SWTW

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Drilling Methods and Materials for Advanced Vertical Probe Cards

OXFORD LASERS INDUSTRIAL DIVISION

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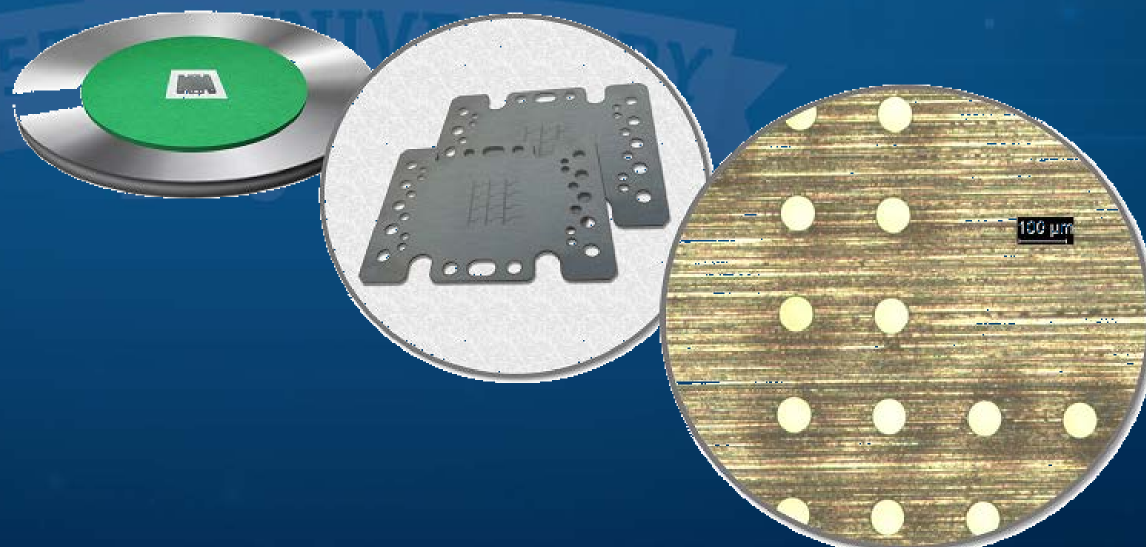
Oxford Lasers

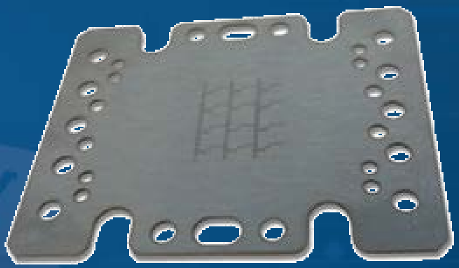
Overview

- Introduction
- Advanced Vertical Probe cards
- Mechanical Drilling
- Laser Drilling
- Materials
- Roadmap
- Summary



Introduction

- **Guide Plates**
  - Are an essential component in Vertical probe cards.
  - Consist of 1000's micro-holes through which probes are fitted, ensuring accurate location of each probe.
  - Typical probe card uses several guide plates.



- **Guide Plate Features**
  - Accurately locate probe pins.
  - Pin size and pitch to match DUT.
  - Appropriate current capacity, impedance, contact resistance etc.
  - Appropriate guiding/sliding of pins, scrub, wear, cleaning etc.
  - Mechanically stable substrate.
  - Match CTe to DUT.

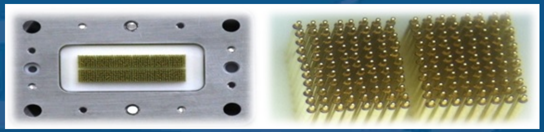
Introduction

- **Advanced Vertical Probe Card Types**
  - Cobra
  - Micro-pogo
  - MEMs
- **Minimum Probe Pitch**
  - Reducing from 120um to <50um.
  - Driven by transition from solder bump to copper pillar.
- **Materials**
  - Ceramics (SiN, Alumina, Macerite, Photoveel).
  - Polymers: Polyimides, (Kapton, Vespel, Cirlex), PEEK.
- **Methods**
  - Mechanical drilling
  - Laser drilling

