Assembly & Packaging Solutions for 3D Miniaturised Integrated Products

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(Contributions from Duncan Hand, Jens Kaufmann, Jack Ng, Keith Sinclair, David Flynn)

What is it all about?

- A project to develop radically new ways of thinking for the end-to-end design, processing, assembly, packaging, integration and testing of complete 3D miniaturised/integrated “3D-MINTEGRATED” products
- Winner of EPSRC’s UK Grand Challenge competition
- The vision is a momentous departure from the production of silicon-based "microsystems" whose processing derives from the flat-land of semiconductors
- The project is very large, a £9.2M 4-year programme involving 7 Research Institutes and 23 companies
- With 50 Man/Years of research, an equipment spend of £1.1m, and an existing equipment asset base of £7m, this is big!

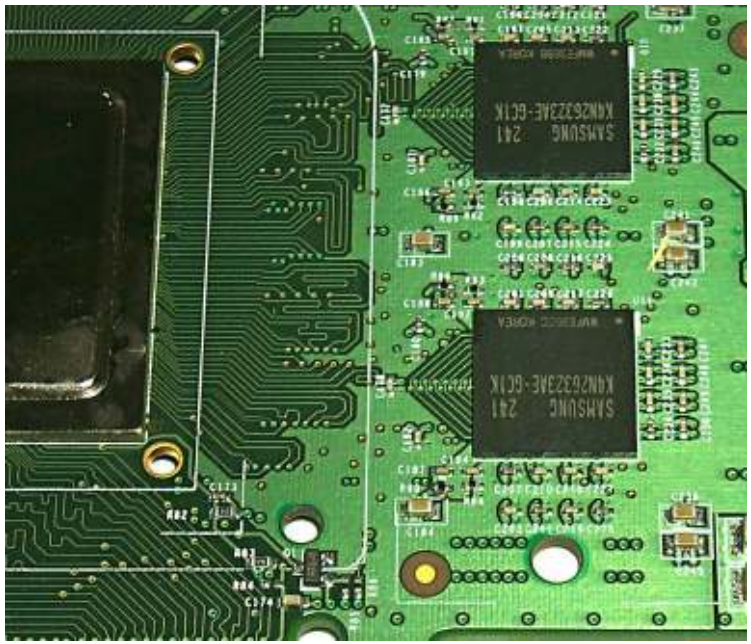
Outline of the talk

- DEPOSE:
  - Megasonic assisted filling of blind vias using pulse reverse electroplating (Jens Kauffman, David Flynn).
- WRITE:
  - Direct UV-writing of metal tracks onto polyimide (Duncan Hand, Jack Ng).
- CURE:
  - Variable frequency microwave curing of paste material for encapsulation and interconnects (Keith Sinclair).

