Laser Micromachining of Transparent Materials

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Outline

- Oxford Lasers
- Principles of Laser Micromachining
- Machining Transparent Materials
- Examples of Machining Transparent Materials
- Applications

Oxford Lasers Ltd

- Didcot, Oxon (UK), Boston (USA), Paris (France)
- Founded in 1977 (Excimer and Copper Laser Manufacturer)

  Oxford University spinout (inventor gas preionisation technique)
- Two divisions: (a) Laser micromachining

  (b) High-speed imaging
- Markets: microelectronics, solar, healthcare, automotive, biomedical, telecoms etc etc

We offer:

- Turn-key Laser Micromachining Systems
- Sub-contract Laser Micromachining Service
- Proof-of-Concept Trials, Contract R and D

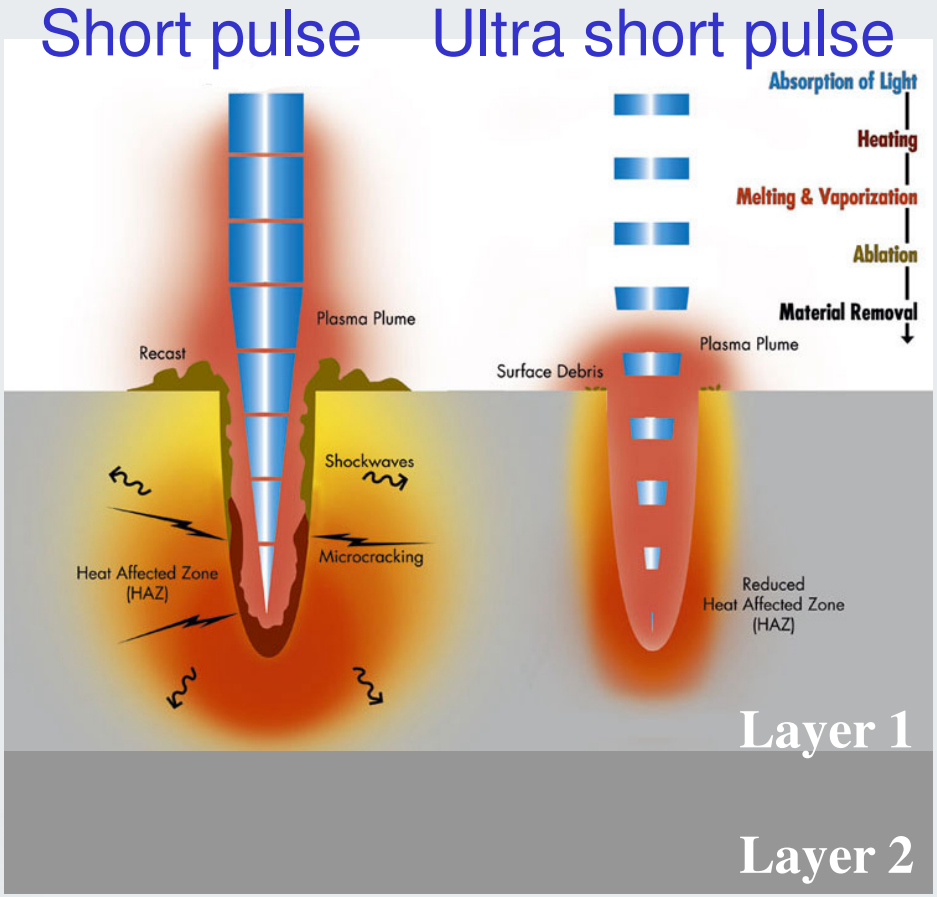
What is Laser Micromachining?

"*Laser micromachining is an advanced 2.5D microfabrication process using lasers as non-contact tools for precision material removal, in ambient conditions, to produce any feature geometry on virtually any material surface with micro or nanoscale resolution*"

