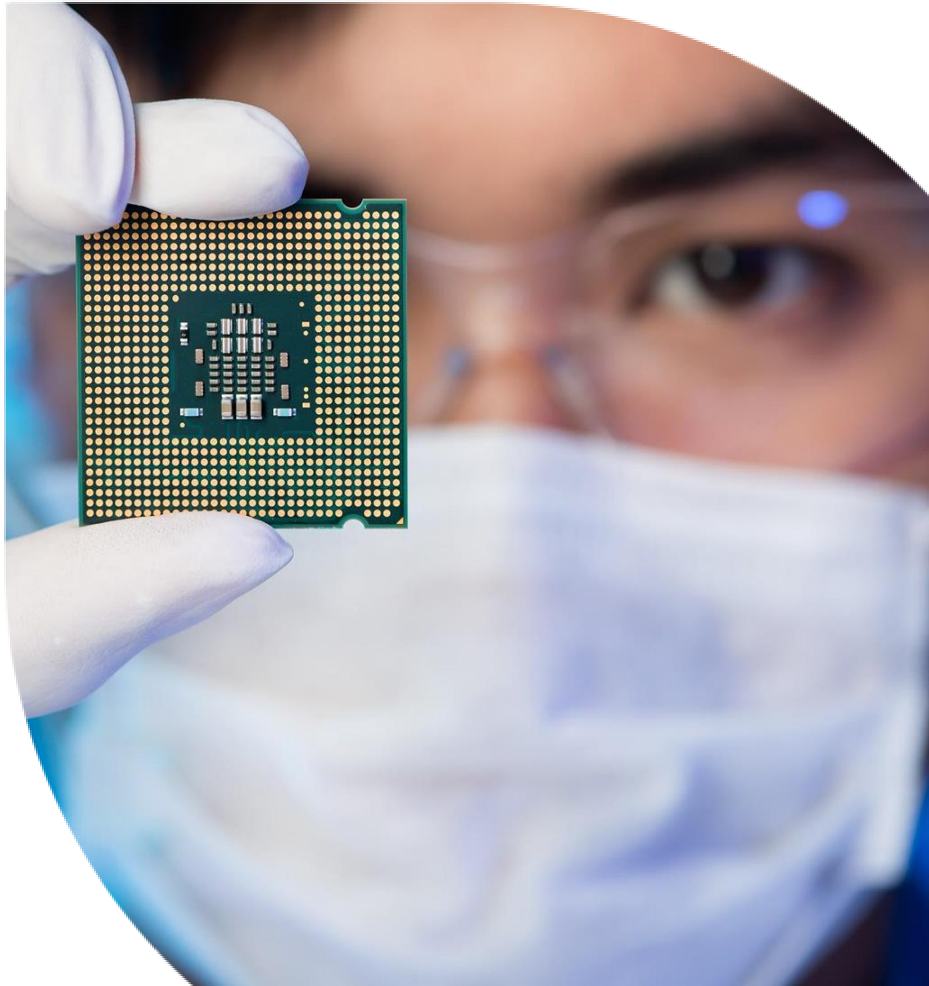
- Precursor analysis
- Micro-contamination control (AMC, SMC)
- QA/QC and troubleshooting

Equipment

- Precursor delivery system
- VMB, mixer and GC
- Design & manufacturing

Air Liquide
creative oxygen

Thank You ! Q&A



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