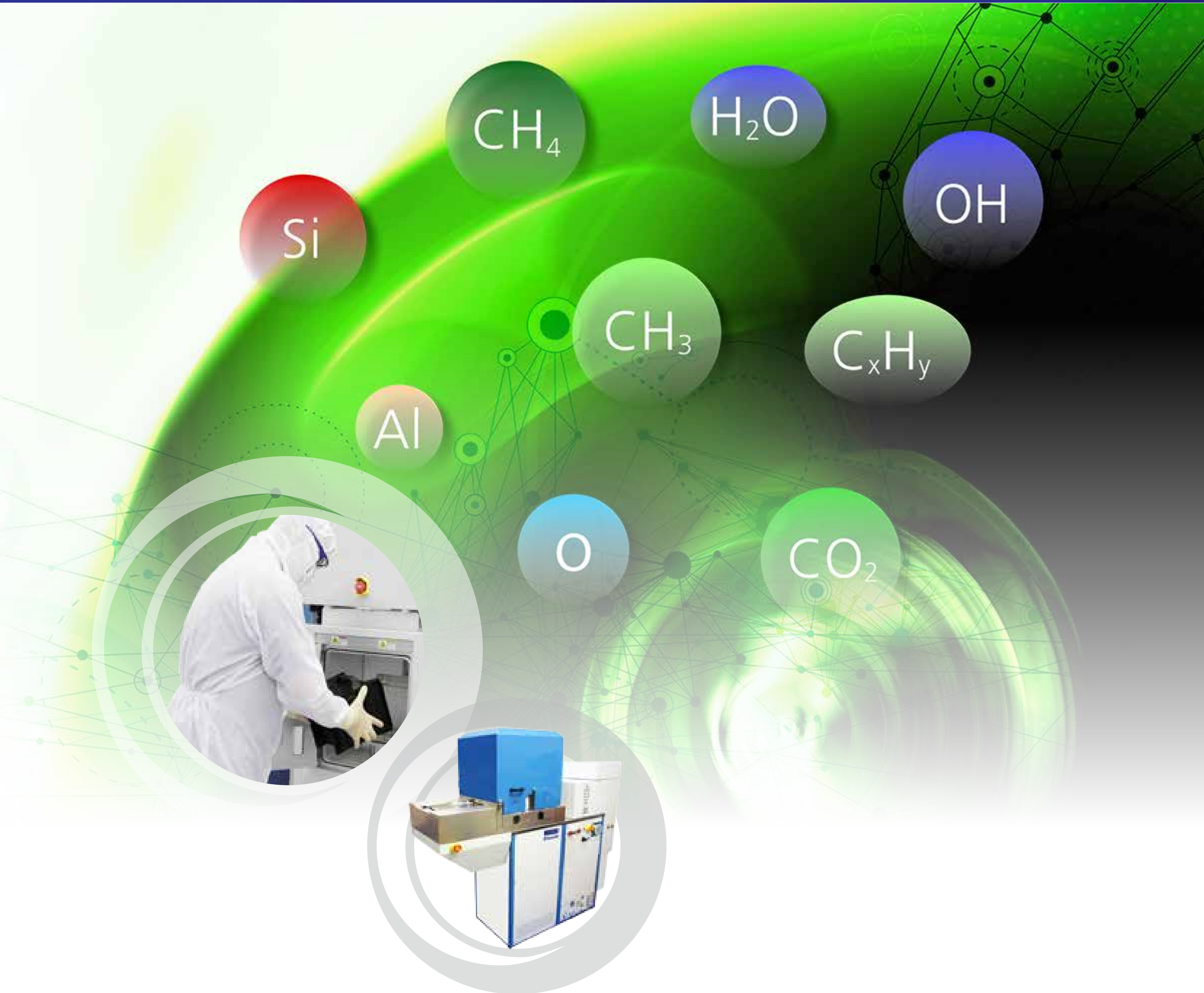
Atomic Layer Deposition

ALD process solutions using FlexAL and OpAL



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Introduction to ALD

Self limiting digital growth

Atomic Layer Deposition (ALD) offers precisely controlled ultra-thin films for advanced applications on the nanometre scale, with conformal coating into high aspect ratio structures.

Oxford Instruments' ALD product family offers a unique range of flexibility and capability in the engineering of nanoscale structures and devices by combining remote plasma ALD processes with thermal ALD.