Importance of laser pulse duration

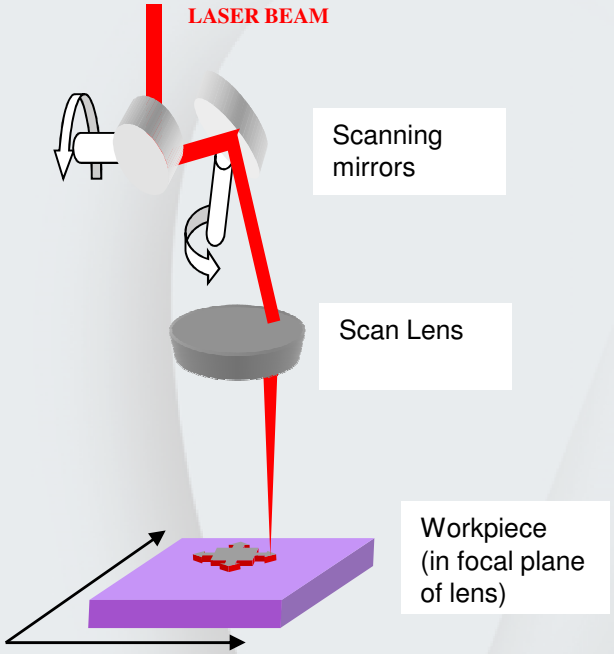
- Short pulses (>10ns) associated
  - Thermal ablation processes
  - Prolonged laser+plasma heating
  - Beam attenuation losses
  - Melting and recast debris (evident)
  - Heat affected zone, HAZ (hidden)
  - High removal rates

- Ultra short pulses (<0.1ns)
  - "Cold" ablation processes
  - Shorter plasma lifetime
  - Rapid energy deposition (less debris)
  - Deterministic ablation thresholds
  - Restricted HAZ
  - Low removal rate

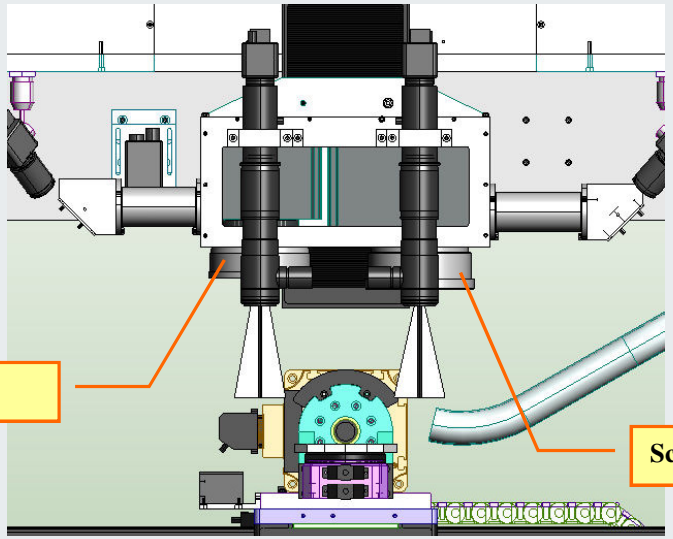


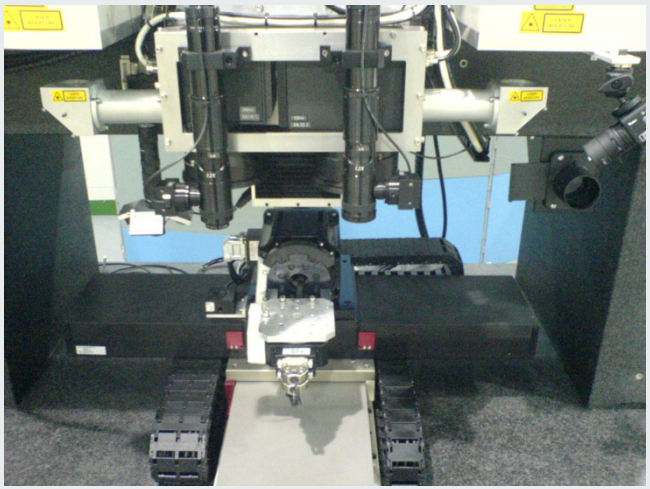
The laser pulse duration determines the **"heat spreading"** in the material, crucial here is a lack of heat spreading for thin-film ablation.

What do I need for Laser Micromachining?



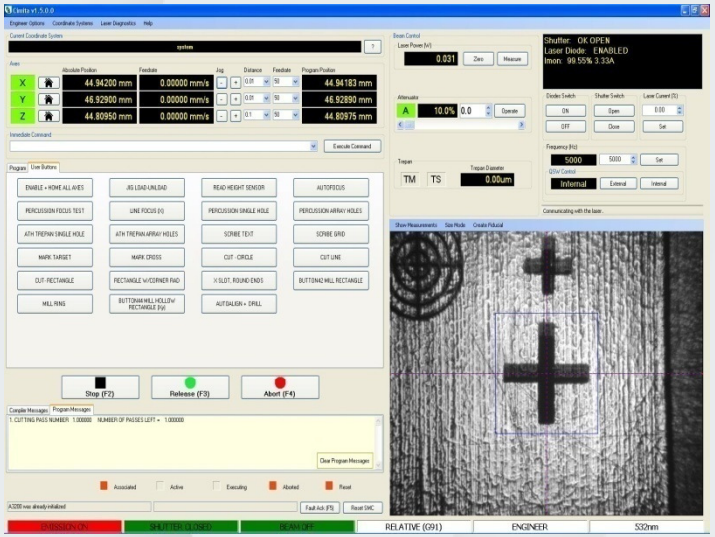
High Speed Galvo
+
Linear Axes
+
Rotary Axes (3D)