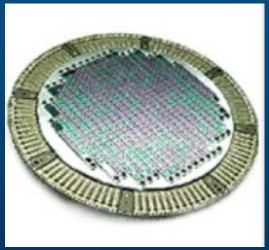
Advanced Vertical Probe Cards

- **Cobra**
  - Ceramics and Polymers
  - Round holes

- **Micro-pogo**
  - Ceramics
  - Round holes

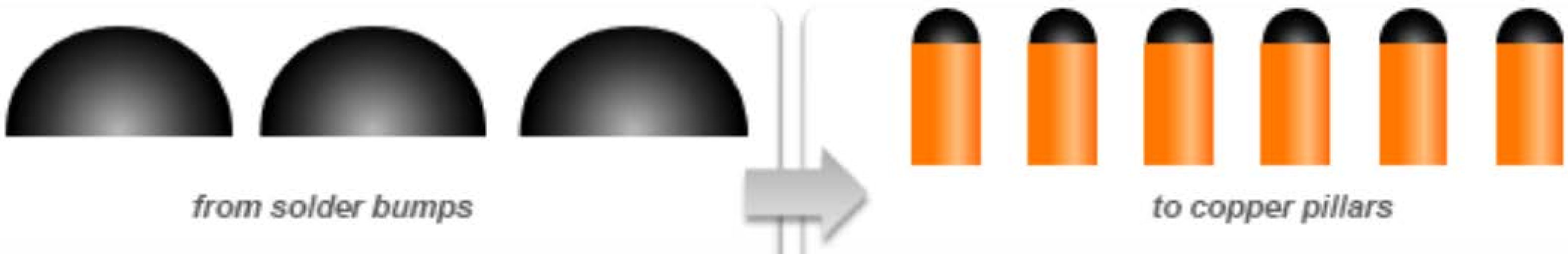


- **MEMS**
  - Ceramics
  - Rectangular holes



Minimum Pitch

"Pillars" of copper are typically plated on the chip in wafer form through photolithography techniques. Solder bumps have fixed aspect ratios lower than one, whereas copper pillars offer aspect ratio flexibility, and therefore can increase I/O bump densities for many applications in addition to other advantages...

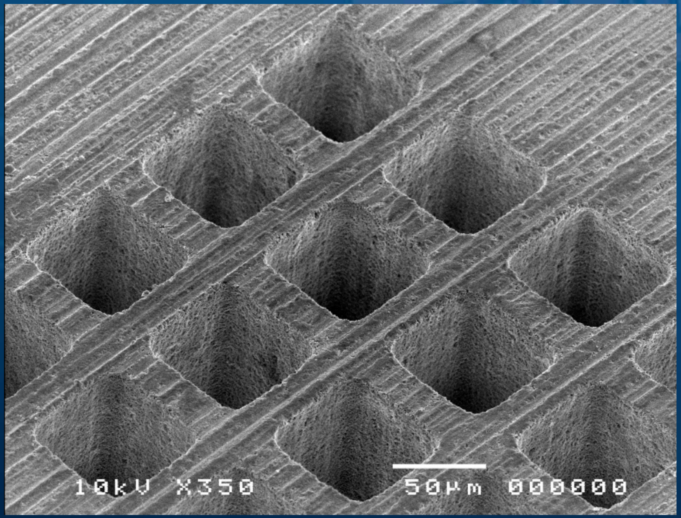


- Pitch limited to 150µm min, 120µm at best, due to spherical aspect and need for sufficient z-height gap for underfill flow
- Risks of electrical shorts by bridging
- Limited spacing between adjacent bumps for signal routing
- Limited spacing between adjacent bumps prevents the underfill from flowing causing underfill voids
- Reduced pitch leads to lower bump height (due to 1:1.3 aspect ratio) causing
  - Reliability issue by lack of bump elasticity
  - Reduced stand-off height making it more difficult for the underfill to flow.

- Finer pitches possible down to 20µm
- Reduced risk of shorts between adjacent bumps
- Larger spacing between adjacent bumps for signal routing and easier underfill flow
- High bump aspect ratio (→ easier underfill flow)
- Copper pillars are a reliable lead-free bumping option
- Copper offers higher electrical conductivity than solder: 25% lower resistance than SnPb
- Higher current density capability (better resistance to electromigration)
- But higher elastic modulus (stress during attach process)

Minimum Pitch

- As pitch decreases, necessarily probe and probe hole size must also decrease.
- Hole size typically 5 – 15um smaller than pitch to ensure sufficient land for strength.
- Material influences drilling capability and material strength.



Guide Plate Materials

- **Range of ceramics and polymers used.**
  - Once a design is qualified then material is fixed.

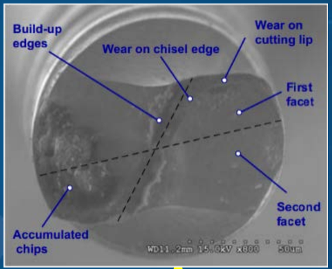
- **Hard Ceramics**
  - Alumina, Silicon Nitride and others.
  - Laser drilling only.

- **Machinable Ceramics**
  - Macerite, Photoveel, Macor and others.
  - Mechanical or laser drilled.

- **Polymers**
  - Polyimides (Kapton, Vespel, Cirlex etc.), PEEK.
  - Mechanical or laser drilled.

