AML

AML- Technical Benefits

4 Sept 2012

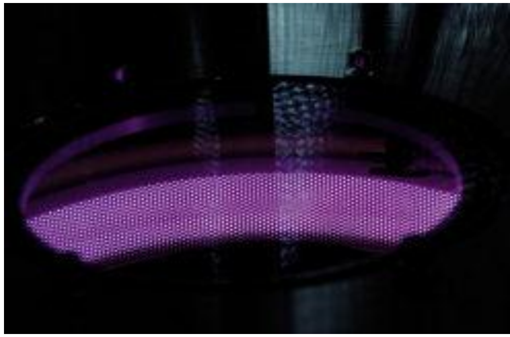
www.aml.co.uk

AML In-situ Aligner Wafer Bonders

Wafer bonding capabilities:-

- Anodic Bonding Si-Glass
- Direct Bonding e.g. Si-Si
- Glass Frit Bonding
- Eutectic Bonding
- Thermo-compression
- Adhesive Bonding
- Aligned Embossing
- In-situ UV cure
- Temporary Bonding

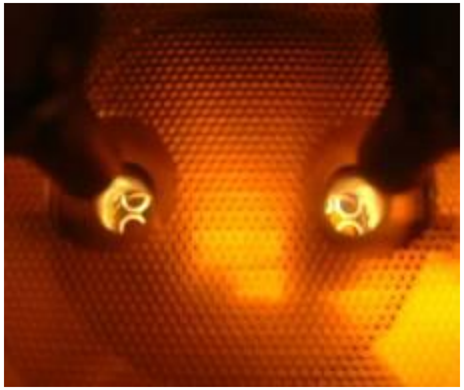
These various techniques have different tolerances to particles, wafer flatness, surface topography….



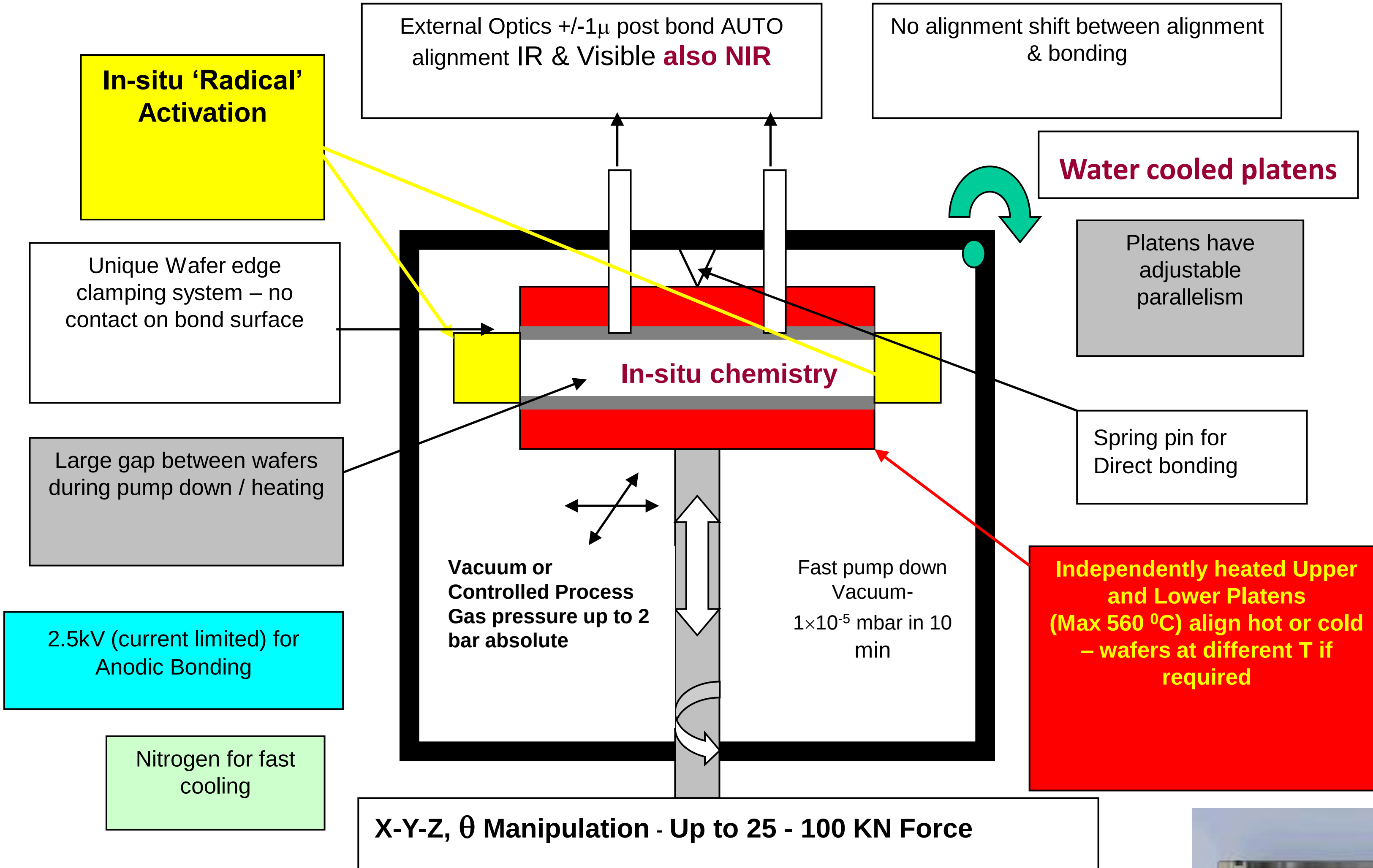
RAD activation for low T bonding

In situ chamber alignment & bonding

= more process flexibility & higher throughput



AML in-situ Bonding Platform



AWB Platform Outline Spec:-

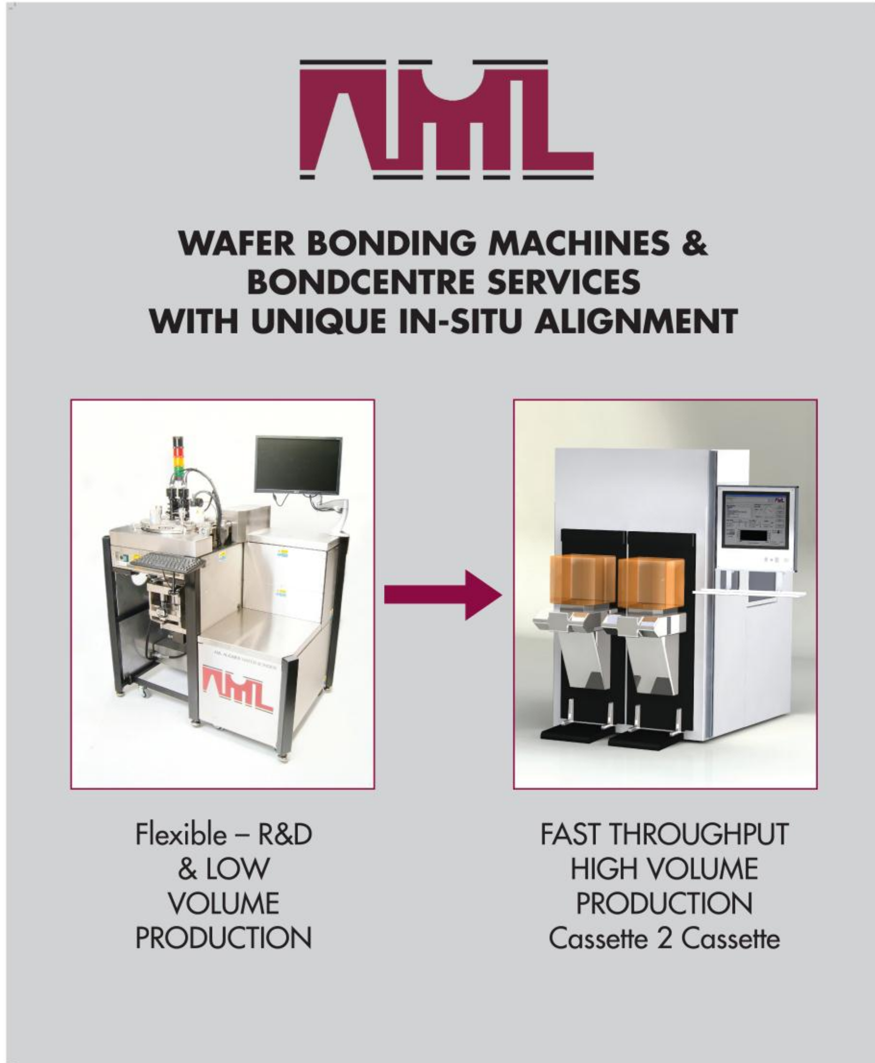
- Unique In-situ alignment system (X,Y,Z & θ)
- Up to 1 micron accuracy manual & Auto alignment
- Full automatic PC control & data acquisition,
- Application of High Voltage up to 2.5KV
- Temperatures up to 560oC,
- Forces up to 25000 to 100,000 N
- Self contained dry pumping system (Turbo & back pump) for vacuum up to 10-6 mBar
- Forced nitrogen cooling.
- 2” to 8” wafers (Depending on model chosen)
- RAD Wafer activation for low T bonding
- Water cooling
- **In-situ Chemistry!**
- Remote interrogation –via Teamviewer http://www.teamviewer.com