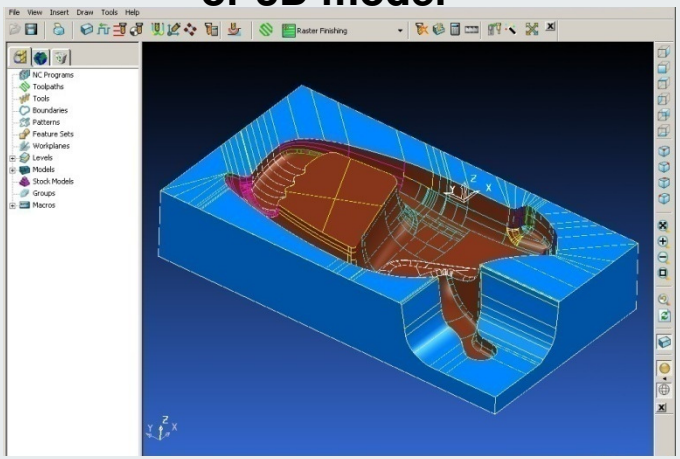


System Requirements

Cimita

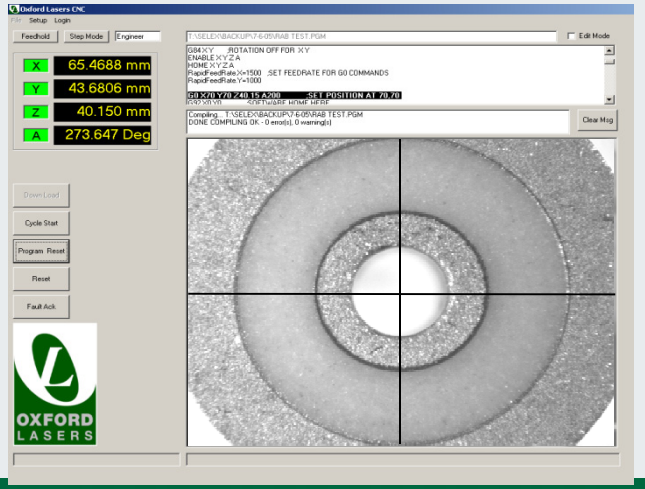


Import 2D drawing or 3D model



CAM Software

User Interface

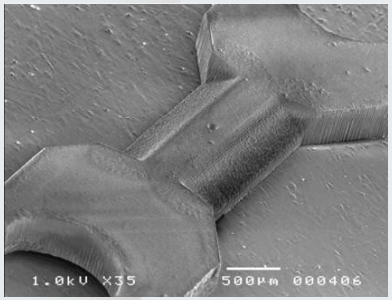


Workstation

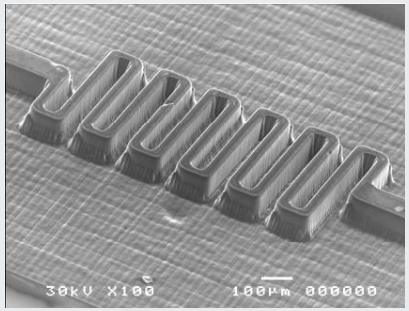
Configurations can include:

- Different lasers
- Different motion control
- Beam conditioning
- Camera systems
- Auto Align
- Auto Focus
- Power measurement
- ect...