Mechanical Drilling

- **Round holes only.**
- **Polymer or Machinable Ceramic guide plates only.**
  - Hard ceramics produce un-acceptable wear and breakage. See Chang et al. Advanced Materials Research Vol. 579 (2012) pp 227 – 234. 100um dia. drill bit has life of <400 holes in Alumina.



- **Diameters down to 35 microns.**
- **Tool wear, breakage and variation become an increasing problem as hole diameter decreases.**
- **Lower capital cost but slow drill rates with poorer hole size and positional tolerances.**
- **Hole size and material capability does not meet requirements of latest generation Advanced Probe Cards.**

Use of Lasers in Guide Plates

- **Used for drilling guide plates since mid 1990's.**
- **Laser Technology Advances**
  - Original drilling was by Excimer lasers - now legacy only.
  - In mid 2000's solid state nanosecond UV lasers became mature.
  - Ultrafast (picosecond) lasers available 2010 and now maturing.
- **Laser Drilling Tool Design Advances**
  - Advanced drilling strategies for smaller holes.
  - Circular, rectangular and other hole shapes.
  - Larger range of materials can be drilled.
  - Improved positional accuracy and dimensional tolerance of holes.

How Does Laser Ablation Work?

1. Laser pulse strikes a surface.
2. Light absorption + material excitation in ultrafast timescale (ps region).
3. Build up of high temperature + **pressure gradients** in the absorbed volume of the material.
4. Material-dependent thermo-mechanical response.
   a) Melting
   b) Mechanical damage
   c) Ablation (evaporation, lift-off, etc.)
   d) Plume formation (plasma ionization, etc.)
5. Target re-solidification.

Choose Laser Parameters to Favor Ablation

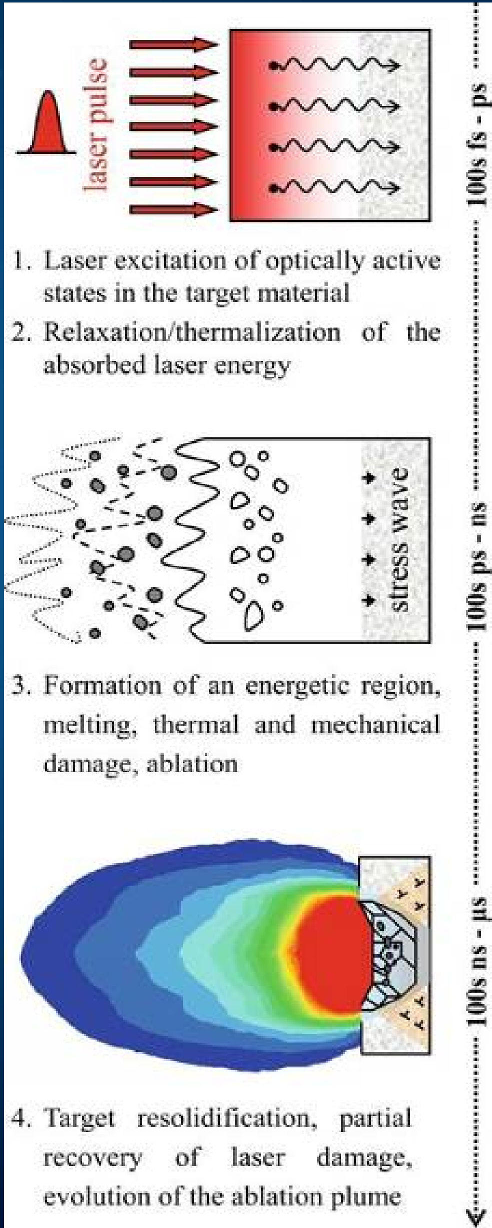
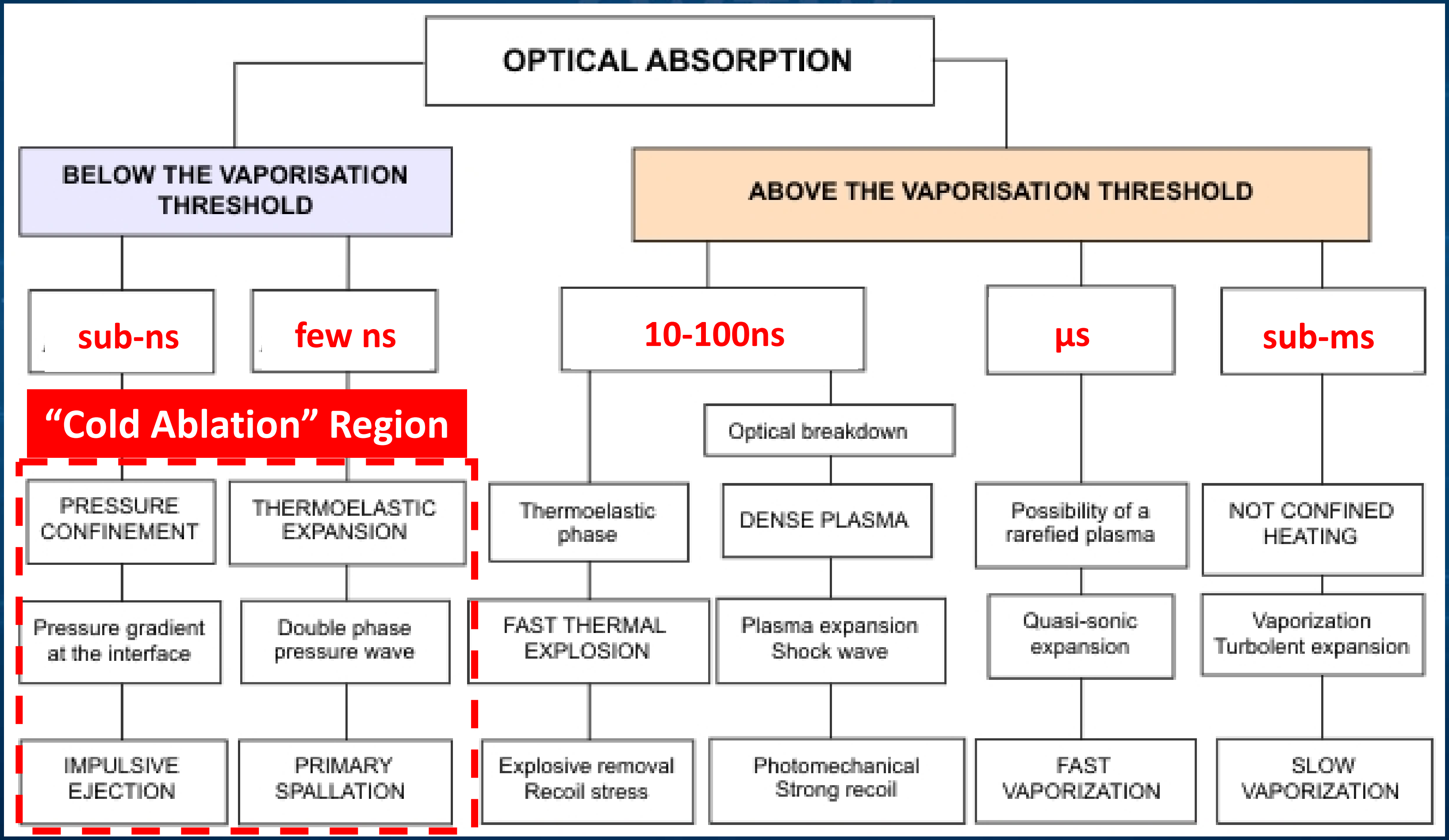