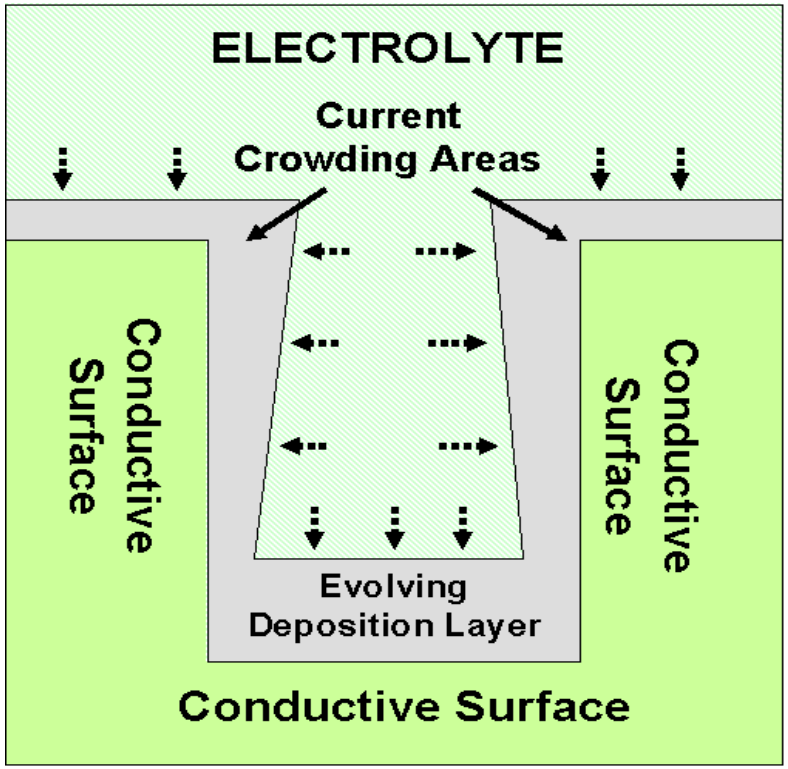
DEPOSE

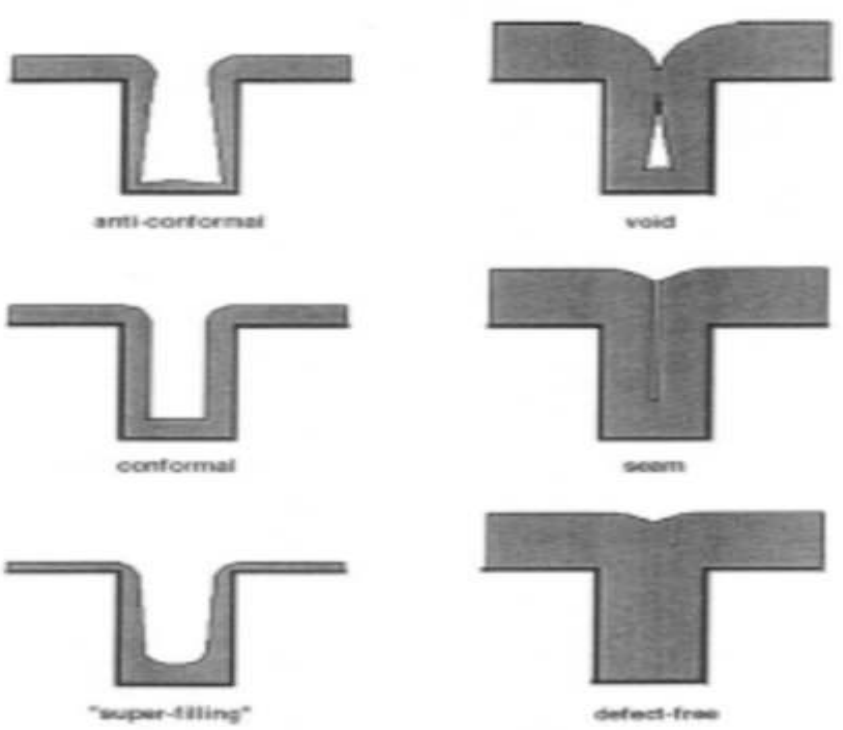
Motivation

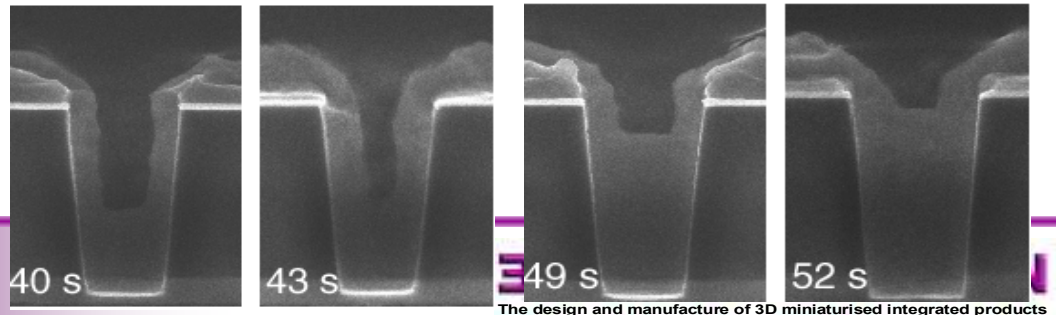
- Create a new process that permits the optimum filling of high aspect ratio blind vias in Printed Circuit Boards (PCB).
- Combination of megasonic agitation and/or pulse reverse electroplating.
- The technology can be used for enhanced development of HARMS