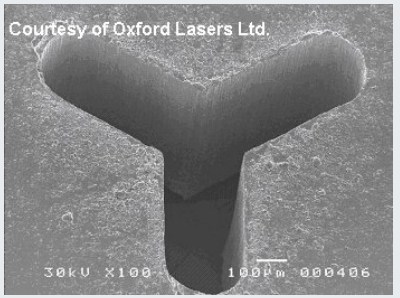
Examples of ns laser machined features



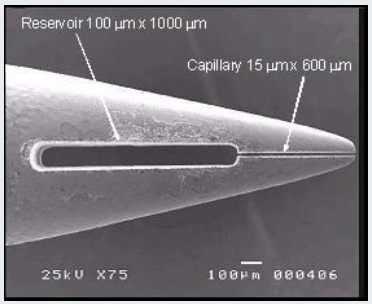
Silicon Nitride



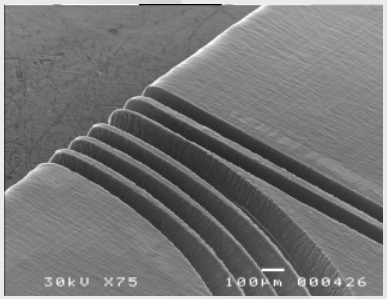
Diamond



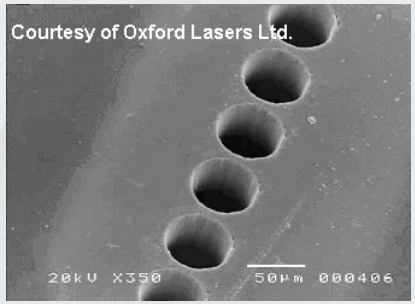
Stainless Steel



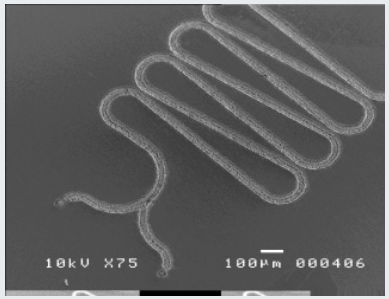
Tungsten



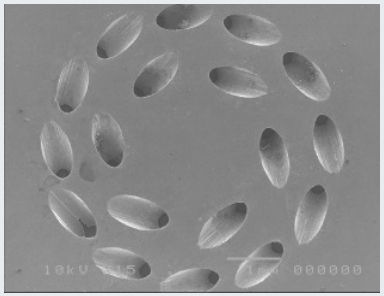
Polyimide



Polyimide



Glass

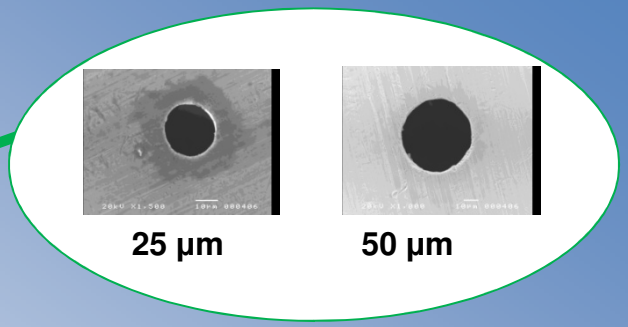


Stainless Steel

Example of Application for non transparent materials

Specialist in Blister Pack Laser Drilling

Blister Pack for Leak Detection Application



Hole sizes from 5 µm to 150 µm!

Contact:
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Difficulties with Transparent Materials

The laser wavelength and material optical properties determine **light absorption** (i.e. the extent to which the material takes up the deposited energy)

Incident laser light on surface = [reflected] + [absorbed] + [transmitted]

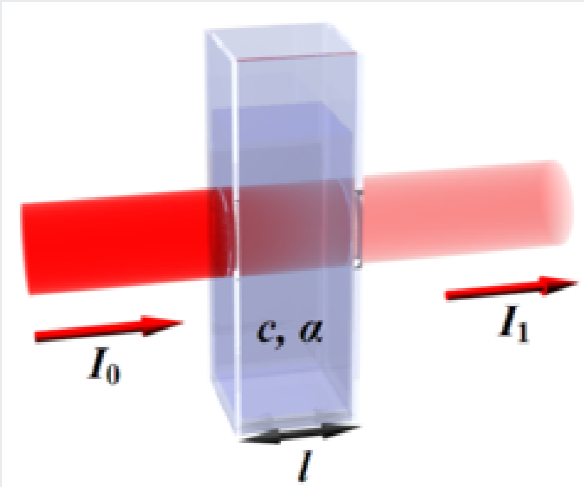
Only [absorbed] light in the material is useful for *Laser Micromachining* and the optical penetration (absorption) depth defines the process resolution

Linear Absorption requires high material absorption coefficient

difficult to achieve if materials transparent

- requires deep UV wavelengths

Beer-Lambert law
(assuming linear absorption)