Image source © L.V.Zhigilei et al in Laser-Surface Interactions for New Materials Production: Tailoring Structure and Properties (Springer, NY 2010)

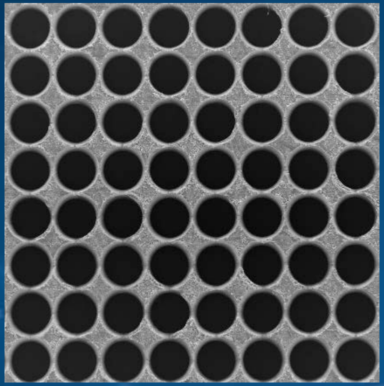
Laser Ablation Channels

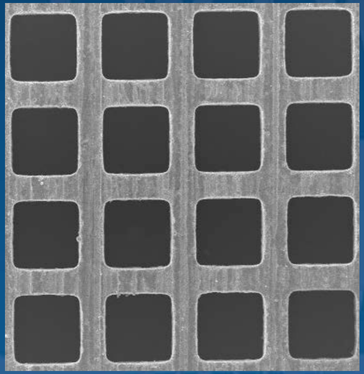


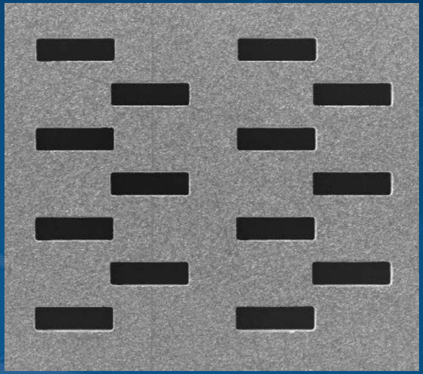
Laser Drilling

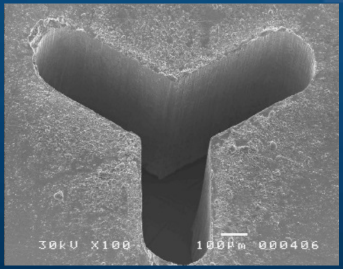
- Round, rectangular and other hole shape capability.
- Hole taper control.
- Minimum diameters 20um or better (material and thickness dependent).
- Hard Ceramic, Machinable Ceramic and Polymers.
- Non-contact process, no tool wear or breakage.
  - Increasingly important as hole count increases.
- High speed – drill times down to 0.1 sec/hole.