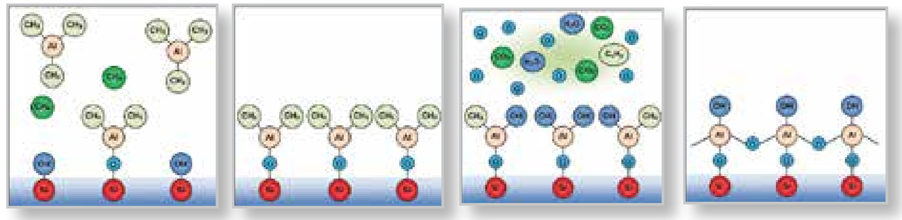
Exploit the benefits of plasma ALD

The remote plasma option allows for the widest possible choice of precursor chemistry with enhanced film quality:

- Plasma enables low-temperature ALD processes and the remote source maintains low plasma damage
- Eliminates the need for water as a precursor, reducing purge times between ALD cycles
- Higher quality films through improved removal of impurities, leading to lower resistivity conducting layers and higher density insulators

ALD cycle for Al_2O_3 deposited using TMA and O_2 plasma

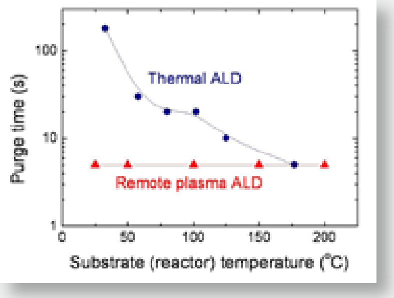
Only step C varies between H_2O for the thermal process or O_2 plasma.



A. TMA chemisorption *B. TMA purge* *C. O_2 plasma* *D. Post plasma purge*

Example applications of ALD:

- Nano-electronics
- High-k gate oxides
- Storage capacitor dielectrics
- High aspect ratio diffusion barriers for Cu interconnects
- Pinhole-free passivation layers for OLEDs and polymers
- Passivation of crystal silicon solar cells
- Highly conformal coatings for microfluidic and MEMS applications
- Coating of nanoporous structures
- Bio MEMS
- Fuel cells

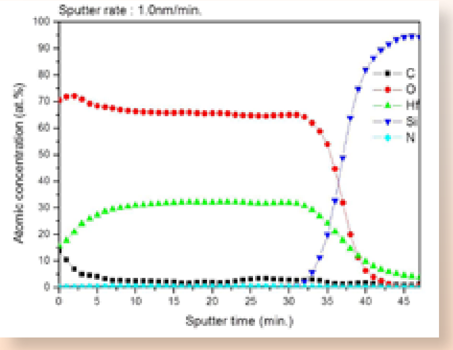


ALD Process Benefits

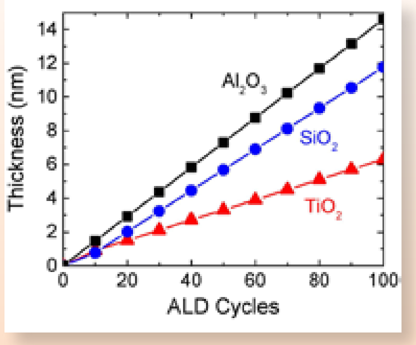
Conformal, controlled, low pin-hole nano-scale growth

ALD Process Benefits

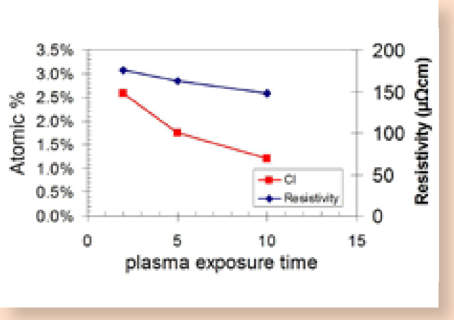
- Excellent process control with wafer to wafer repeatability <±1%
- Up to 200mm wafer with typical uniformity <±2%
- Excellent step coverage even inside high aspect ratio structures
- Virtually pin-hole free films
- Low film impurities; particularly with plasma ALD
- Growth at room temperature possible with plasma ALD
- Low resistivity for conductive nitride and metal films by plasma ALD
- Superb thin film barrier properties