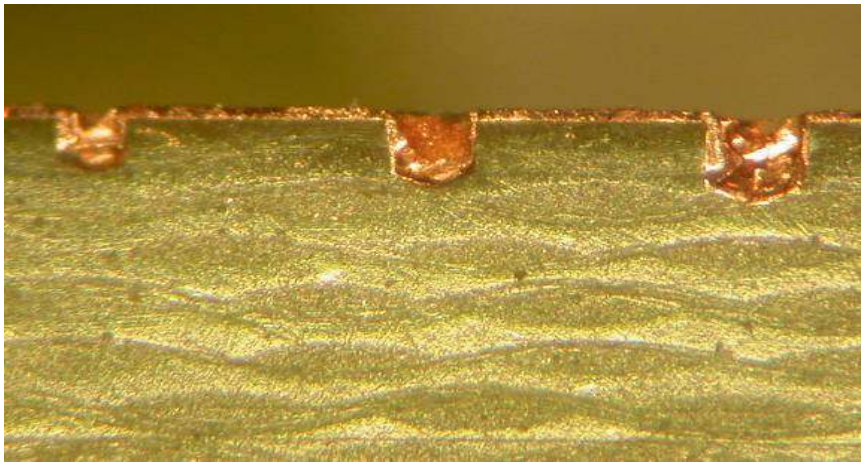
Filling of vias







Filled vias



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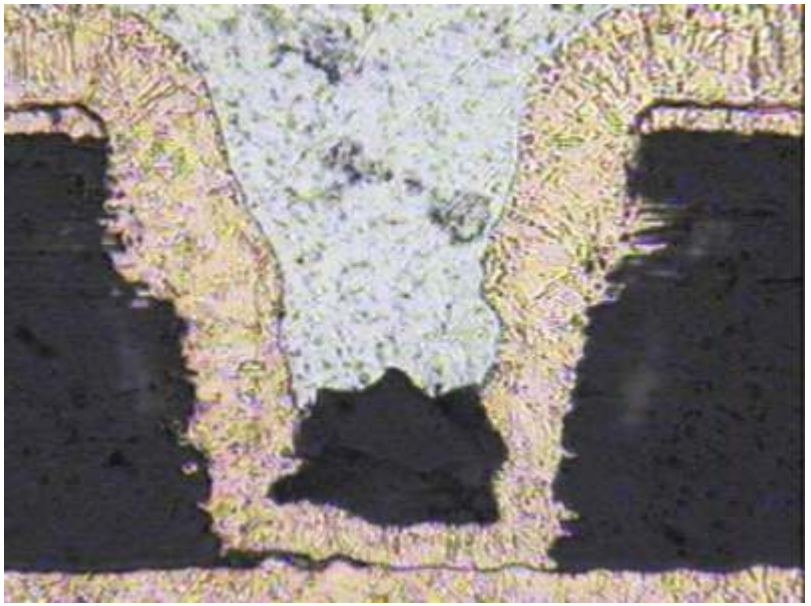

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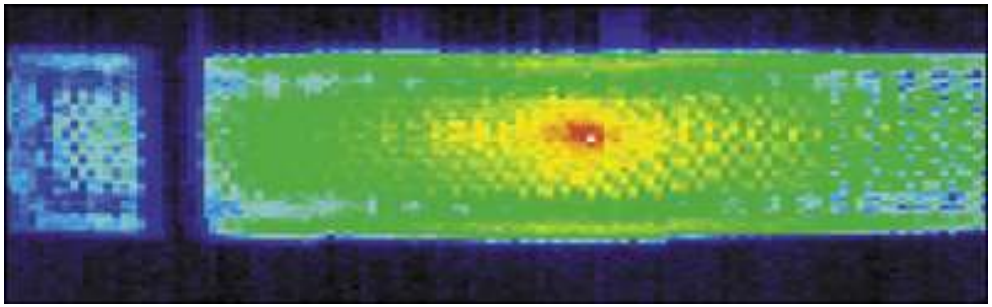


Thermal trace

Motivation for enhanced agitation

$$E = E^{o} + \frac{RT}{z_e F} \ln \frac{a_{Ox}}{a_{\mathrm{Re}\,d}}$$

Electrical potential
of an ox-red chemical reaction
Increase activity (concentration)