Laser Drilling – Hole Shapes









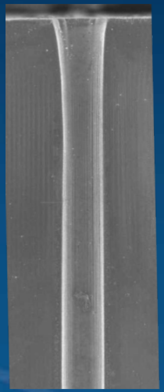
Hole shape is programmable so the possibilities are endless…

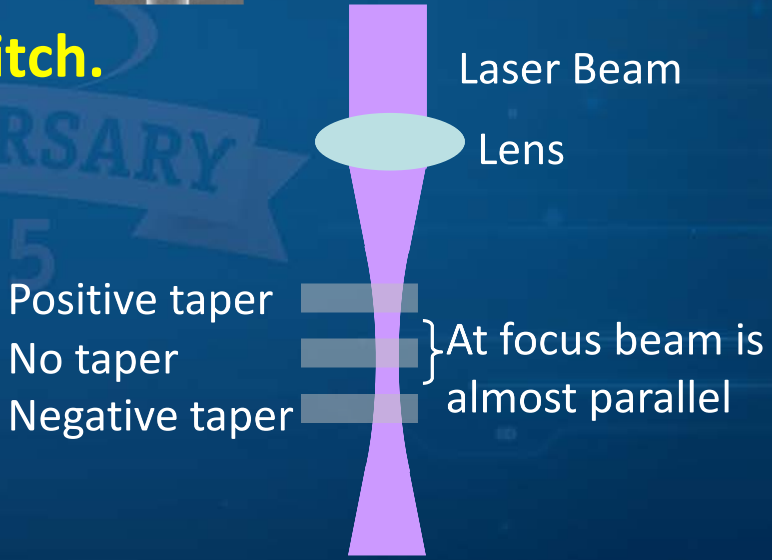
Hole Taper

- Combination of laser beam delivery design and process parameters enable adjustment of taper.
- Advanced beam scanning methods can further enhance taper control.
- Taper control allows optimization of probe insertion, scrub characteristics etc.
- Taper can be parallel, positive, negative, hour-glass.
- Fine pitch requires <u>low taper</u> to avoid hole break-through!!!

Hole Taper - Laser Drilling

- **Other profiles possible.**
  - Allows some influence on scrub, wear etc.
- **Low Taper is required for very fine pitch.**

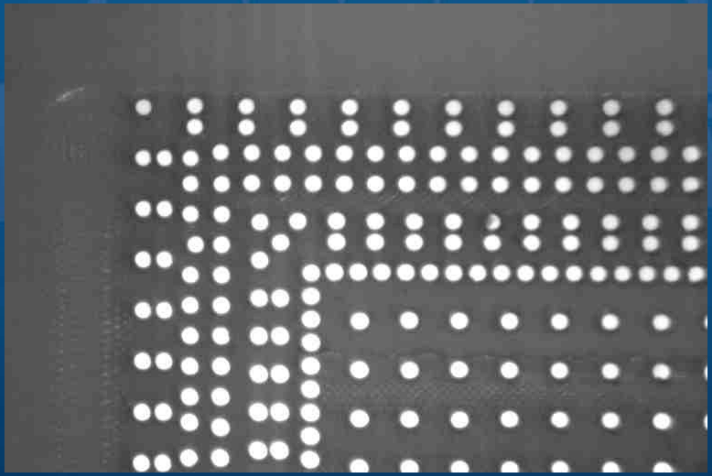




Simple illustration of taper control

Laser Drilling – Hole Size

- **Hole size is a programmed parameter, no hard tooling.**
- **Adjustable in small increments (0.1 micron).**
- **Minimum hole diameter or corner radius is proportional to laser wavelength – use short wavelength e.g. 355nm.**

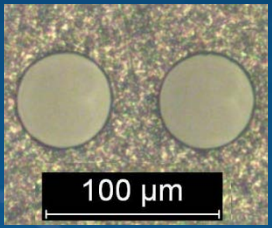


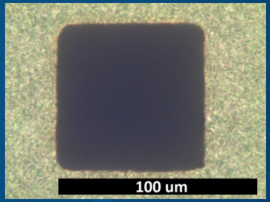
15um holes in Vespel

Advanced Laser Drilling

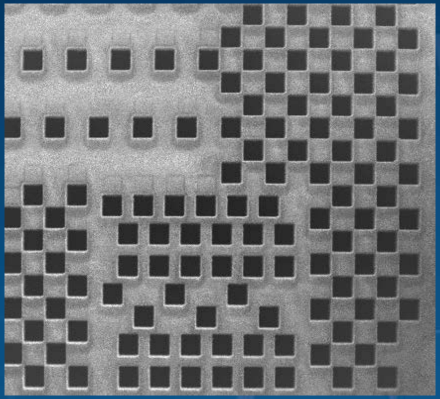
Smaller Holes

- **Require**
  - Small laser focus spot
    - Short wavelength
    - Excellent beam quality
    - Careful optics design and high quality optics
  - Optimized drilling strategy
    - Appropriate laser-material interaction (wavelength, pulse duration, power)
    - Ultra-precise motion control systems
- **Demonstrated 15 micron holes**