Optics: Visible, IR & NIR (for highly doped wafers & hot alignment)

Trend in MEMS to use highly doped wafers

Manual Load

Fully automatic

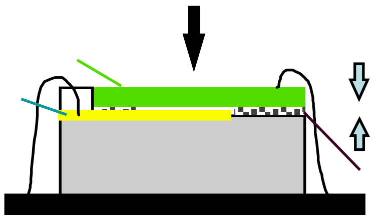


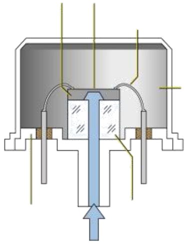
Robot Wafer Load

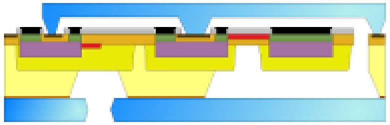
Fully automatic

Wafer bonding has found many applications in field of MST, MEMS, III-V, ICs & Optical devices:

- **MEMS devices - Pressure Sensors, Accelerometers, Microfluidics**
- **Vacuum encapsulation (absolute pressure, IR detectors…)**
- **1st Level Packaging to isolate package induced stresses.**
- **Wafer scale Packaging – MEMS & IC**
- **III-Vs e.g. high performance LEDs bonded reflector - heat sink**
- **3D Interconnects**
- **Temporary bonds for handle wafers (interlayer & direct)**
- **Advanced bonded substrates e.g. Si on Glass (SOG), GaAs on Si…**
- **Layer transfer - Smart cut**







Front End	Bonded Substrates Starting material	FAB Device construction	WLP 3D Packaging & Int	**Back End**

Wafer Bonding Machines & Services www.aml.co.uk MEMS, IC, III-Vs….

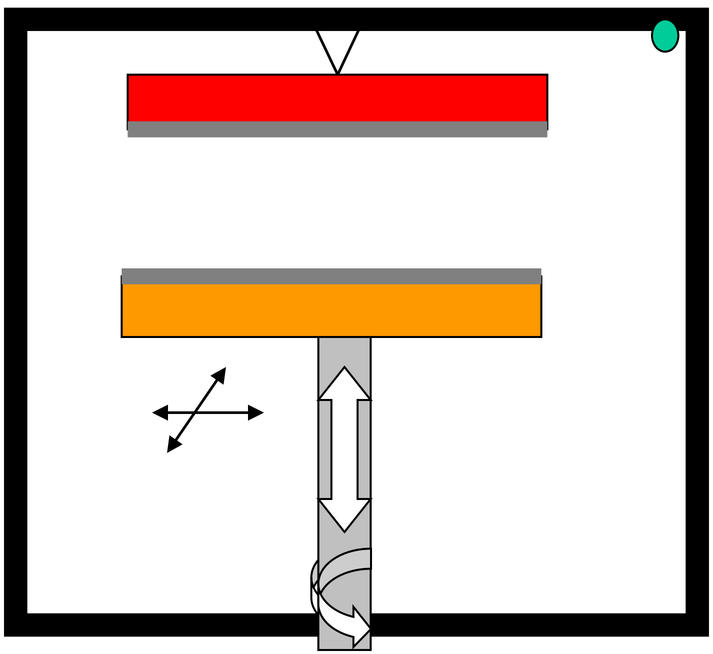
Difference between AML & EV/SUSS

- AML – align & bond in 1 machine, 1 process chamber
- EV/SUSS need 2 machines; align wafers in an aligner then transfer wafers via a jig to a bonder

AML Platform

Align & contact wafers **cold** or **hot** at bond OR Intermediate temperature (reduces expansion misalignment due to TCE difference e.g. Si-Sapphire

Allows out gassing at T and then align without waiting to cool down



EV / SUSS Method

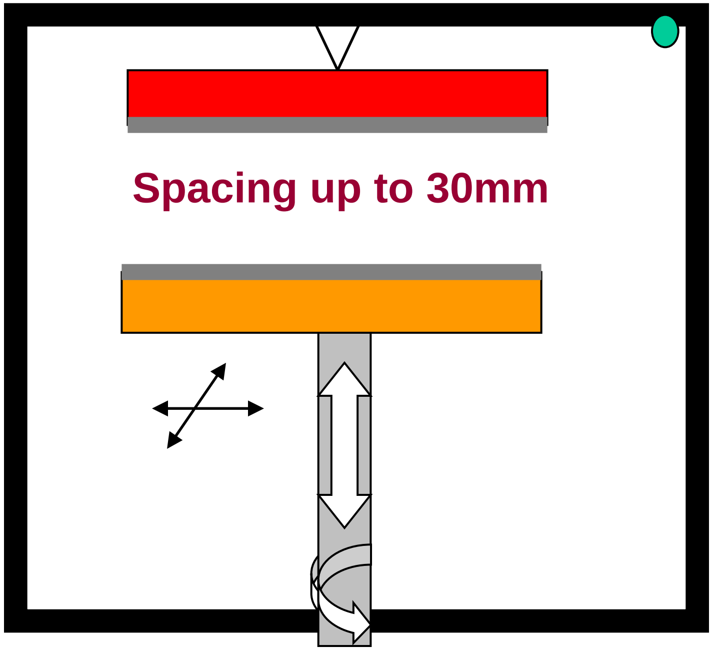
Wafers can ONLY be aligned and contacted **COLD**

Spacers ~100 microns thick

AML Platform

Able to hold two wafers at different Temperatures, can keeping 1 wafer at high T & keeping other e.g. CMOS wafer at <400C Getter activation

