IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

June 8 - 11, 2014 | San Diego, California

Challenges and Solutions in future designs of Vertical Probe Cards

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Oxford Lasers

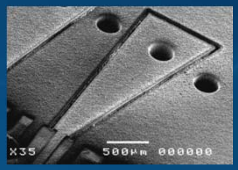
Overview

- Introduction
- Probe Cards & Laser Micro-machining
- Vertical Probe Card Challenges
- Laser Drilling Results
- Conclusions & Future Work

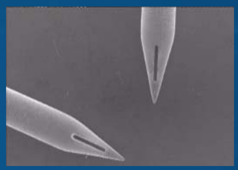
Introduction

- **Laser micro-machining techniques can be used in**
  - Guide plates - drilling and cutting

  - Interposer - fine circuit contouring and routing



  - Probes - precision cutting of metal probes



- **Today lasers are used predominantly in Guide Plate drilling**
- **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.

Vertical Probe Card Challenges - ITRS 2013

- **Delivery Interval**
  - often longer than time between chip design and availability of wafers
- **Cost**
  - especially high in fine pitch or high pin count probe cards
- **Rising Pin Counts**
  - 20,0000 pins
- **Tighter Pitches**
  - now down to 40um
- **Smaller Pads/Bumps**
  - probes and holes < 40um
- **Increasing Switching Currents**
  - can be > 1.5 amps though individual pins

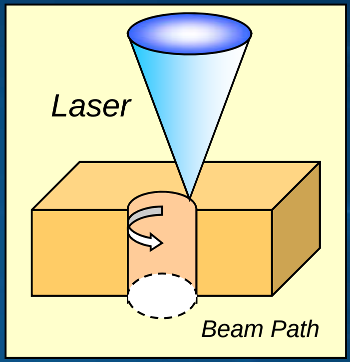
Use of Lasers in Guide Plates

- **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

Introduction to Laser Drilling

for Vertical Probe Cards

- **Laser beam diameter at focus - typically 0.2 mil (5µm)**
  - this is the diameter of the "laser drill-bit"



- **Typical required hole diameters are (40µm) to 4 mil (100µm)**

- **Latest Systems rotate the beam around the hole center**
  - this gives excellent hole circularity

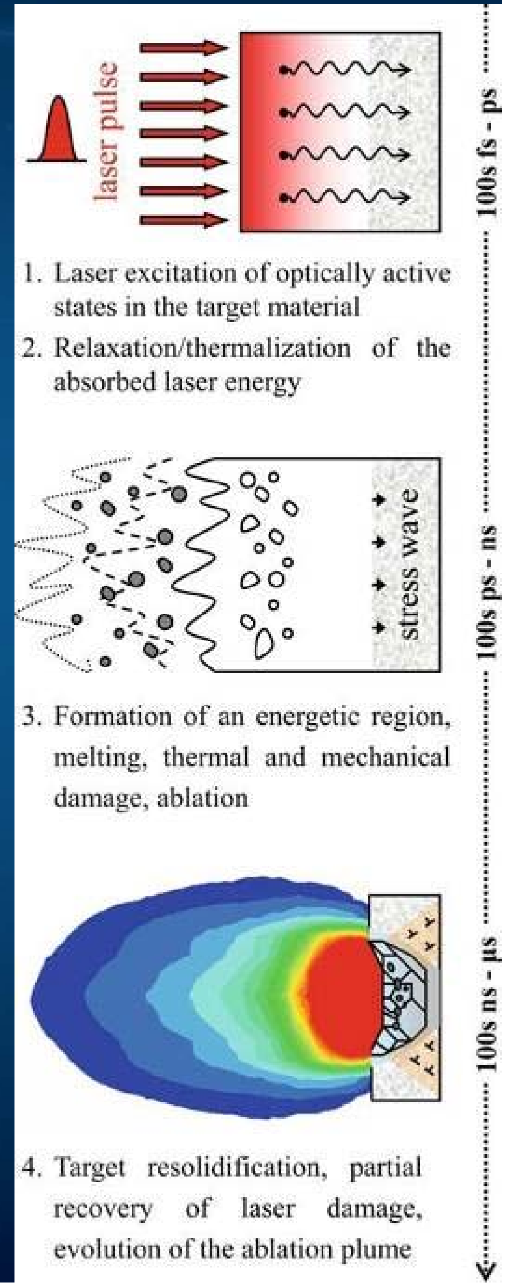
- **Laser beam "evaporates" the material**
  - so the laser does not care if the material is hard or soft etc
  - non-contact process
  - actual process is "ablation" - see next slides

How Does Laser Ablation Work?