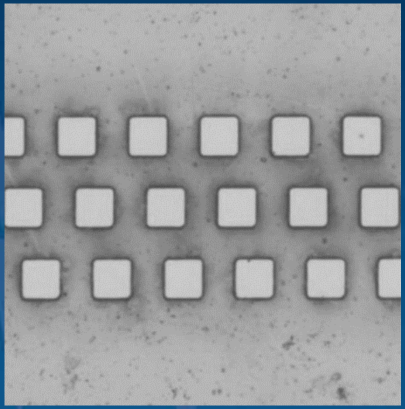




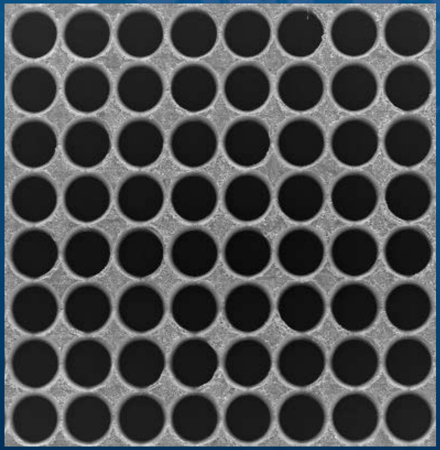
Polymers – Laser Drilling



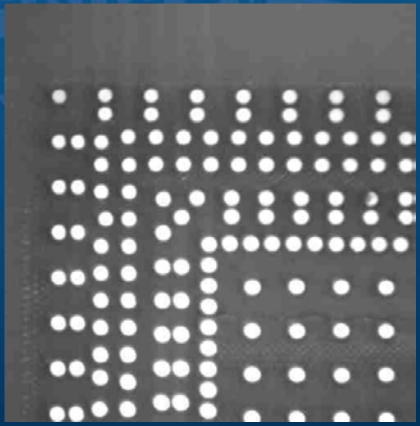
Vespel



Kapton

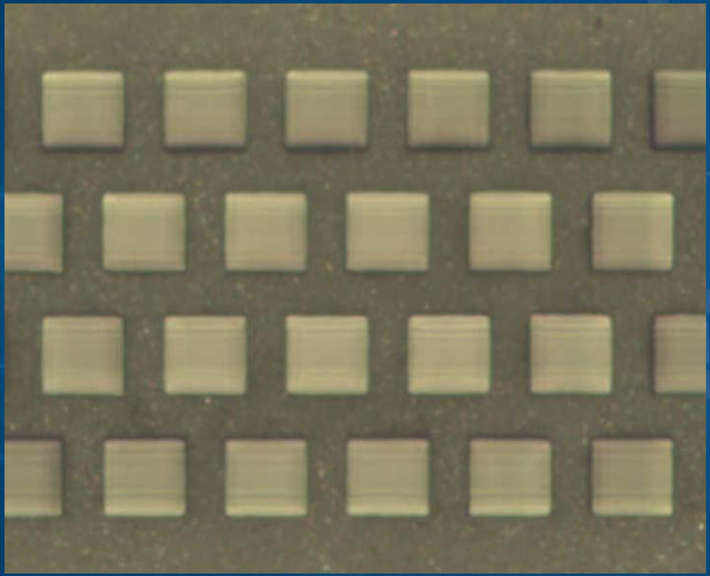


Cirlex

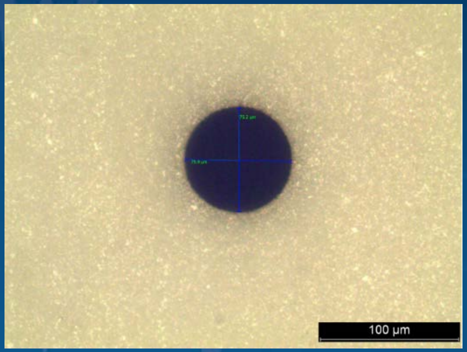


Vespel

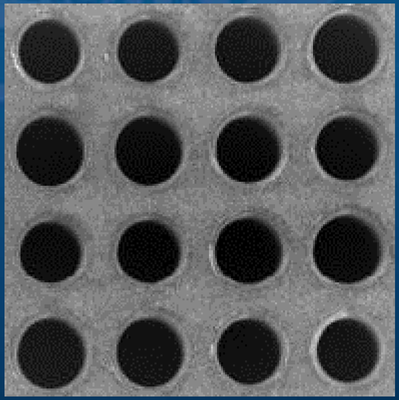
Machinable Ceramics – Laser Drilling



Photoveel – 50um square holes

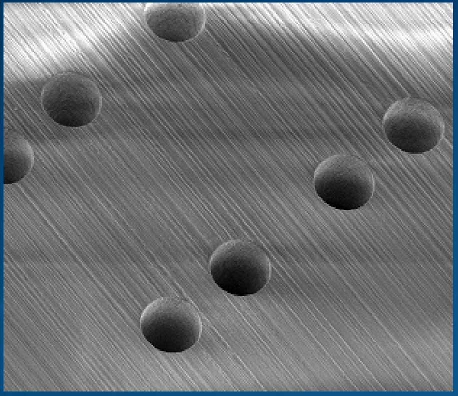


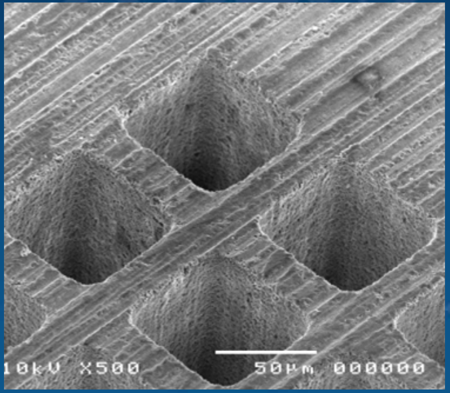
Photoveel – 75um dia. hole