Outgassing other wafer before getter wafer is activated – increasing its life



EV / SUSS Method

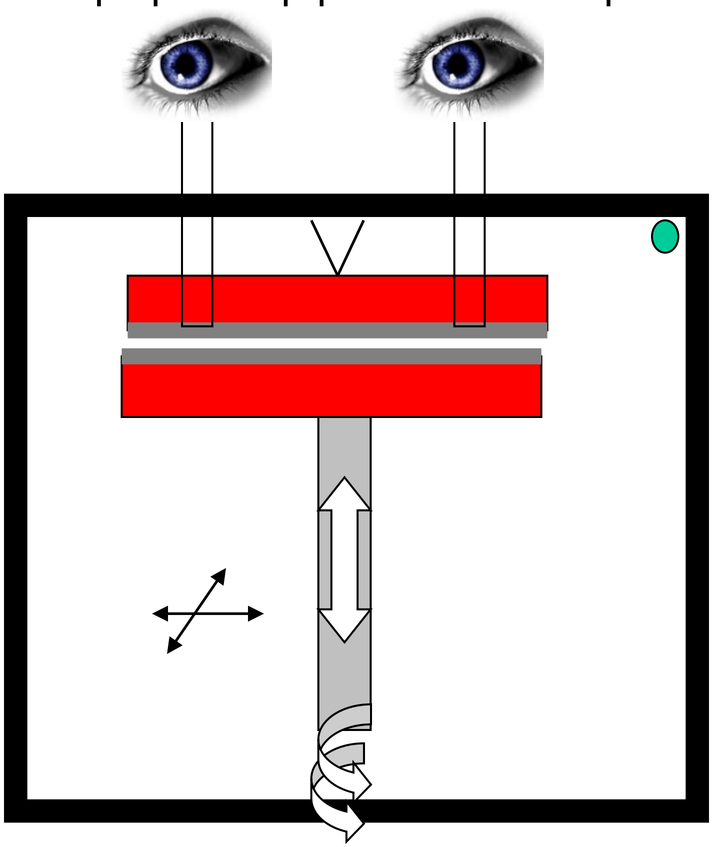
Impossible to keep wafers at different T

Spacers ~100 microns thick

AML Platform

Confirm alignment accuracy before committing to bond

Observe bonding process in real time to help speed up process development



EV / SUSS Method

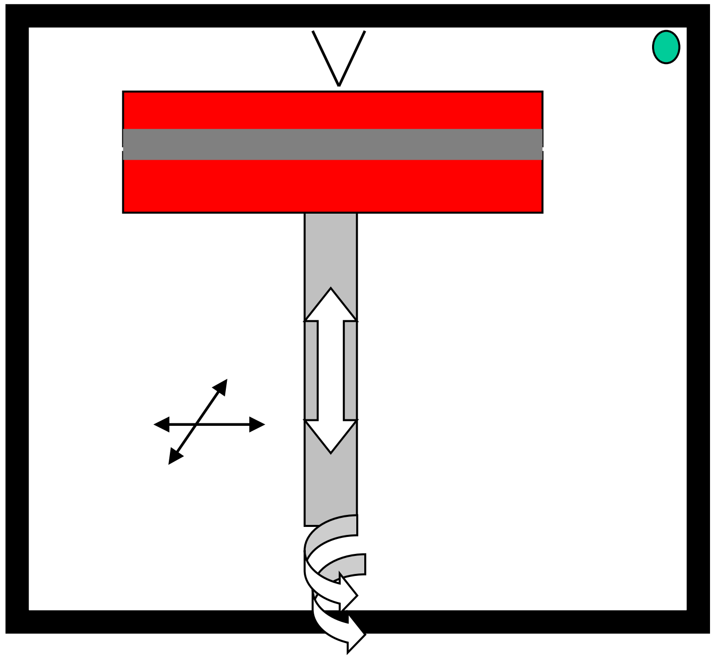
Impossible optics & bonding in different machines!

BLIND!

Spacers ~100 microns thick

AML Platform

No wafer movement between alignment & bonding – guaranteed alignment accuracy No Jig!
Esp when “soft flowing” interlayer is present e.g. adhesive or glass frit



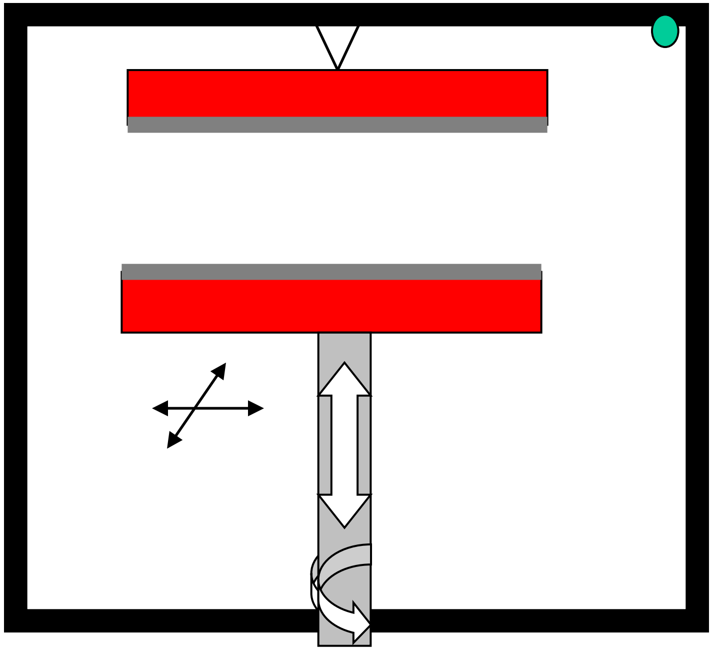
EV / SUSS Method

Remove spacers – wafers sometimes move - & you will not know!

Spacers ~100 microns thick

AML Platform

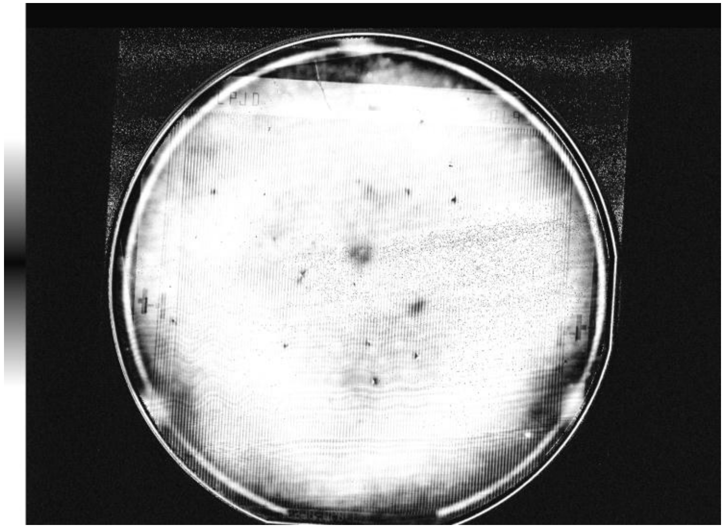
No flags touching bond surfaces so no damage or flag removal issues – Edge grip



