OXFORD INSTRUMENTS
The Business of Science®

Atomic Layer Deposition (ALD) overview

Oxford Instruments Plasma Technology
Gases and precursors

© Oxford Instruments 2015 CONFIDENTIAL

Oxford Instruments ALD

OXFORD INSTRUMENTS
The Business of Science®

- Cutting edge plasma ALD systems with thermal ALD as standard
- Mixed mode operation within a single recipe
  - No hardware changes required to switch mode between plasma and thermal ALD
  - e.g. for platinum, start with plasma to minimise nucleation delay and continue with thermal

OpAL

FlexAL

© Oxford Instruments 2015

FlexAL

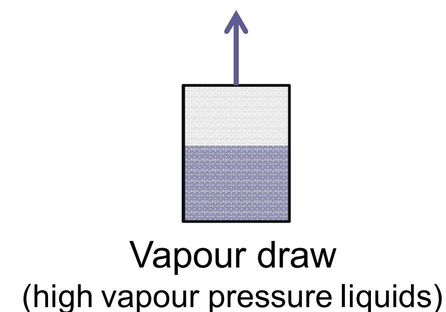
- Extensive process capability;
  - Precursor options for research (up to 100g) and production (up to 500g)
  - Up to 8 liquid/solid precursors (3+3+1+1)
  - Up to 10 gas precursors
  - Water and ozone in addition
- Clusterable to PECVD, RIE, sputter modules
- Turbo pump for moisture sensitive nitrides and metals.

© Oxford Instruments 2015
CONFIDENTIAL

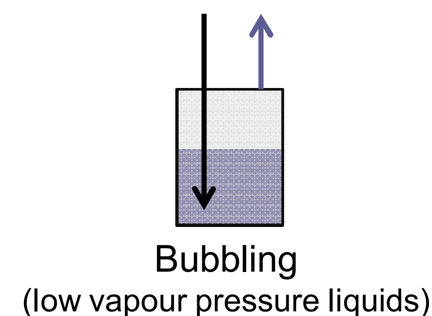
Precursor Delivery Options

- Each module with wide capabilities for;
  - Liquid or solid precursors
  - Temperature range from 30 – 200°C
  - Vapour draw, carrier gas assist or bubbling modes
  - Uses standard canisters from all major precursor suppliers - no need to send a special canister for filling

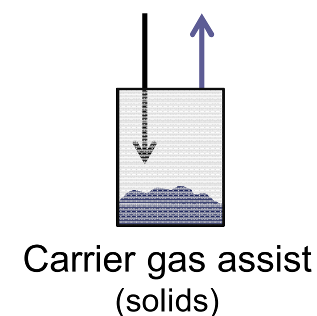
Dip tube



Vapour draw
(high vapour pressure liquids)