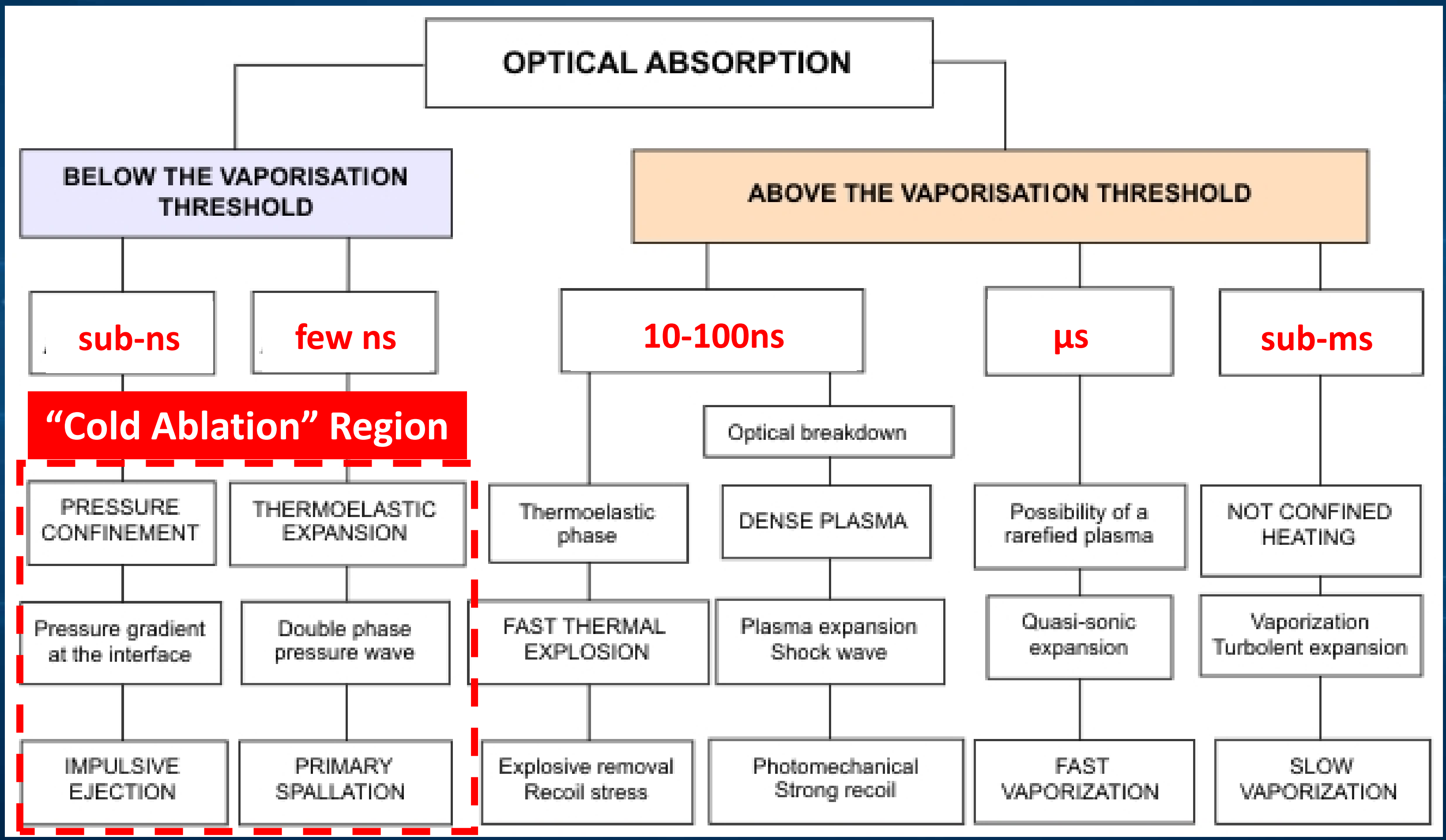
1. Laser pulse strikes a surface
2. Light absorption + material excitation in ultrafast timescale (ps region)
3. Build up of high temperature + **pressure gradients** in the absorbed volume of the material
4. Material-dependent thermo-mechanical response
   a) Melting
   b) Mechanical damage
   c) Ablation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