EV / SUSS Method

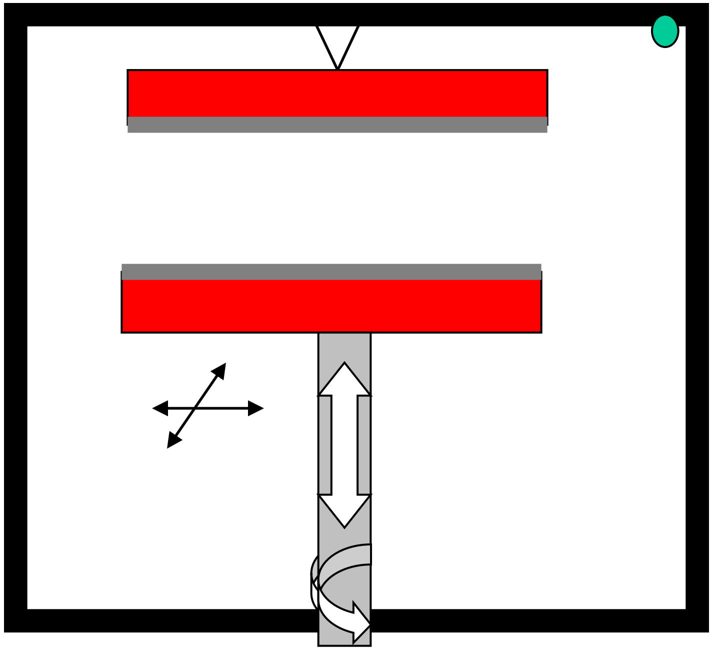
Flags touching wafer surface

Spacers ~100 microns thick



AML Platform

Simultaneous Alignment, Heating & fast Pumping



EV / SUSS Method

Heating & Pumping only

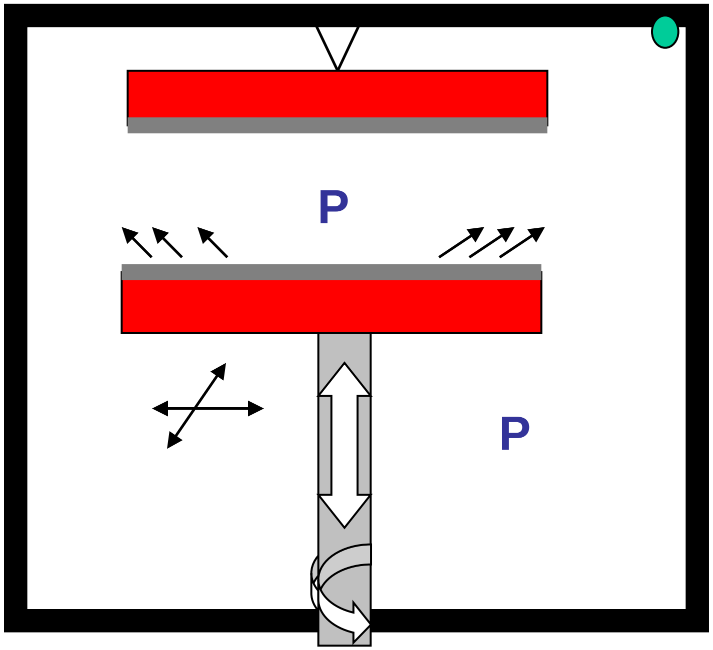
Pumping rate low due to trapped volumes

Spacers ~100 microns thick

AML Platform

Best system for vacuum encapsulation – **outgas with separated wafers - Frit**

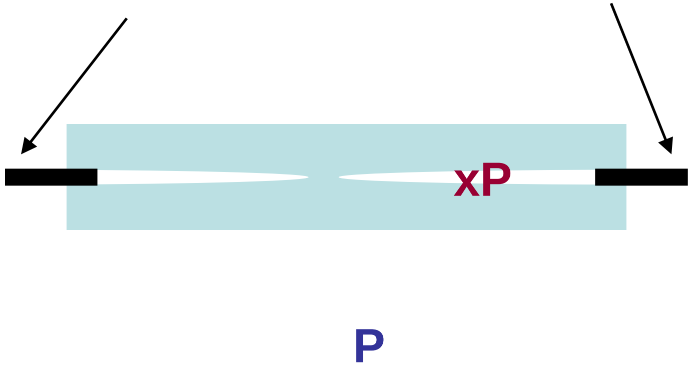
Reliable & known process gas conditions at the wafer surface i.e. Pressure (P) reading representative of P between wafers



EV / SUSS Method

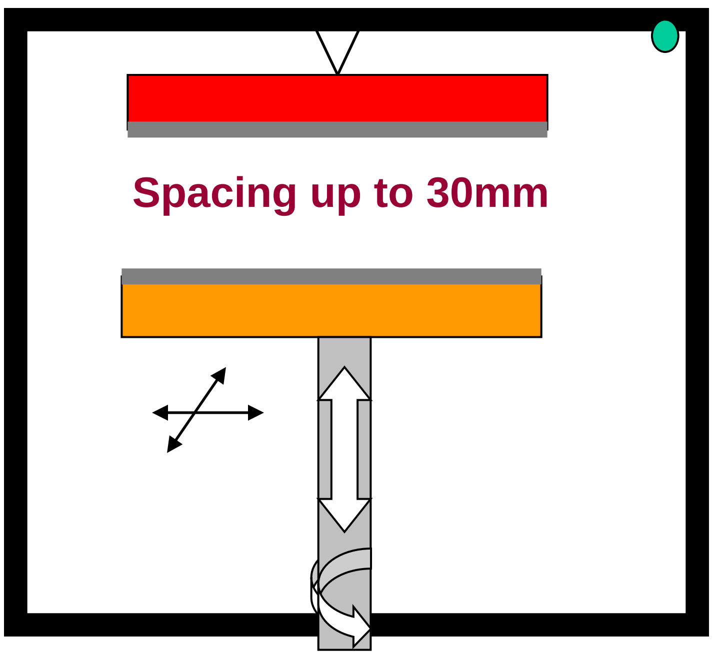
Unknown conditions at wafer surface. Pressure between wafers could be decades higher than measured in chamber

Spacers ~100 microns thick



AML Platform

Spacing allows in-situ processing or Chemistry



EV / SUSS Method

Impossible wafers in contact

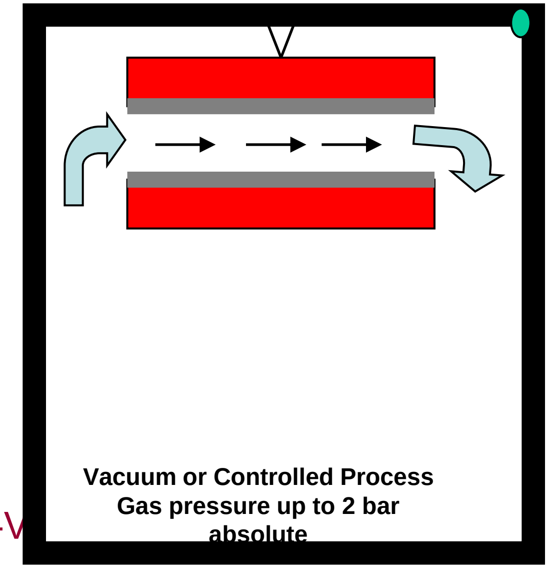
Spacers ~100 microns thick

Unique In-situ Chemistry CAB

- Only machine to perform in-situ **C**hemistry, **A**lign, **A**ctivate & **B**ond in 1 chamber without any handling between steps. Simple as **CAB**
- e.g. Metal Oxide removal on the wafers surfaces just before alignment & contact – with forming gas or Formic acid - due to wide wafer separation in bond chamber
- See paper Tyndall/UCL/AML 'Waferbond' conference, Chemnitz, Germany 6-8 Dec 2011

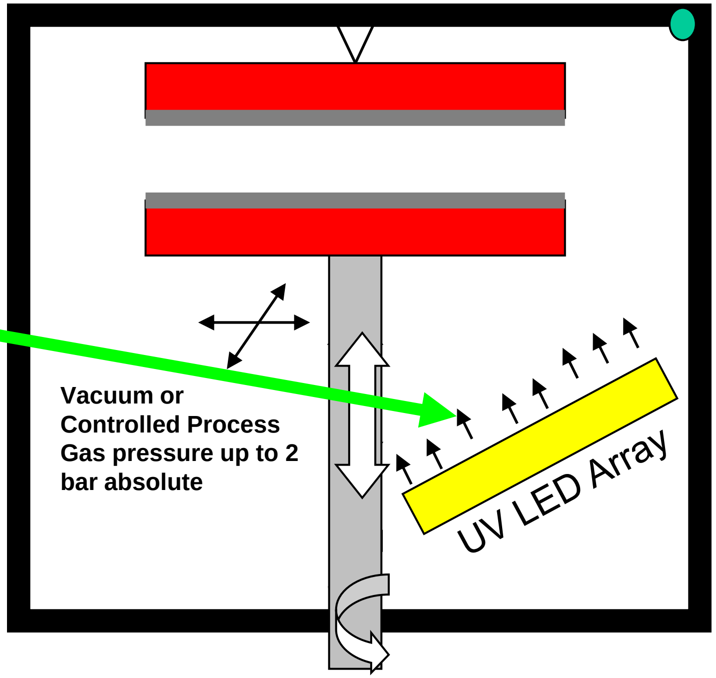
Many other possibilities; e.g.