Difficulties with Transparent Materials

Ultra Short Pulse Ablation

relies on a change in the light / material interaction

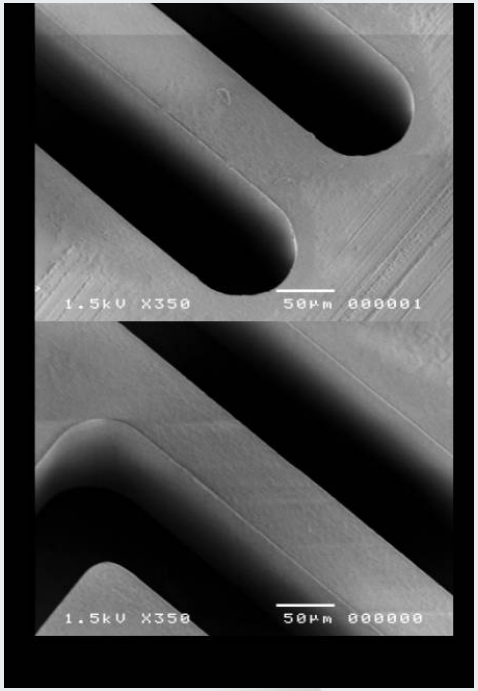
- high intensity light energy is partially transferred to electrons
- these electrons then thermalise with ions causing material removal

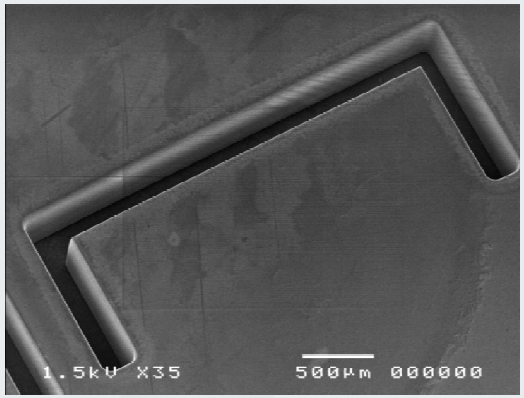
Thin Film Removal requires

selective layer removal

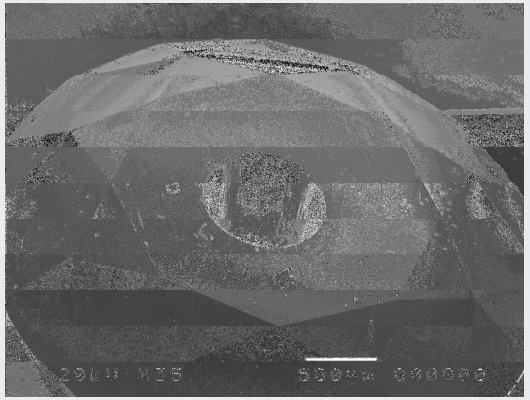
- easier achieved with ULTRA short pulse lasers, e.g. ps

Examples of Machining Transparent Materials





Milling - Sapphire
200 micron wide slot
500 micron deep



Drilling – Diamond
500 micron hole

Patterning - ITO
10 micron wide tracks on 70 micron pitch

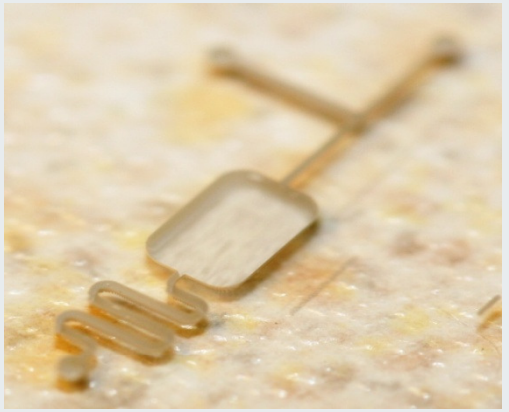
Application 1 : Transparent Materials

Microfluidics

Uses - Biomedical research, Inkjet printer heads - where control, manipulation of small volumes of liquids are important

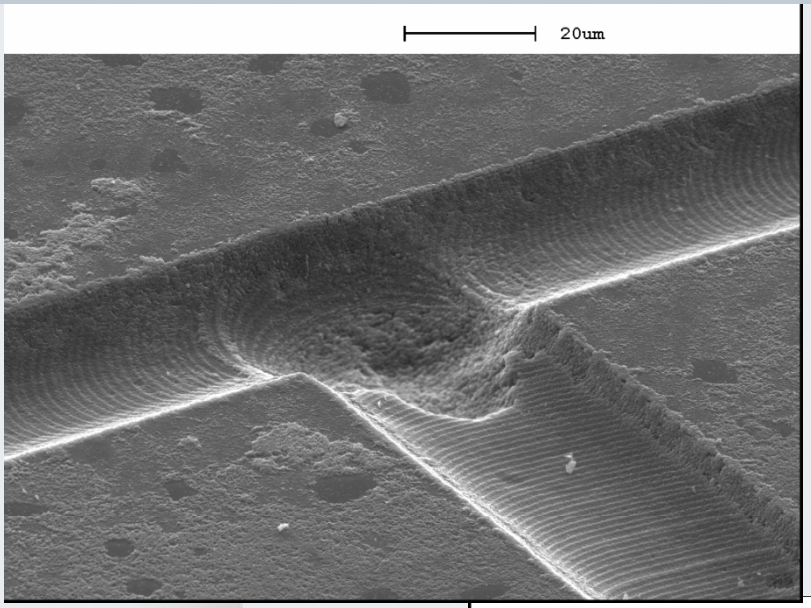
Geometries - Channels, mixers, reservoirs, diffusion chambers, etc