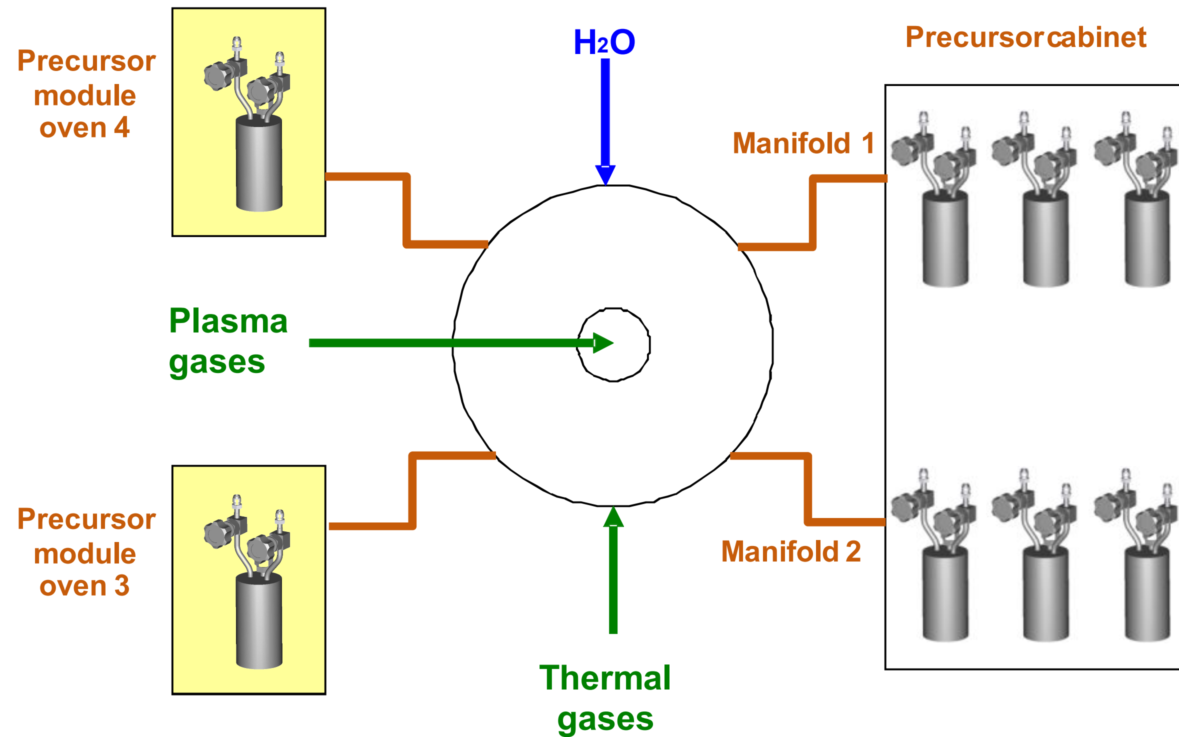
Bubbling
(low vapour pressure liquids)



Carrier gas assist
(solids)

Multiple precursor inputs

- **8** metal liquid or solid rapid bubbled precursors
- **10** plasma and thermal gases
- **Water** and **Ozone** delivered separately



© Oxford Instruments 2015

Precursor 6-way cabinet

- Extensive process capability
  - Up to 6 liquid/solid precursors on two manifolds
  - Options for up to 100g
- Precise and uniform temperature control with jacket design up to 200ºC
- Optimised heated delivery lines up to 200°C

© Oxford Instruments 2015

Precursor single cabinet

OXFORD INSTRUMENTS
The Business of Science®

- When a dedicated manifold is required
  - Highly reactive precursors
  - Development and integration of new precursors
- Uniform precursor temperature control 190°C
  - Allows for heating of irregular shaped ampoules
- Optimised heated delivery lines up to 200°C