Plasma etch Oxide before wafer contact



Summary of AML Uniqueness & Benefits

- Only machine that can align, activate & bond in 1 chamber without wafer handling
- Only machine with high accuracy alignment adhesive bonding - with in-situ UV cure in vacuum
- Ultimate Process Flexibility– Including Nano-Imprint – polymer embossing
- Unique In-situ Chemistry



New “Brute” 100kN High Force machine

Bonds that require high force

- AlGe eutectic bond – Application is encapsulation of CMOS MEMS for which the final aluminium metallization layer is used to define bond frames. The high force is required to break through the aluminium oxide layer to enable direct contact of aluminium (on CMOS device wafer) to germanium (on capping wafer) in order to form the eutectic. Typical force needed is 40kN

- Cu-Cu bond – Application is 3D interconnect. Again high force needed to break through copper oxide. Typical force needed is 30kN. (Note that AML’s in situ formic acid vapour clean reduces the required force to <10kN)

- Low forces can be used instead with CAB

RADICAL ACTIVATION
(enables low temperature Direct Bonding)

- **Inside chamber RAD activation option – activated surfaces are not exposed to atmosphere between activation & aligned contact**
- **Less surface roughening and more uniform activation than plasma**
- **No exposure of wafers to energetic ions --> can be used with sensitive device wafers**
- **Wider process time window for activation than with plasma- process time less critical**
- **In-situ system provides better reproducibility and therefore better process stability**

AML AWB Commercial Benefits

ECONOMIC

- **Lowest cost per bond & ownership – Machine cost (Align & Bond), speed…**
- **Small footprint**
- **No mask aligner required- free to choose best mask aligner for your 'mask aligning'. Leaves your mask aligner always available for photolith**
- **System is complete – no other equipment required**
- **Reasonably priced spares & support**

EASY

- **Very high reliability – minimal servicing – fast & simple to maintain**
- **Standard machines as well as custom options to suit specific customer needs**
- **Easy to use - system up and running & in use in minimum time.**
- **Process recipes easy to generate**

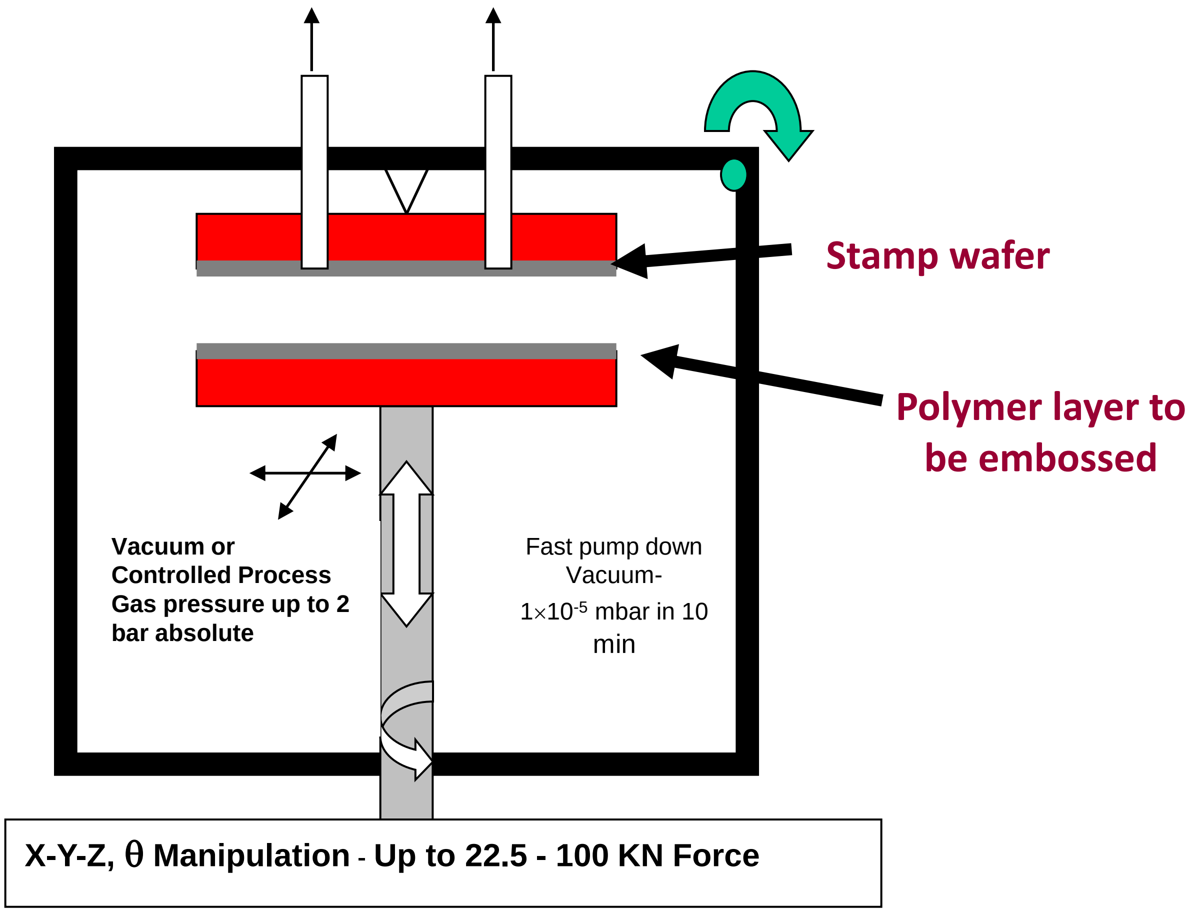
SUPPORT

- **Excellent process support via BONDCENTRE – fast response**
- **More than 25 years machine & wafer bonding process experience.**
- **Worldwide Machine base.**

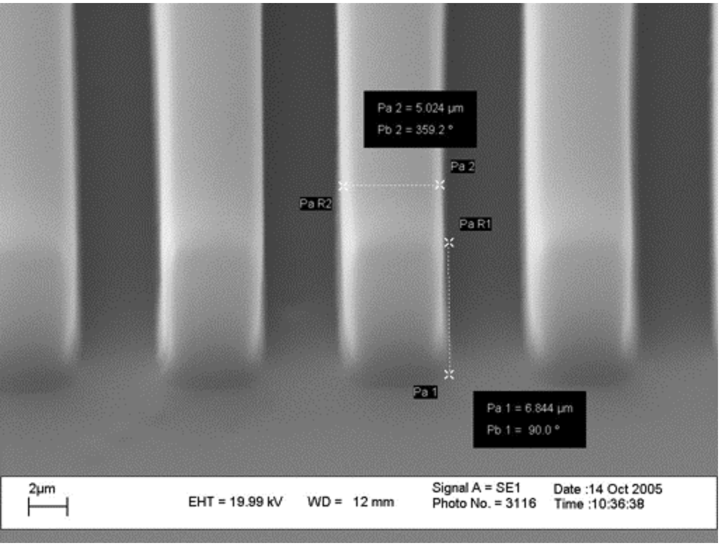
Embossing capability included for free!
3 Machines for the price of One! Aligner, Bonder & Embosser!

- AWB platform can be configured to also perform Aligned Hot Embossing of Polymers to form Micro & Nano structures.

- No extra tools or tool changes are necessary



New Polymer Micro-Nano Hot Emboss & Print tool



Applications: e.g.