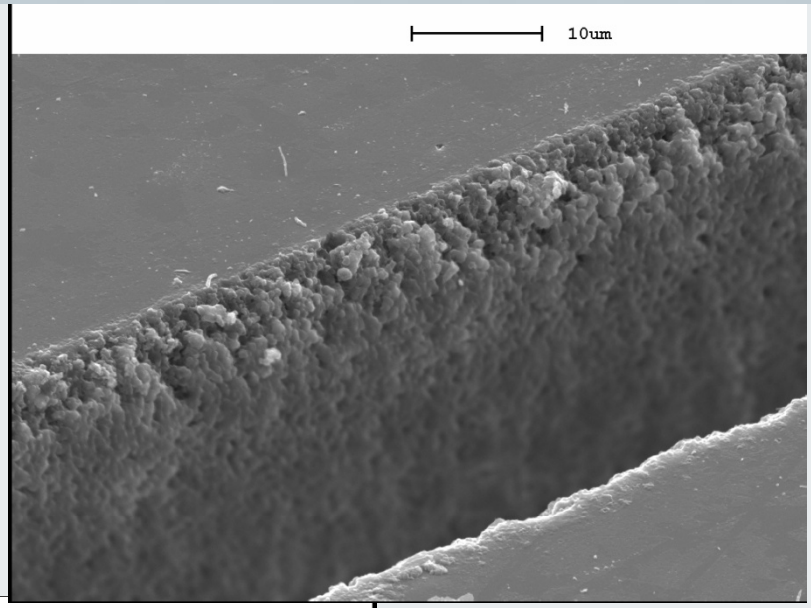
Sizes -Channel width and depth dimensions ranging from 10 to 100 microns