$$a_{M^{z+}} = \gamma \cdot c(M^{z+})$$

Increase ion concentration, *c*, near
Reaction boundary surface

$$\frac{dc}{dx} = \frac{c_0}{\delta}$$

Nernst diffusion layer equation
Decrease δ diffusion layer

$$\delta_{acoustic} = \left(\frac{2\nu}{\omega}\right)^{\frac{1}{2}}$$

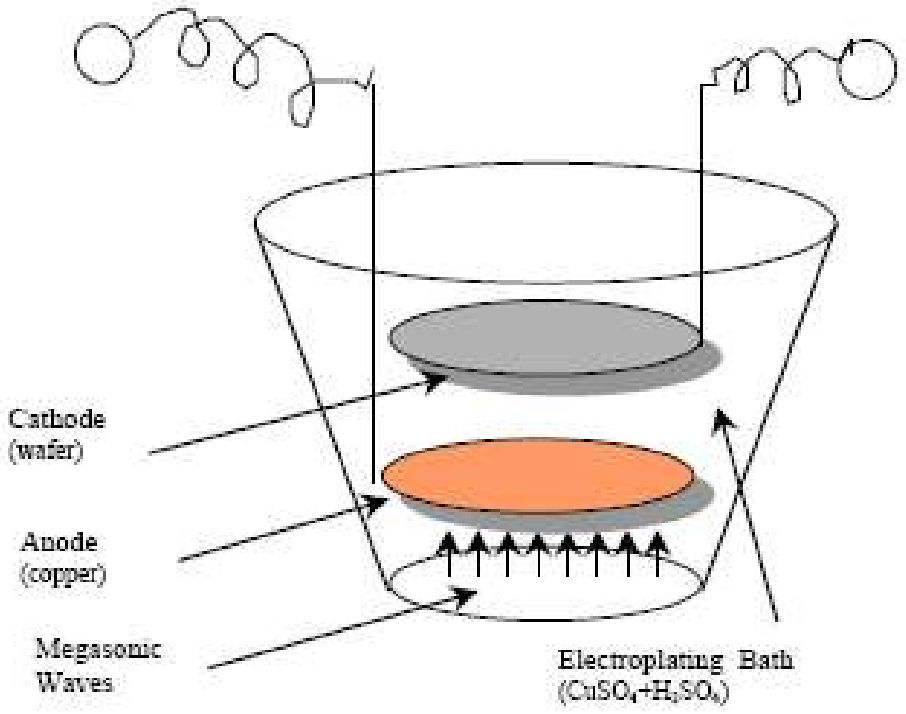
Acoustic streaming

$$\delta_{Hydrodynamic} = 0.16\left(\frac{\nu}{Ux}\right)^{\frac{1}{7}} \cdot x$$

For laminar flow

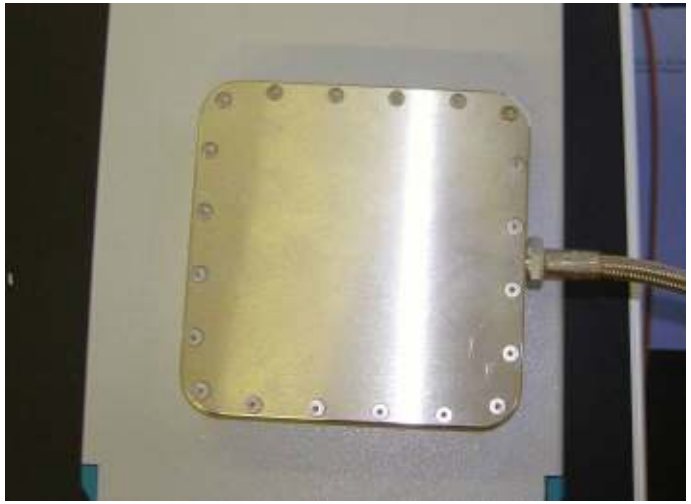
Megasonic agitation

- Megasonic agitation is similar to ultrasonic agitation but with a frequency in the MHz range instead of KHz frequency



Experimental set up

Megasonic generator



Megasonic Transducer

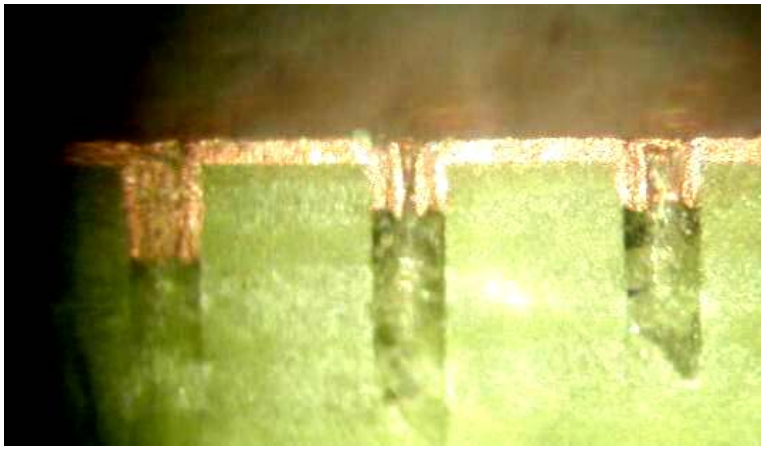
Output power	500W
Output power adjustment	App. 30% - 100%
Frequency	1MHz
Transducer active area	100x100mm; completely continuous active area
Transducer array	Special PZT-Piezoceramic (Butterfly-Technique)

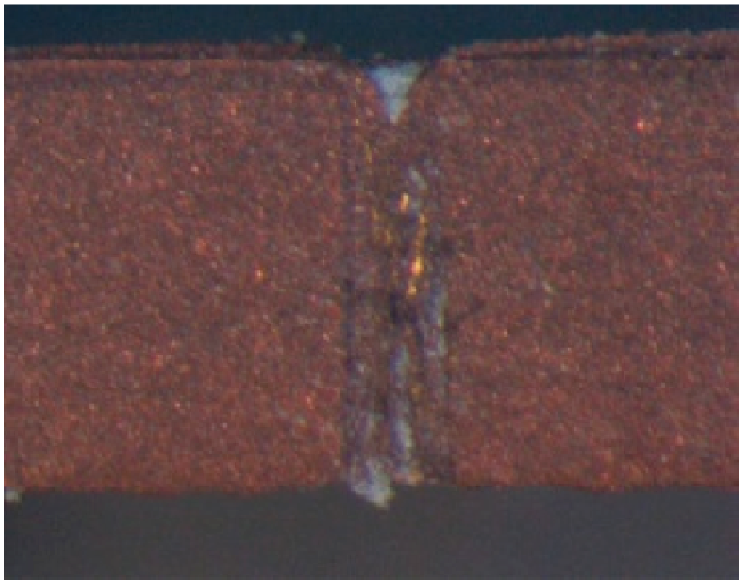
Initial results (with DC !)