Bio-sensors & Microfluidics

Nano arrays, Polymer electronics

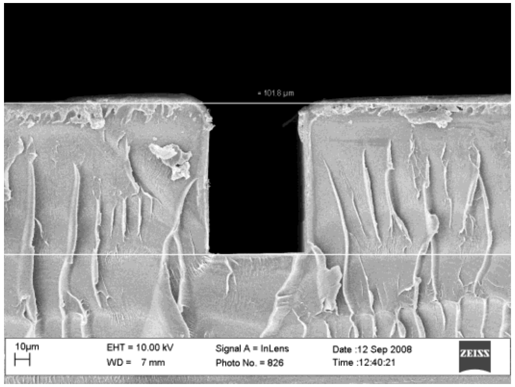
Polymers: SU8, PDMS, PMMA..

< 100nm structures

ALIGN, EMBOSS & BOND WITH ONE MACHINE

Based on same equipment platform

Outline Specification	
Force up to25kN	Stroke < 750 microns to 2mm
T </= 500 C	700N De-emboss force
Operation in Vacuum	micron alignment between stamp & substrate



Long stroke with high lateral precision for the formation of high aspect ratio embossed structures

Case History 1. Vacuum Encapsulation

- A large US company was having difficulties developing an aligned anodic bonding, vacuum encapsulation process

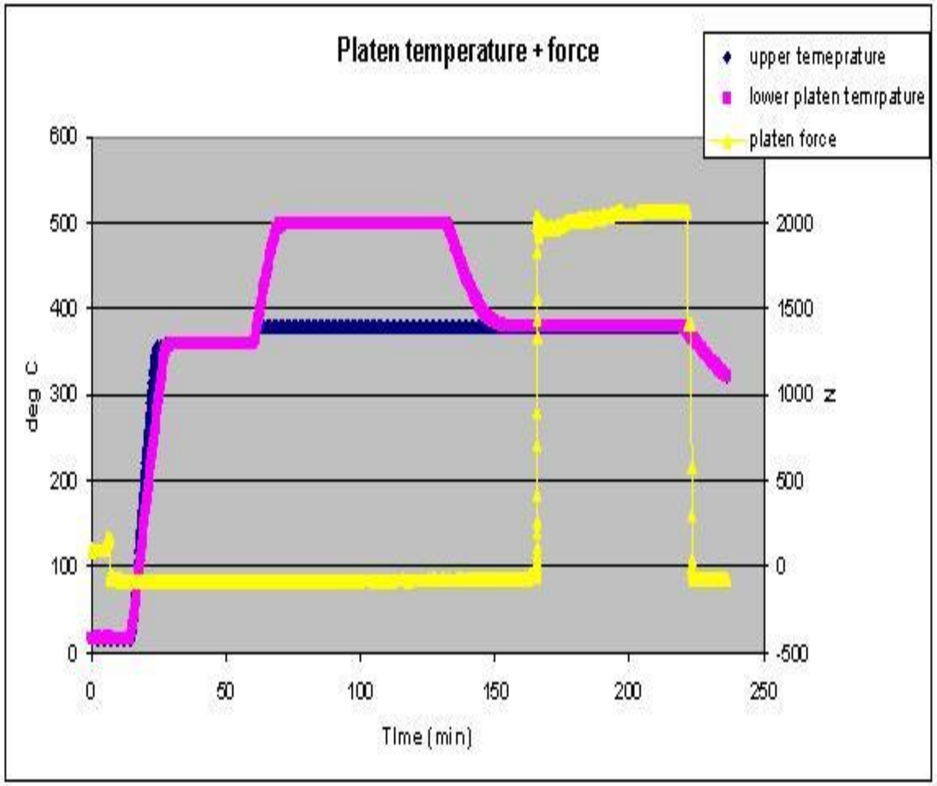
- Needed to maintain the wafers at two different temperatures (to thoroughly activate getter material at > 500C, while maintaining a temperature sensitive device wafer at below 400C)

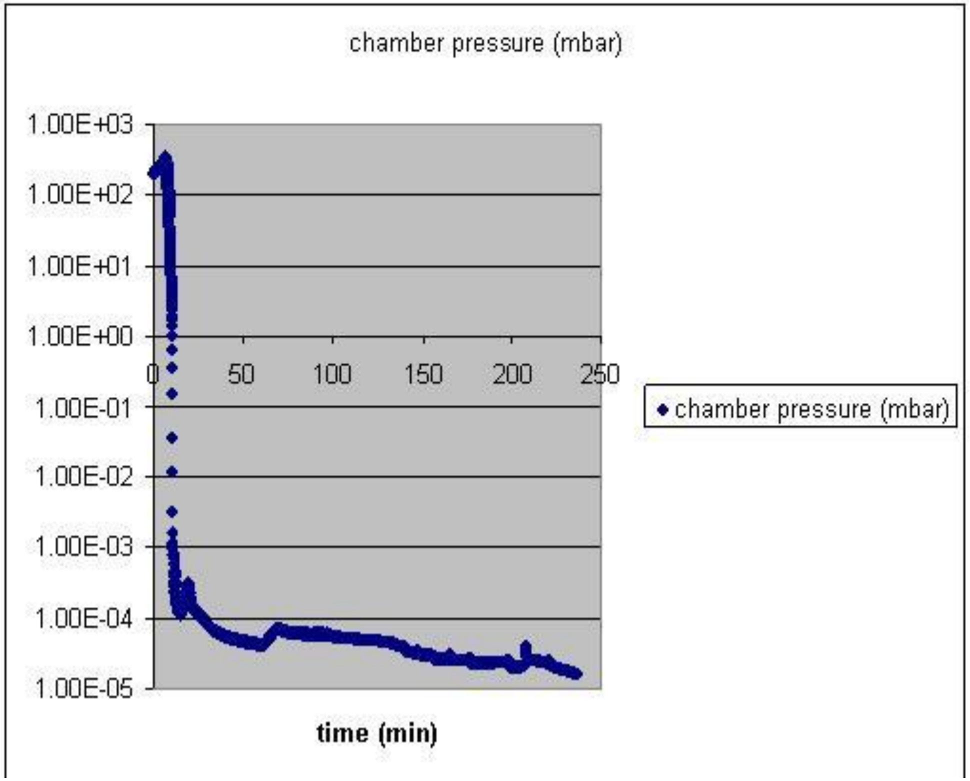
- An in-situ process with large large platen separation allowed this bonding to be successfully performed

- (in practice the second wafer could have be maintained at <100C)

- After the activation process the getter wafer was allowed to cool down to the bonding temperature without breaking vacuum

Case History 1 Getter Activation Temp –Time Profile





Subsequent testing of the device functionality indicated a cavity pressure of < 10 mTorr (<10-2mBar).

Two scenarios where you would want to maintain a differential temperature when processing a wafer containing a getter