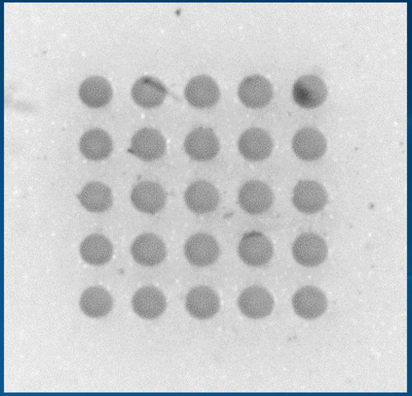


Shapal
(Machinable Aluminum Nitride)

Hard Ceramics – Laser Drilling



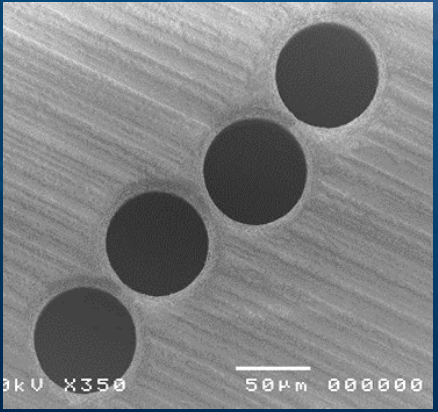


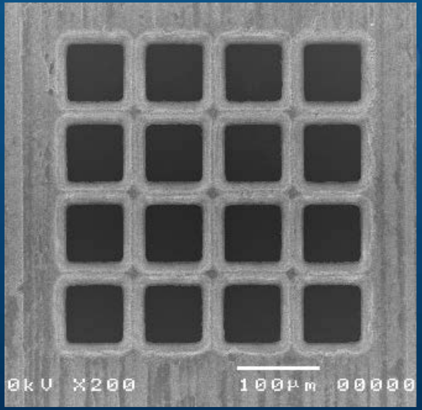


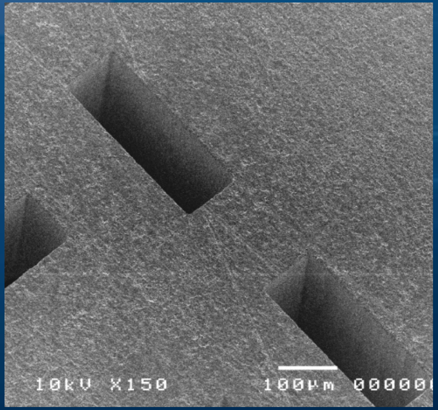
Silicon Nitride

Silicon Nitride

Alumina

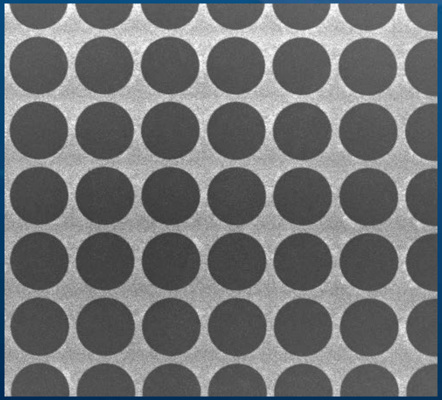






Laser Drilling Speed

- **Depends on**
  - Material type
  - Material thickness
  - Hole size
  - Hole tolerances and quality
- **In the range 5 – 0.1 seconds/hole.**