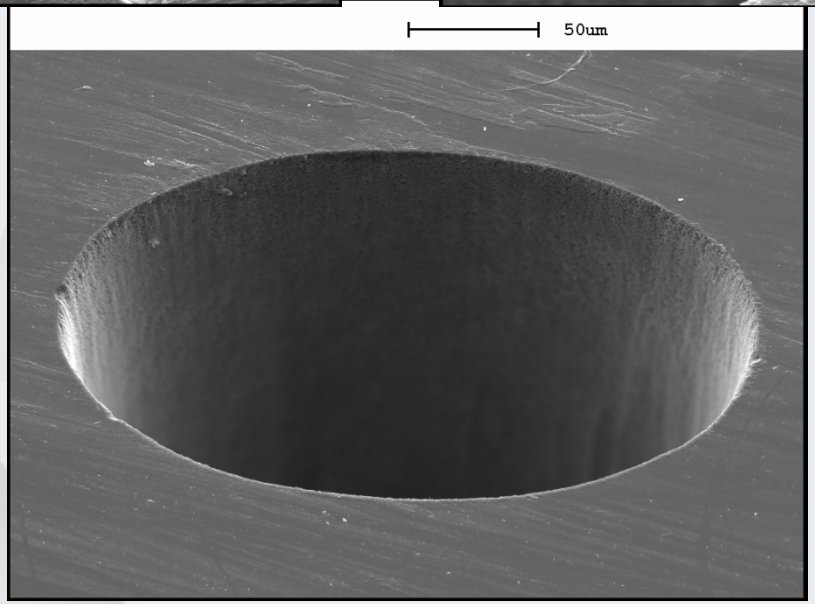


Borosilicate

Application 1 : Microfludics

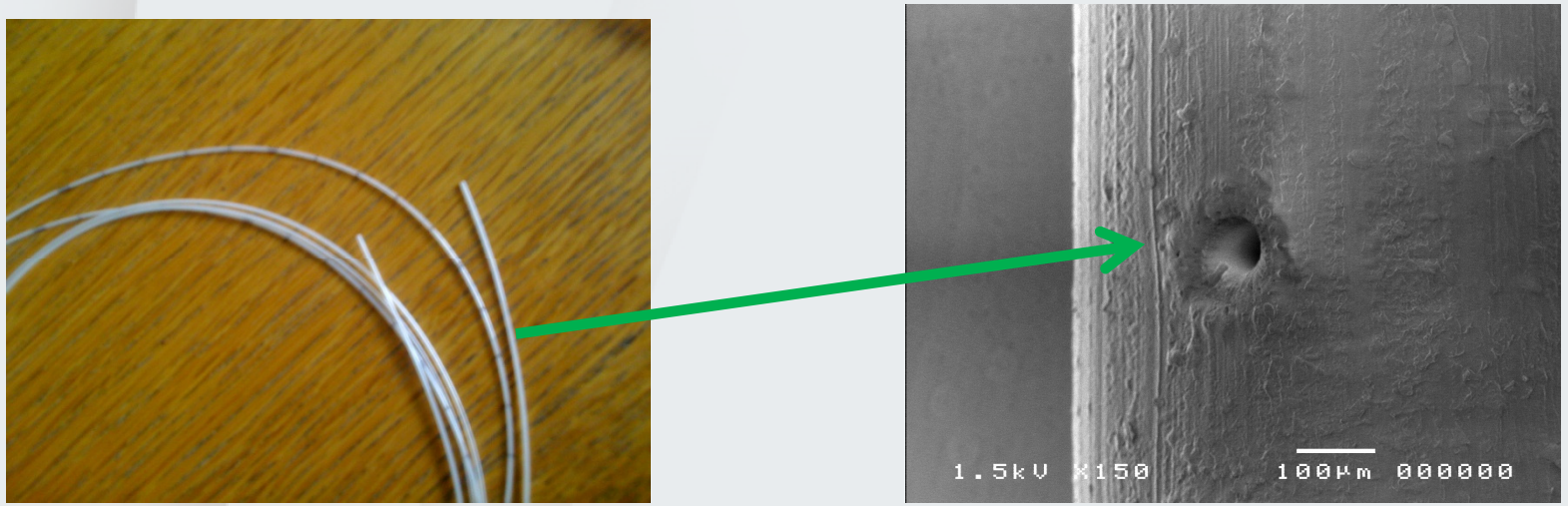






Application 2: Medical

Transparent Polymer



60 um hole on 1 side of the tube

Application 3 : Transparent Materials

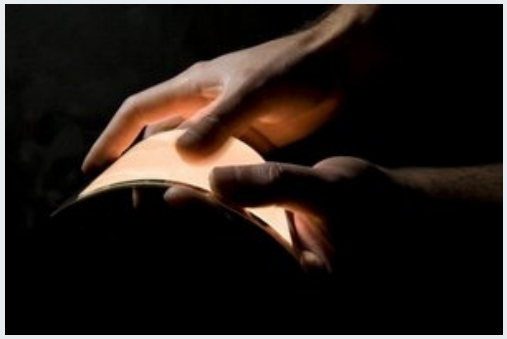
Organic LED Production

(thin film removal)

OLEDs advantages over LCDs -

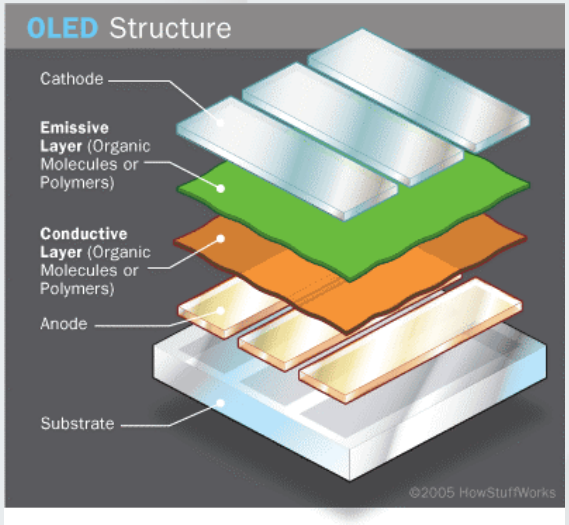
- No backlight - so more efficient and thinner displays
- High contrast ratios, deeper blacks etc
- Richer deeper colours (direct colour production)
- OLED screens are emissive - so no viewing angle problems
- Flexible Screens (newspapers)