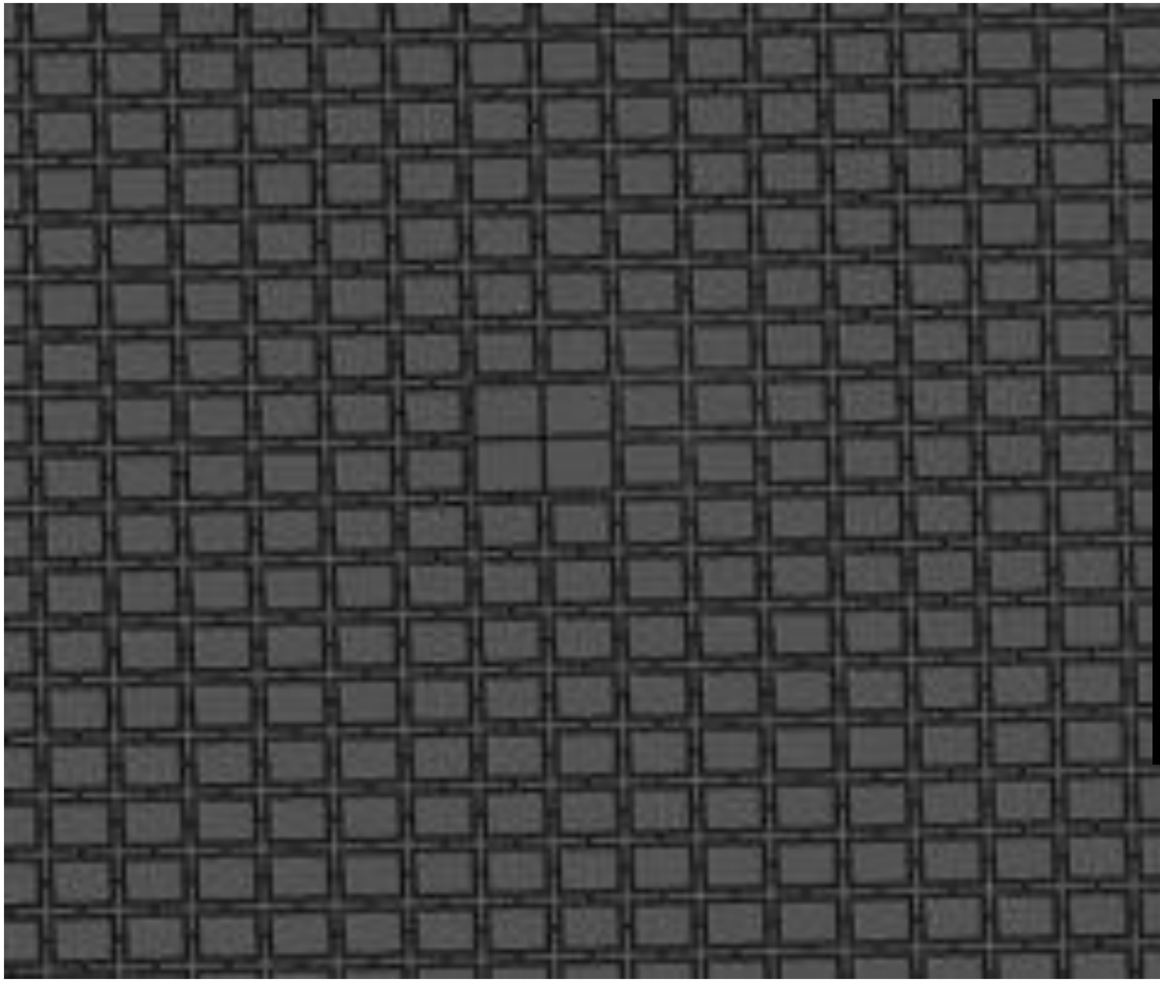
- If you have a temperature sensitive wafer which must not experience the temperature required to activate the getter then differential temperature can be used, with the higher temperature platen being used to activate the getter, whilst the temperature sensitive wafer is maintained at a lower temperature. Once activated the getter wafer temperature can be reduced and the two wafers bonded.

- If you have a wafer that exhibits a lot of outgassing you may want to prevent that outgassing from saturating the getter prior to encapsulation. Again differential temperature can be used, this time with the getter wafer being kept below the activation temperature whilst the other wafer is heated to higher temperature in order to perform outgassing. The getter wafer can then be heated to activation / bond temperature and the wafers bonded.

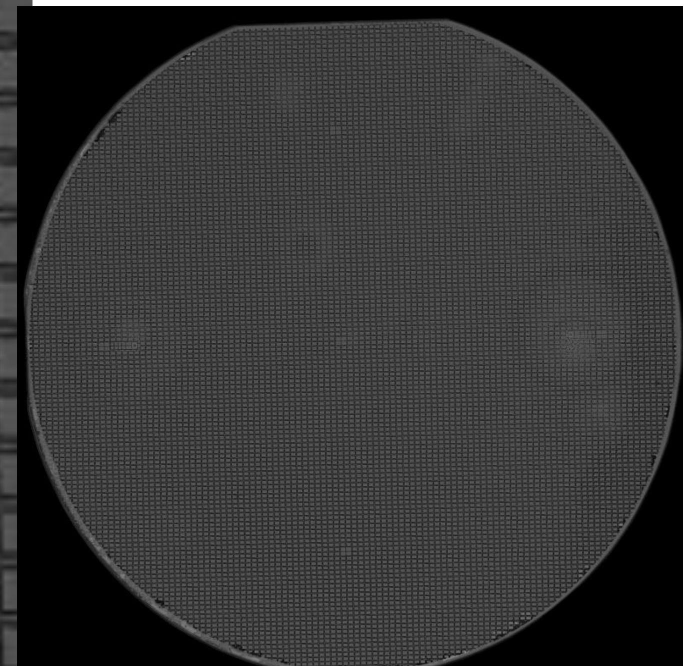
Case History 2. Removal of Surface Oxide

- A European Packaging company required a eutectic gold – tin bond with an in-situ forming gas treatment to remove surface oxide immediately before contacting the wafers.
- Wafers were widely separated in the bond chamber
- Good access of the forming gas to the oxidised tin surface.
- Reducing process is fast and efficient
- After the reducing process, chamber evacuated to <10-4 mbar for the bond.
- No opportunity to re-oxidise before the bonding process.

Scanning Acoustic Microscope Image of Eutectic Bond



Case History 2



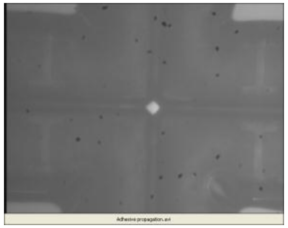
Example SAM scan of eutectic bonded wafer.
zoom image of approx. 15 mm × 15mm area.

Case History 3. In-Situ Observation of Bonding Layers

- A Chinese packaging company required a 200mm epoxy bonding process to be developed.
- In-situ optics enabled observation of epoxy spread as wafers clamped
- Allowed rapid process development - epoxy spread was controlled
- Avoided excessive bond line width, while creating robust bond-lines.
- Also optimised the in-situ time / temperature cure process
- Direct observation of the adhesive to see when the cure is complete.