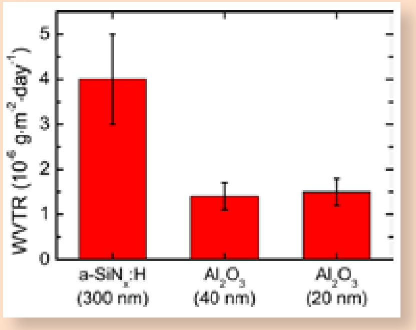
HfO_2 from TEMAH and O_2 plasma – Auger analysis showing low carbon content of <2% obtained by FlexAL remote plasma ALD



Al_2O_3, SiO_2 and TiO_2 grown at room temperature. Due to the high reactivity of plasma ALD, many materials can be deposited at lower temperature as compared to when using thermal ALD.



Chlorine impurities of TiN by RBS and resistivity by FPP deposited at 350°C. Resistivity <200μΩcm possible with plasma ALD even at low temperatures. (350°C plasma = 550°C thermal)



Diffusion barriers with excellent water vapour transmission rates. 20 and 40nm Al_2O_3 deposited using plasma ALD at room temperature, perform even better than a 300nm a-SiN_x:H deposited by PECVD. Data courtesy of TU/e.

Process

Process library and development

Oxford Instruments has an extensive process library, and new processes are continually being developed. We provide free on-going process support for the lifetime of any ALD tool, offering advice on developing new materials and continued access to our latest ALD process developments including new process recipes.

Precursors

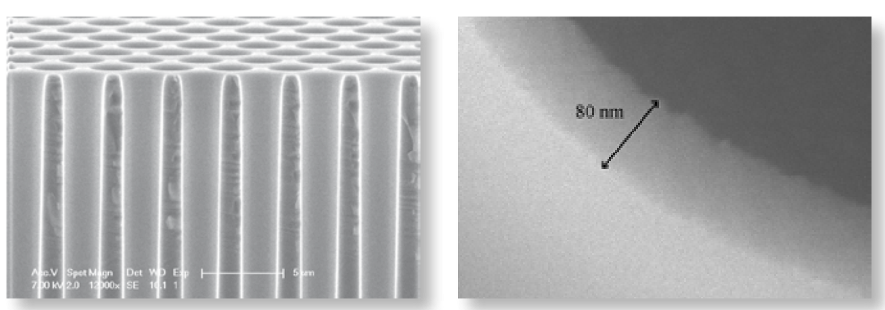
Metal Precursors

Liquid or solid precursors vapours can be delivered to the reaction chamber by heating up to 200ºC. Delivery modes:

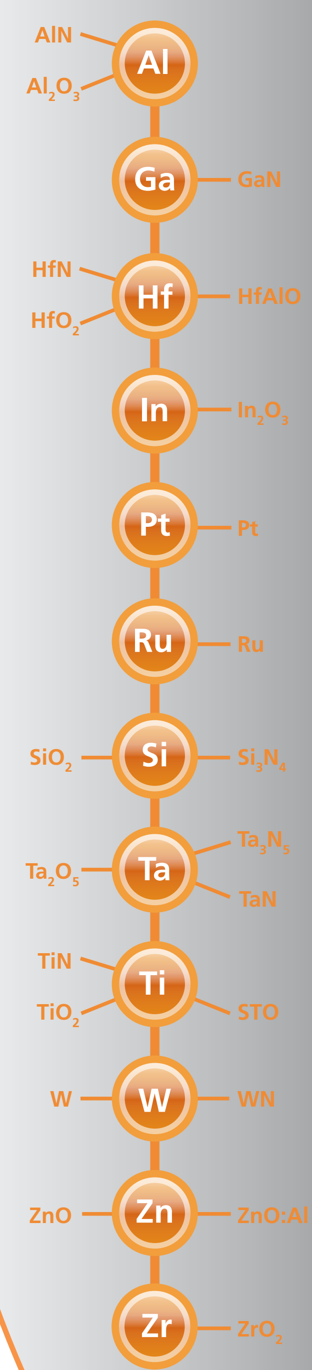
- Vapour draw under own vapour pressure
- Vapour with carrier gas assist
- Bubbling with carrier gas

Non-metal precursors

H_2O	Thermal Oxides
Ozone	Thermal Oxides
O_2	Plasma oxides, plasma metals, thermal metals
N_2	Plasma nitrides
H_2	Plasma metals, plasma nitrides, some thermal metals
NH_3	Thermal nitrides and some plasma nitrides



Plasma ALD of 80 nm Al_2O_3 from TMA and O_2 plasma in a 10:1 aspect ratio deep trench capacitor structure. Courtesy of Eindhoven University of Technology and NXP



Hardware

A family of tools to meet your needs

The ALD product family encompasses a range of tools to meet the varied demands of academia, corporate R&D and small scale production.