Parallel growth within the via hole

Aspect ratio up to 2:1 limited by the insufficient seed layer from the manufacturer of vias

Aspect ratio of 6:1 for through vias (1.6mil board). Interesting concept for thermal plugs.



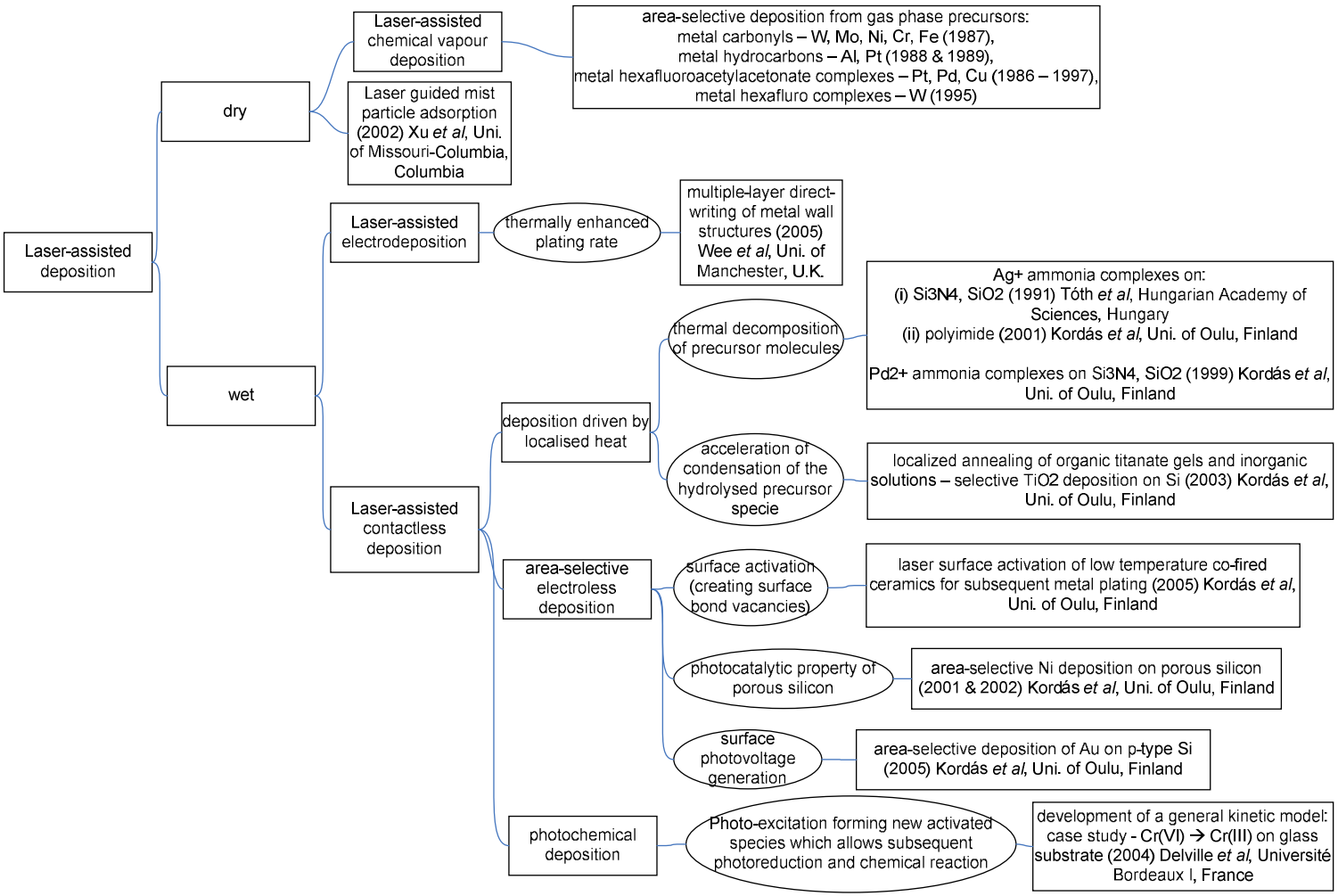


WRITE

Motivation

- Directly deposit metallic tracks without seed conductive layers to reduce processing time and costs.
- Possibility to achieve nano-scale metallic tracks.
- Possibility to write onto 3D surfaces.
- To be placed onto multiple DOF high precision placement machine.