In Situ Observation of epoxy spread during aligned bonding

Case History 3

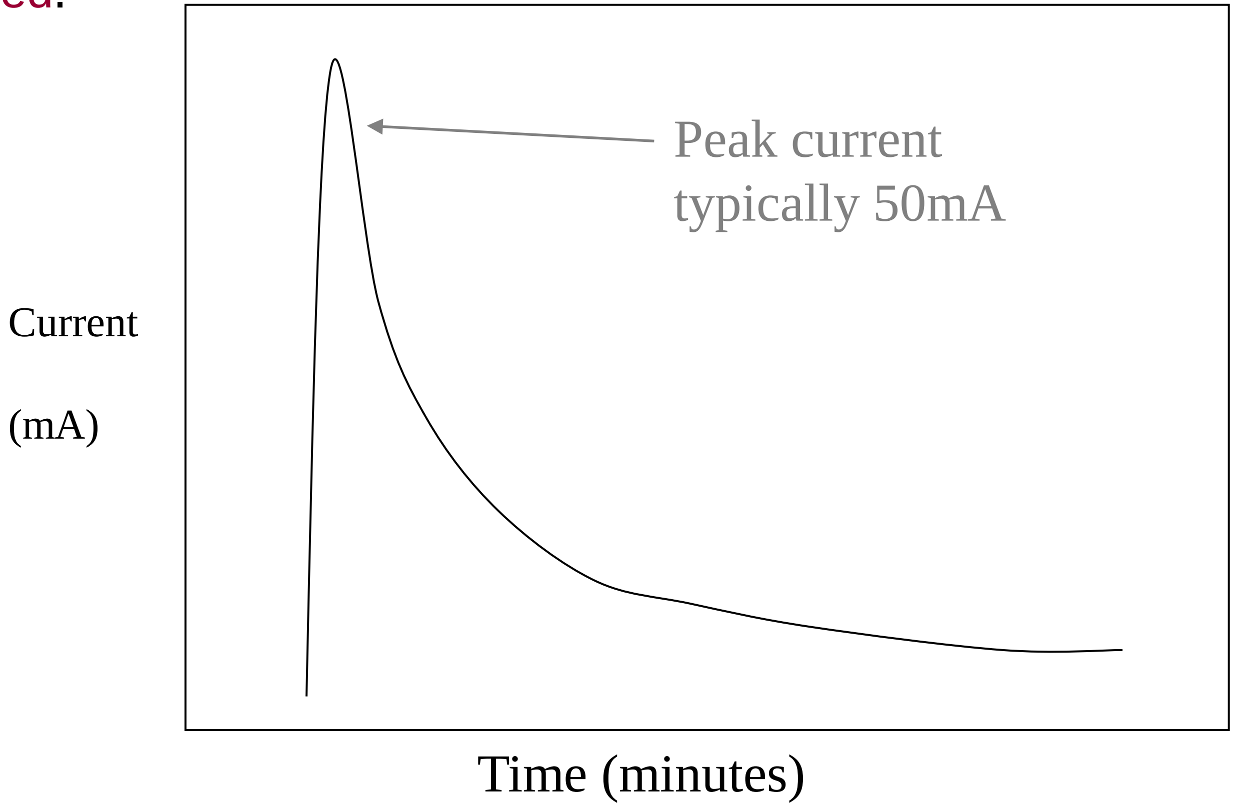


Case History 4. Control of Stress During Anodic Bonding

- A manufacturer of Gyrosocopes was achieving low yield due to large differences in temperature sensitivity for the devices.
- Thermal sensitivity is often an indicator of the degree of stress in the bonded wafers
- Traditional anodic bonding methods using voltage limited bonding can lead to large variations in stress across the bonded wafer pair
- By using "current-limited anodic bonding" the post-bond stress can be made much more uniform leading to improved device thermal stability

Case History 4 Typical current shape vs. time for voltage limited anodic bonding

The peak current can be several 10’s mA (for 100mm wafers) & if the voltage is ~1kV then several 10’sW can be dissipated directly in the wafer pair being bonded.



Consequences of the Current Peak During Anodic Bonding

Case History 4

- Because of the non-perfect flatness of the wafers, they will initially only be in intimate contact at selective points and the current will initially be concentrated here.

- The Joule heating that occurs results in parts of the bond interface being at higher temperature than intended, as set by thermocouples in the wafer chucks.

- Variations in local temperature at the time that the wafers become bonded can result in stress variations caused by the local differences in the differential thermal contraction during cooling, and different diffusion profiles of the various mobile ions in the glass.

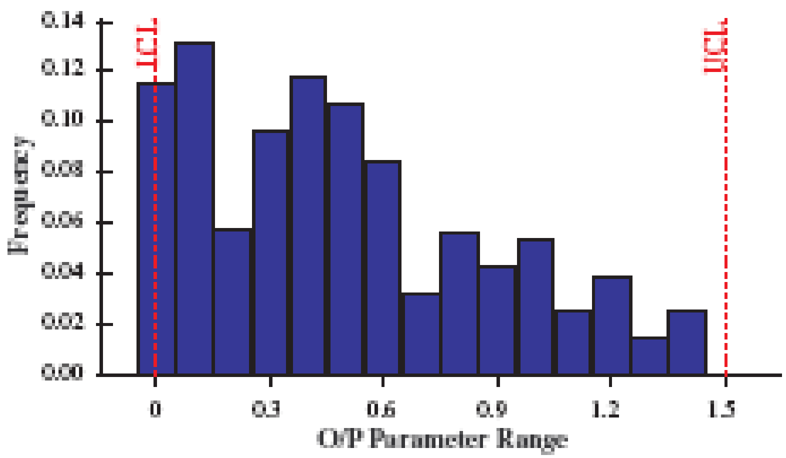
- The stress variations result in different temperature sensitivities for devices from various parts of the bonded wafers .

With current limited bonding the voltage is initially very low & then increases gradually as the bond progresses (see below) & the bond area increases thereby providing better control over temperature uniformity and hence device-to-device reproducibility.

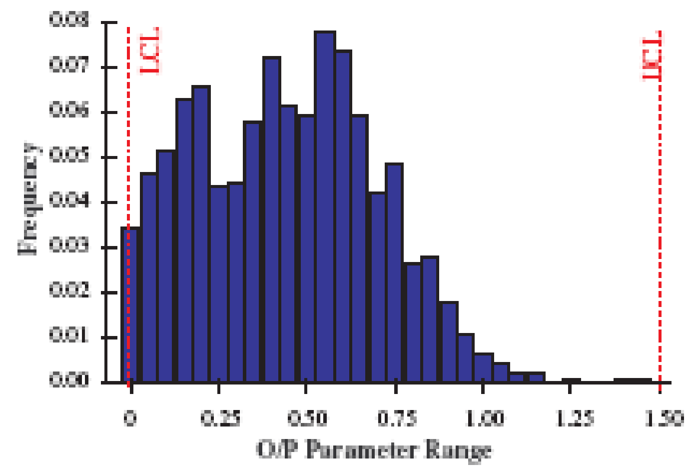
Improvements to Variations in Temperature Sensitivity of the Gyroscopes as a Result of Change to Current Limited Anodic Bonding

Case History 4

The improvements are shown in the Figures below which show the spread of performances in a key monitoring parameter for gyro’s made under voltage limited anodic bonding conditions (A) and current limited anodic bonding conditions (B)



(A)



(B)

Summary

- Wafer bonding is a strategic process (front end to back end) in MEMS, IC & III-V's, applications growing rapidly..
- AML platform ideal for flexible aligned wafer bonding for research to production
- AML BONDCENTRE process support – key if you are new to wafer bonding & WLP

BONDCENTRE SERVICES OFFERED

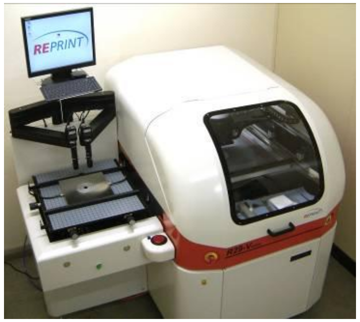
- Development of Wafer Bonding & associated Processes e.g. for many novel materials; silicon, glass, sapphire, strained silicon, InP, GaAs,…>25 years MEMS experience
- Wafer Bonding process selection & design for your application
- Commercial Wafer Bonding Service prototype to production & products e.g substrates
- Wafer Bonding Technology Transfer (inc Equipment) & Training
- Associated Processes (Pre & Post Bond)
- Applications knowledge for:

MEMS
Advanced Substrates
3D integration
Temporary Bonding
Smart cut layer transfer
Wafer Level Packaging
Vacuum Encapsulation
LEDs

Recognised experts & Funded by UK Government to provide services to Industry

Pre & Post Bonding Services & Equipment

- WAFER ALIGNER BONDERS 4 machines in Class 10
- Wafer METROLOGY; AFM, Ra, PROFILE, TTV
- WAFER CLEANING MEGASONIC & Activation
- NEW ‘RAD’ dry ACTIVATION
- INSPECTION: ACOUSTIC MICROSCOPE (SAM) & IR
- ELECTROPLATING: e.g. VIAS in Au, In, Cu & Ni
- SCREEN PRINT - GLASS FRIT/ADHESIVE
- Structuring e.g. Holes via POWDER BLASTING
- CMP



Also access via long term collaboration with CMF @ Rutherford to:

- PHOTOLITHOGRAPHY   DEPOSITION- PVD & CVD & FURNACES
- Standard ETCHING – DRY & WET
- WAFER SAW   WIRE & BUMP BONDING
- METROLOGY: THIN FILM, LINE WIDTH, SEM