Safety Features

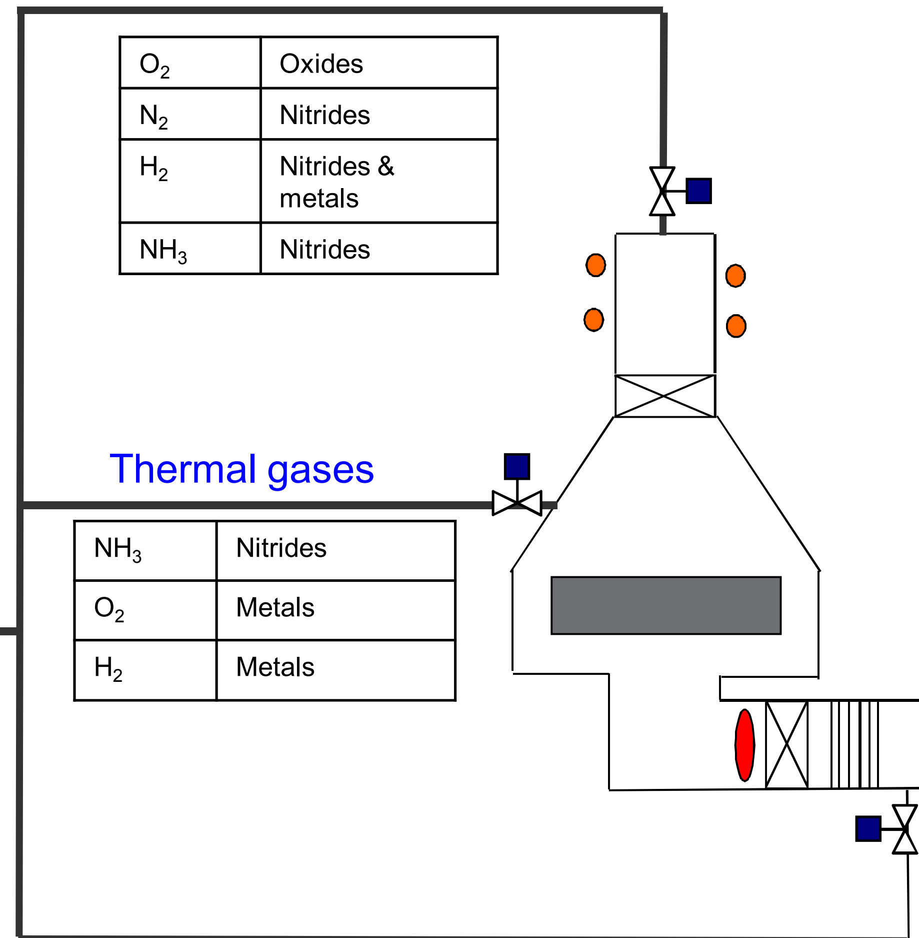
OXFORD INSTRUMENTS
The Business of Science®

- Precursors stored in stainless steel cabinet
- Nitrogen purge and extract to provide low oxygen atmosphere
- Glove panel for use during precursor exchange
- Fully illustrated precursor exchange procedures with check lists
- Remote input to shut down precursors from an external gas detector or extract flow rate monitor

© Oxford Instruments 2015

Rapid gas precursor delivery

Plasma gases



O_2	Oxides
N_2	Nitrides
H_2	Nitrides & metals
NH_3	Nitrides

Thermal gases

NH_3	Nitrides
O_2	Metals
H_2	Metals

Process Knowledge

OXFORD INSTRUMENTS
The Business of Science®

- Extensive process library
- Rapidly growing
- Free of charge access to library for lifetime of tool

Oxides	Metals	Nitrides	Precursor
Al_2O_3	Al	AlN	TMA
HfO_2	Hf	HfN *	TEMAH
PtO_2 *	Pt		$Me_3Pt(MeCp)$
	Ru		$Ru(EtCp)_2$
SiO_2	Si	Si_3N_4	BDEAS/3DMAS/BTBAS
Ta_2O_5	Ta	TaN	TBTDMT
TiO_2	Ti	TiN	TDMAT / TTIP / $TiCl_4$
$SrTiO_3$ *			$Sr(^iPr_3Cp)_2DME$ + TiO_2 prec.
WO_x *	W	WN	WNBURE
ZnO	Zn		DEZ
In_2O_3 *			InCp
	Nb	NbN *	TBTDEN / TBTMEN
Co_3O_4*	Co		$CoCp_2$
Gd_2O_3*	Gd	GdN *	$Gd(^iPrCp)_3$ / $Gd(MeCp)_3$
ZrO_2*	Zr		$(MeCp)_2Zr(OMe)(Me)$
	Ga	GaN	TEG

*** Knowledge from customer base**

Element for reference only

Materials possible by ALD (literature)

OXFORD INSTRUMENTS

The Business of Science®

Deposited by ALD

Blue: compound with element

Gray: 2nd element in compound

Underline: pure element

Red circle: nitride

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
		*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
		**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Adapted from source by Eindhoven University of Technology, source: Miikkulainen et al., *J. Appl. Phys.* **113**, 021301 (2013).