Laser-based deposition processes

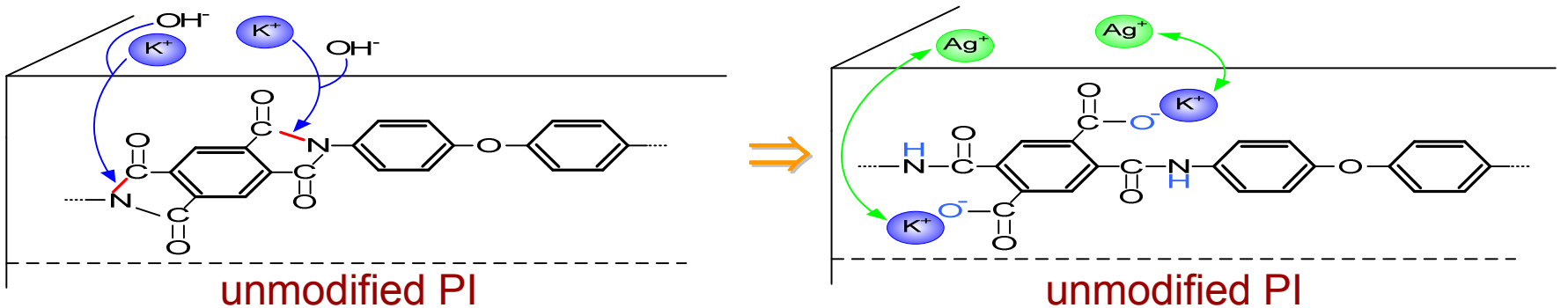


Process Overview

- Laser-induced *photochemical process* (as opposed to a thermal process).
  - No ablation / damage to the substrate or integrated device.
  - Minimising diffusion of deposit (due to heat).
- Substrate pretreatments:
  - Simple immersion in non-hazardous, low cost chemical solution.
- Writing:
  - Low power UV diode laser – low cost.
  - Non-contact writing process in air atmosphere – versatilability.
  - An assisting photochemical functional polymer coating required – low cost, water soluble material; deposition rate enhanced.
- Production line:
  - Samples prepared after each stage can be stored for a long time (weeks) before carrying out laser writing or electroless plating.

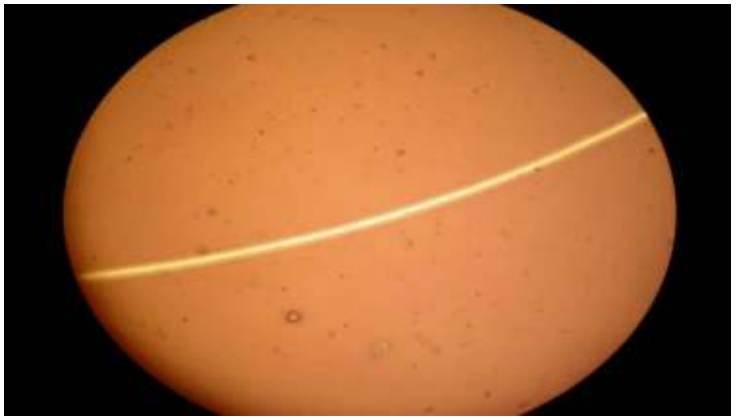
Alkali Treatment and Ion-Exchange on Polyimide

- KOH treatment breaks open imide ring in the polyimide (PI).
- Immersion in $AgNO_3$ exchanges the cations.