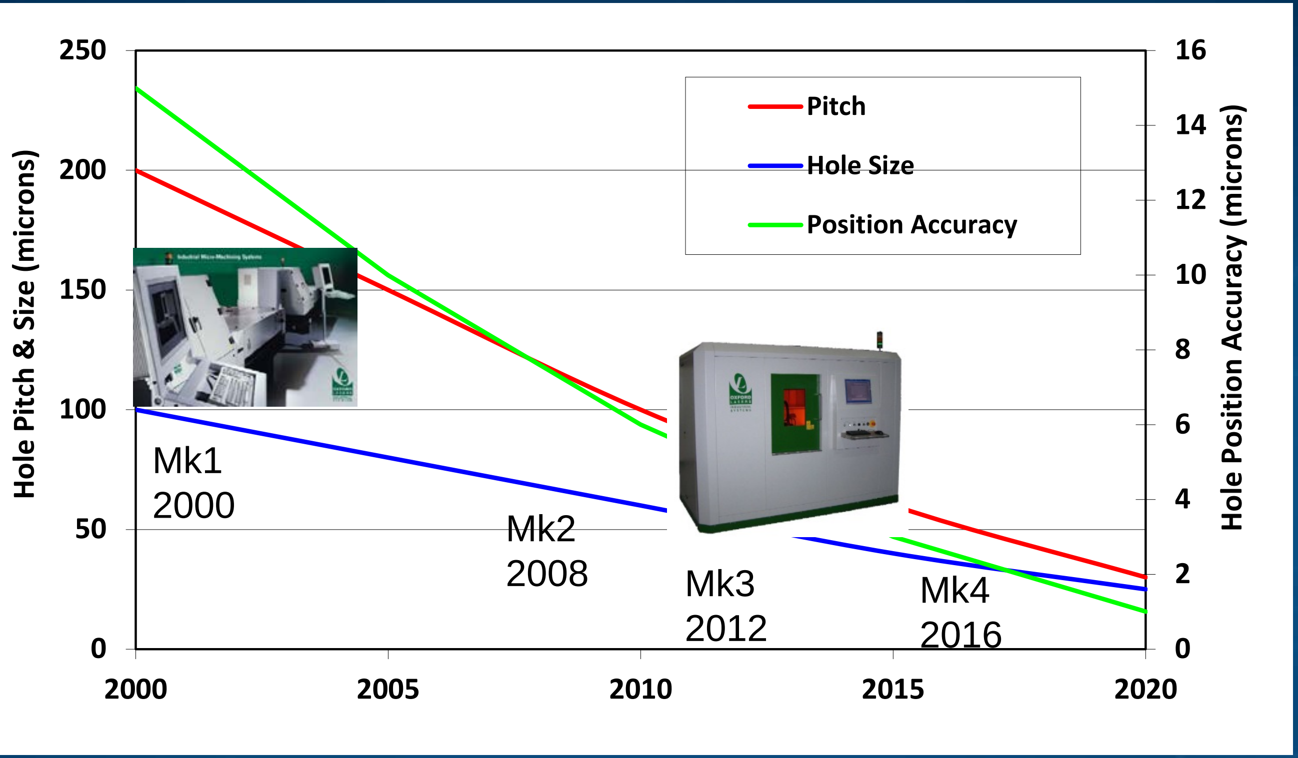


Holes through 620um thick Cirlex
0.5 secs./hole.

Laser Drilling Process Optimization

- **Requirements**
  - **Highest quality** holes with specific size, shape, taper and tolerance in the customer-defined material.
  - **High accuracy** hole positioning.
  - Cutting of outer profile and larger apertures.
  - Economic through-put.
  - Hole tolerances and quality.
- **Process**
  - Laser tool process parameters must satisfy **all** of the above.
  - Requires careful optimization of process parameters and tool design.

Oxford Lasers Tool Roadmap



Tool capability supports industry roadmap for guide plates.

- **15 years experience supporting probecard industry.**
- **Full laser technology capability.**
  - **nanosecond, picosecond, femtosecond**
  - **all wavelengths and laser types**

Conclusions

- **Industry requirements of shrinking hole dimensions and pitch require constant innovation by all sections of the probecard supply chain.**
- **Rectangular holes for Advanced Probe Cards cannot be met by mechanical drilling.**
- **Correct choice of laser tool (laser, optics, motion system) and optimized process strategies can address these challenges.**
- **Latest generation tools can meet the current and near-future requirements.**
  - Hole size (35 micron)
  - Fine pitch (45 micron)
- **Next generation tools are expected to meet:**
  - Hole size 20 micron.
  - Pitch 30 micron.