OpAL® tool

- Open loaded thermal ALD tool with plasma option
- Field upgrade available for plasma option
- Small wafer pieces up to full 200mm wafers – equally suitable for academic and industry R&D

FlexAL® tool

- Remote plasma & thermal ALD in one flexible tool
- Automated 200mm load lock for process flexibility
- Clusterable for vacuum transfer of substrates
- Cassette to cassette handling increases throughput suitable for production

OpAL

FlexAL

Precursor Delivery

- Multiple liquid or solid precursor delivery systems
- Vapour draw or bubbling up to 200ºC source temperature
- Rapid gas delivery
- Designed for safe handling of hazardous precursors by enclosing them in a stainless steel extracted cabinet with attachable glove box for use during precursor exchange

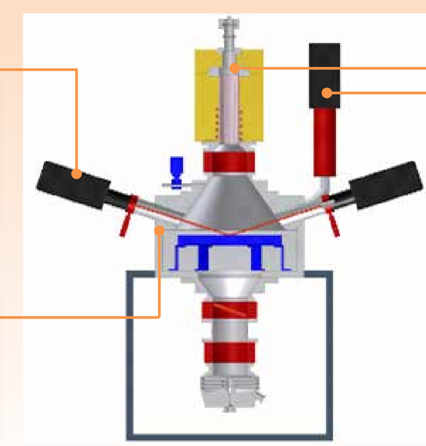
In Situ Diagnostic Options

Ellipsometer

- Nucleation delay
- In situ resistivity
- Linear growth
- Saturation growth

Quartz Crystal Microbalance (QCM)

- Saturation growth
- Linear growth
- Reaction mechanism



Optical Emission Spectroscopy (OES)

- Saturation growth
- Reaction mechanism

Mass Spectrometer (QMS)

- Reaction mechanisms
- Background chamber condition
- Precursor condition

Configuration Options

Systems easily configured for cutting edge research or production

Product Overview

Flexible, configurable, powerful tools

Both **FlexAL** and **OpAL** can be fitted with the remote Inductively Coupled Plasma (ICP) ALD source. This source is close coupled to an Oxford Instruments matching unit with dedicated control systems to enable rapid plasma striking.

Feature:	OpAL	FlexAL
Substrates	Up to 200mm wafers and pieces directly on stage	Up to 200mm wafers and pieces on carrier plate
Bubbled liquid and solid precursors	Up to 4	Up to 8
Max precursor source temperature	200°C (jacket) for all precursors	200°C (oven and jacket) for all precursors
Additional precursors	Water + ozone	Water + ozone
MFC controlled gas lines with rapid delivery system; 1) thermal gas precursors (e.g. NH_3, O_2) 2) plasma gases (e.g. O_2, N_2, H_2)	2 internally. Up to 8 in externally mounted gas pod	Up to 10 in externally mounted gas pod
Plasma	Option / field upgrade	Option
Loading	Open load / glove box	Loadlock or cassette
In situ diagnostic ports	Ellipsometry, QCM, OES, QMS (on foreline)	Ellipsometry, QCM, OES, QMS
10ms rapid pulsing ALD valves	Yes	Yes
Removable inner chamber	Yes	Yes
PC2000 rapid control software	Yes	Yes
Clusterable to other process modules	No	Yes - including third party MESC modules as special option
Wafer stage temperature range	25°C – 400°C (500°C option)	25°C – 400°C (550°C option)
Bias	No	Option to apply bias voltage to substrate table for increasing ion energies

Global Service and Support

For further information about our tools, please contact your local Oxford Instruments Plasma Technology office

Worldwide Service and Support

Oxford Instruments is committed to supporting our customers' success. We recognise that this requires world class products complemented by world class support. Our global service force is backed by regional offices, offering rapid support wherever you are in the world.

We can provide:

- Flexible service agreements to meet your needs
- Tailored system training courses
- System upgrades and refurbishments
- Immediate access to genuine spare parts and accessories

visit **www.oxinst.com/plasma** for more information

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