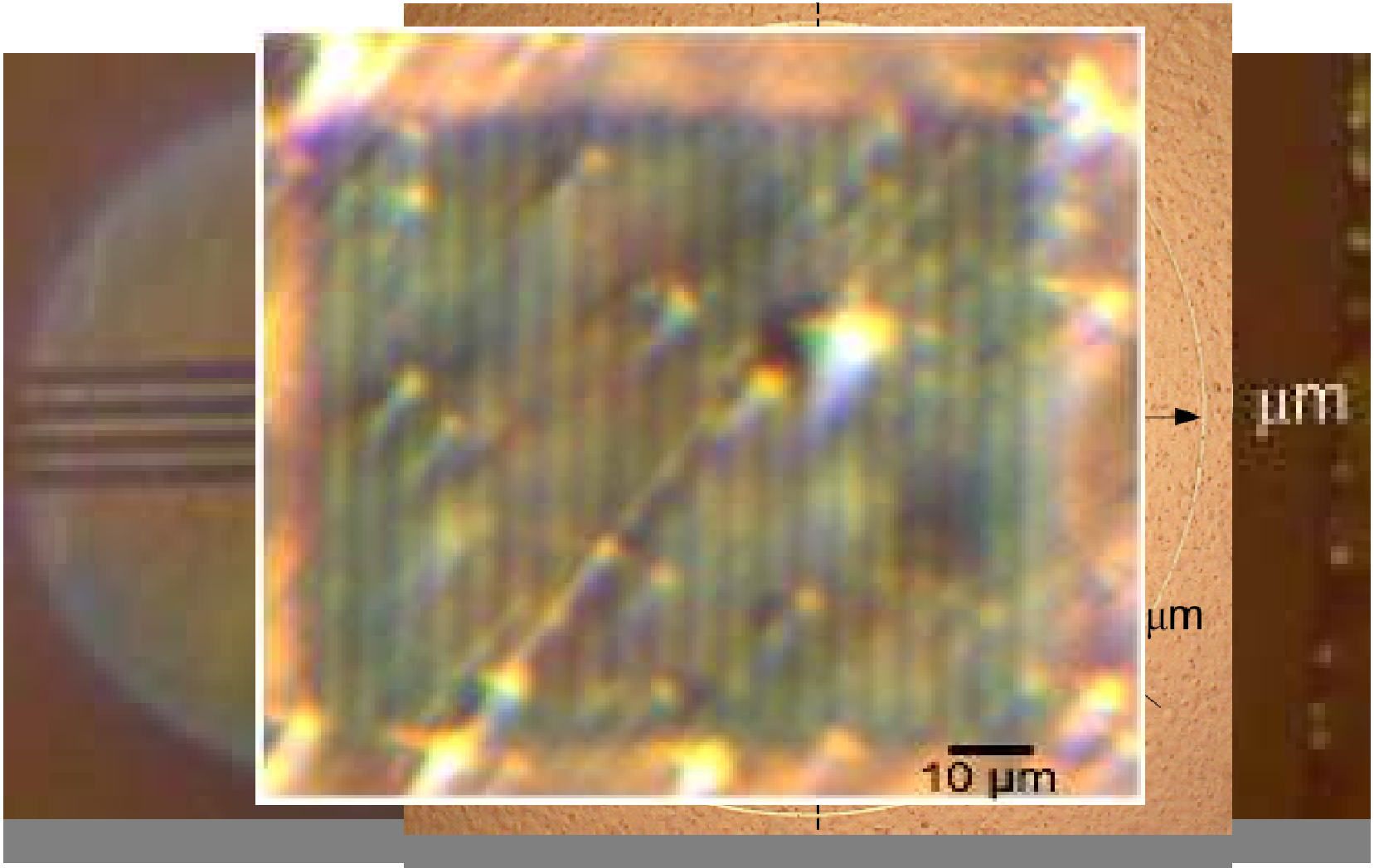
- Ag^+ and K^+ exchanges at a 1:1 ratio.
- Ion loading (nmol cm^{-2}) and thickness of modified layer (μm) are linearly proportional to KOH treatment time (min).
- Conductive Ag film can be photodeposited given high enough Ag^+ loading. Otherwise discontinuous Ag islands are formed which can serve as seed for subsequent electroless plating.

Metal tracks writing on 2D surfaces



Process carried out with a 375 nm laser, power = 15 mW, spot size radius ~ 10 μm, scan rate = 74.5 μm s^{-1}.