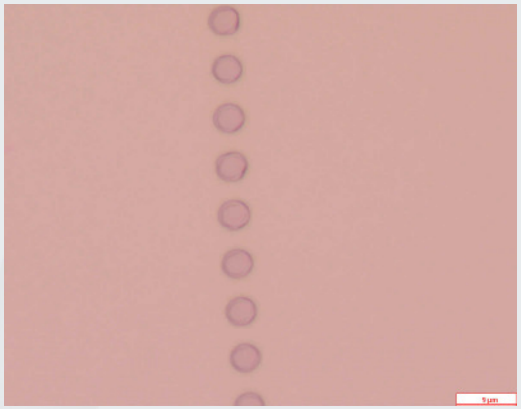
The Sony 11-inch OLED TV

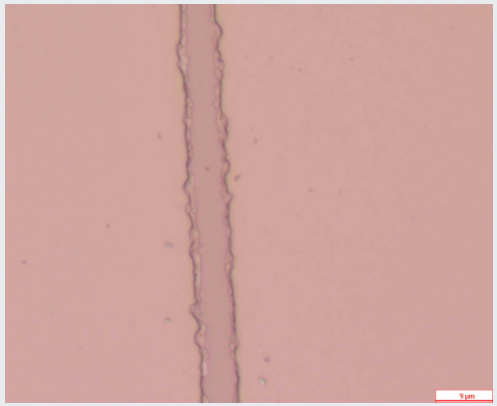


Courtesy of Holst

Patterning Thin Films on Flexible Substrates







Laser scribed ITO on Flexible Substrate using 532nm (a) 4 micron spots with depth of 100nm and (b) scanning five times slower. Bar denotes 9 microns

Demonstration of thin film removal

Expert Process Technology

…20 years experience in laser micromachining

Application 4 : Transparent Materials

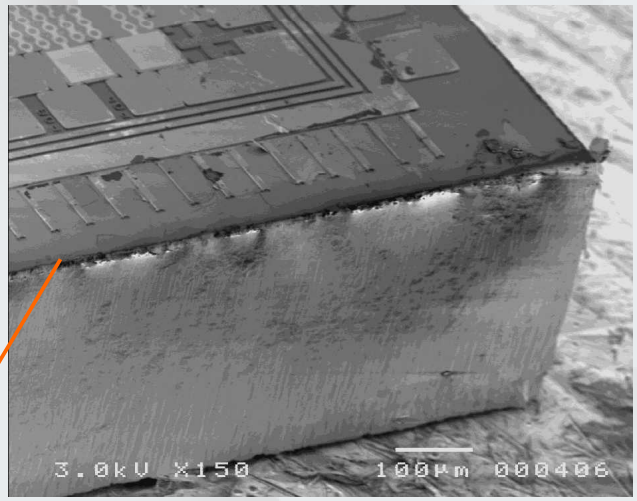
Sapphire Scribing and Cutting

Material: c-face Sapphire

Laser: Deep UV, 15 µm spot size

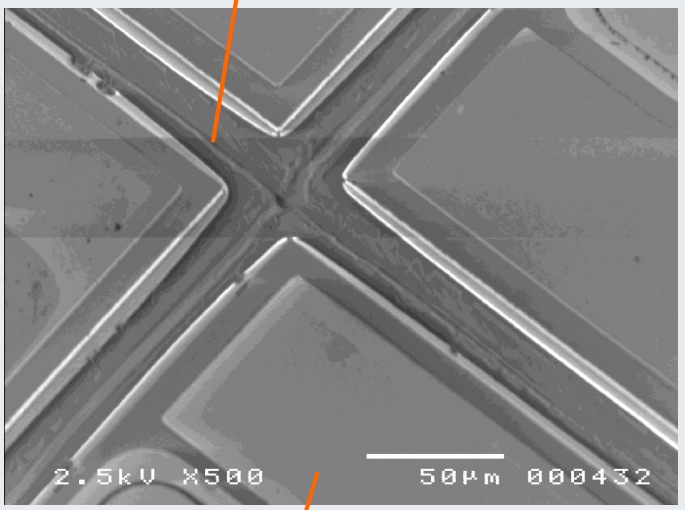
Scribed Lines: 30 µm deep, 20 µm wide

Through Cut: 400 µm



GaN LED die on sapphire
Through Cut, No Heat Damage

Laser scribed street



LED Die

Summary

- Laser Micromachining has the ability to produce a variety of cut, drilled, milled and etched features
- Although many transparent materials are difficult to machine with a judicious choice of laser source and technique excellent results can be achieved
- Pico second lasers are generally the best choice for removal of thin films, particularly on flexible substrates

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