Achieved line width



3D Responsive Manufacturing in Action

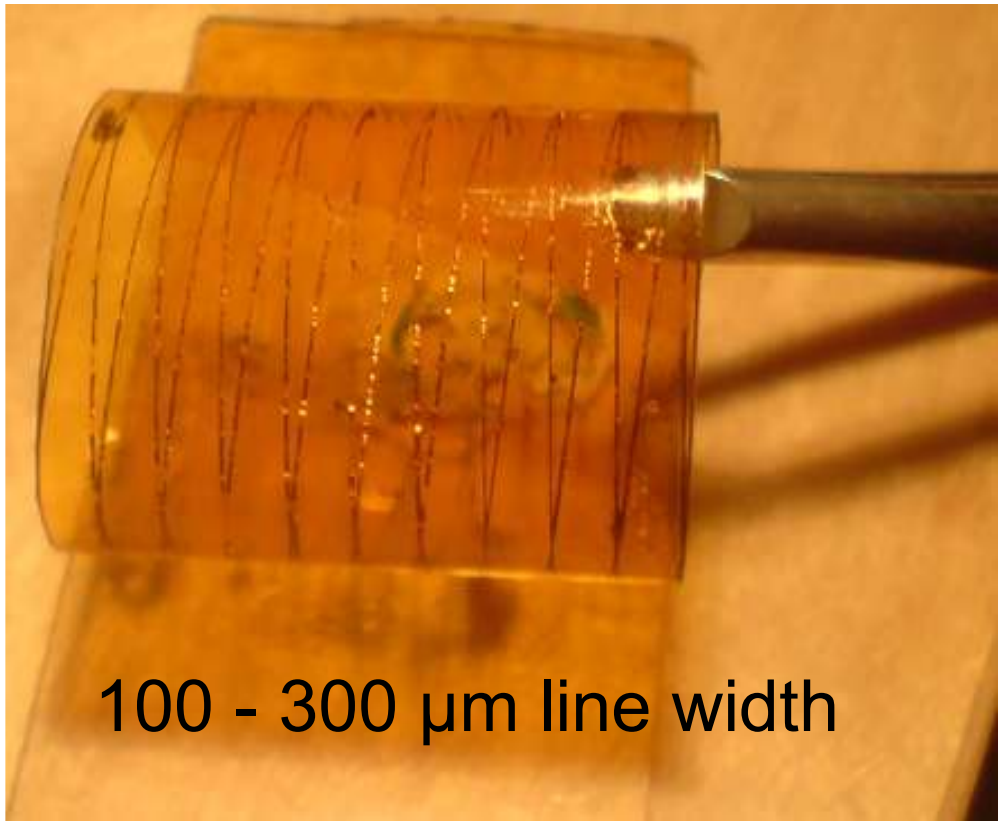
(Click on picture to start movie.)

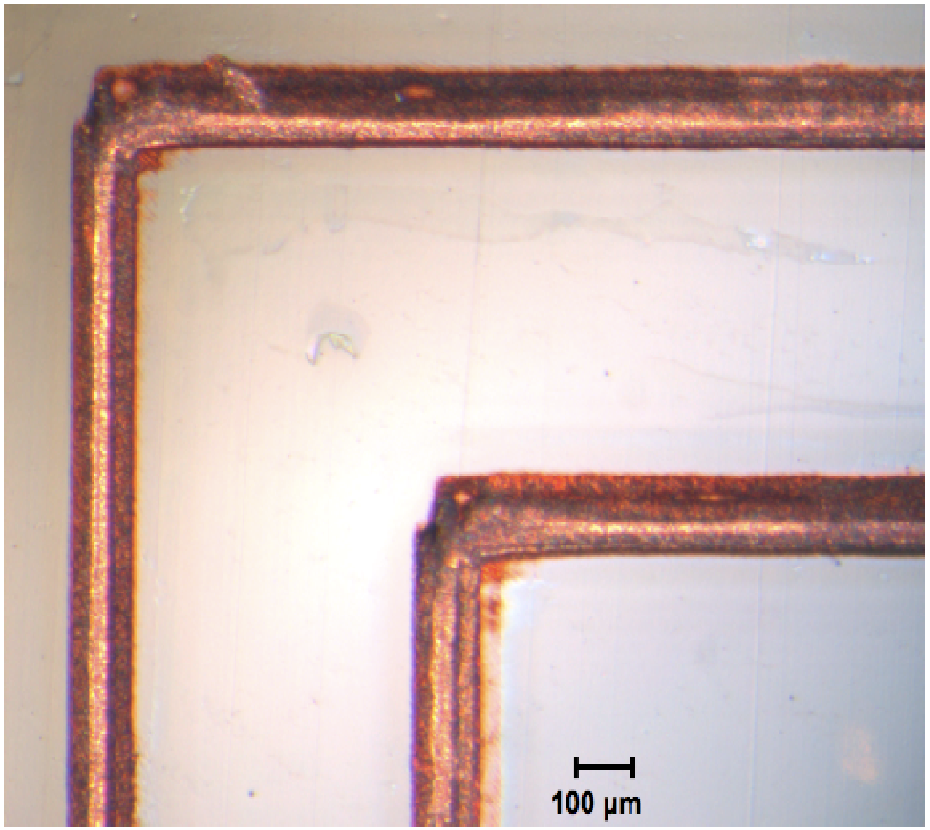
- Rotation speed = 9 rpm.
- Translation speed = 60 μm s-1.

Au/Ag helix track on polyimide rod

- Line width ~ 15 μm
- Smaller line width down to a few μm can be achieved with optimized optics.

Achieved line width





CURE

Variable frequency microwave curing

• To manufacture a partially open, variable frequency microwave (VFM) oven.

• The device configuration is suitable to be installed on the arm of a die or flip-chip bonding machine for micron accuracy alignment capability.

• The main design features are simultaneous alignment, curing & bonding, multiple selective 'hot-spot' heating points, superior control of position of the 'hot-spots' of energy & sequential curing leading to fast packaging.