Choose Laser Parameters to favour Ablation

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

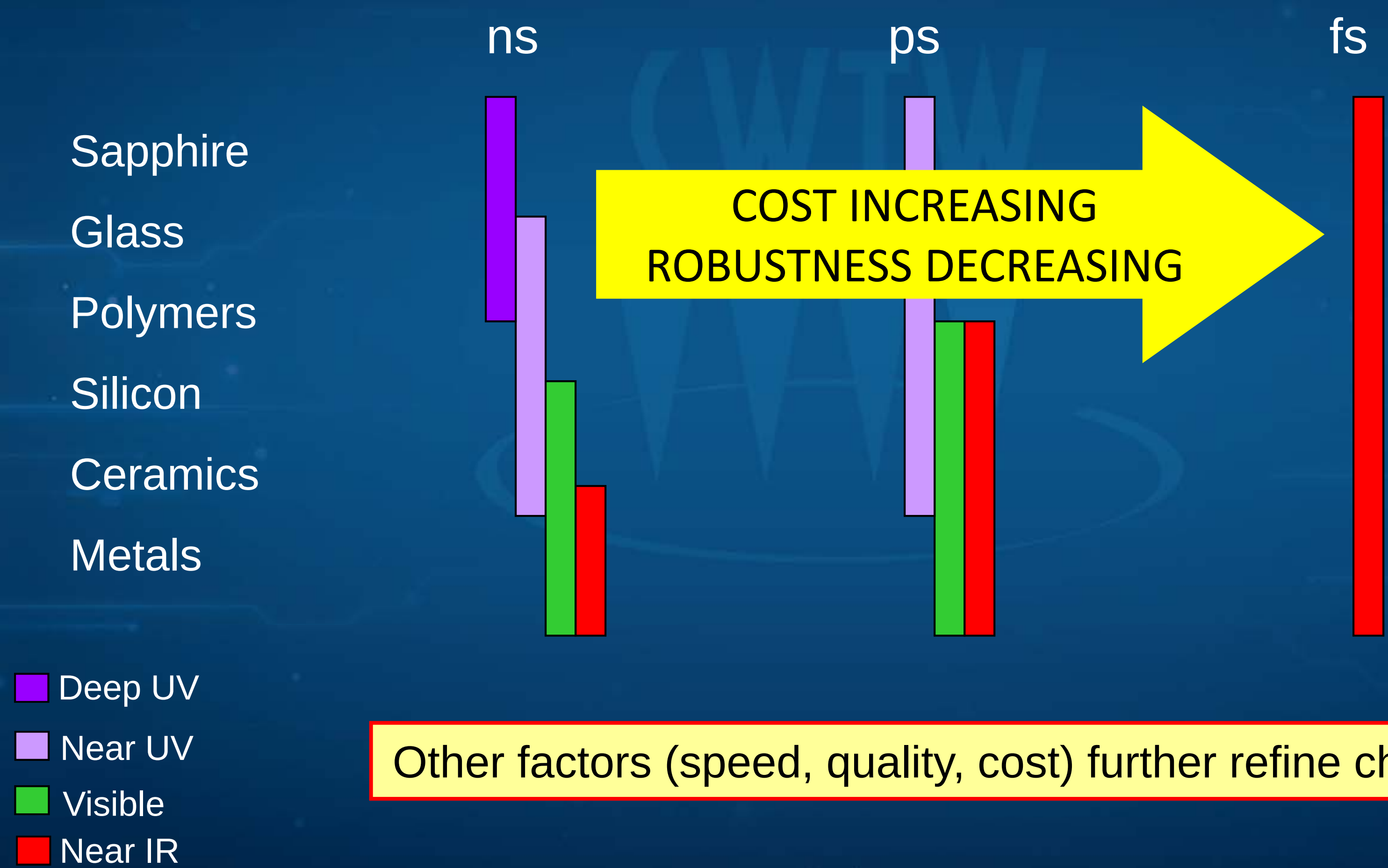


Laser Ablation Channels



Short Pulse Lasers for Micro-Machining

Which Wavelength? Which Pulse Duration?



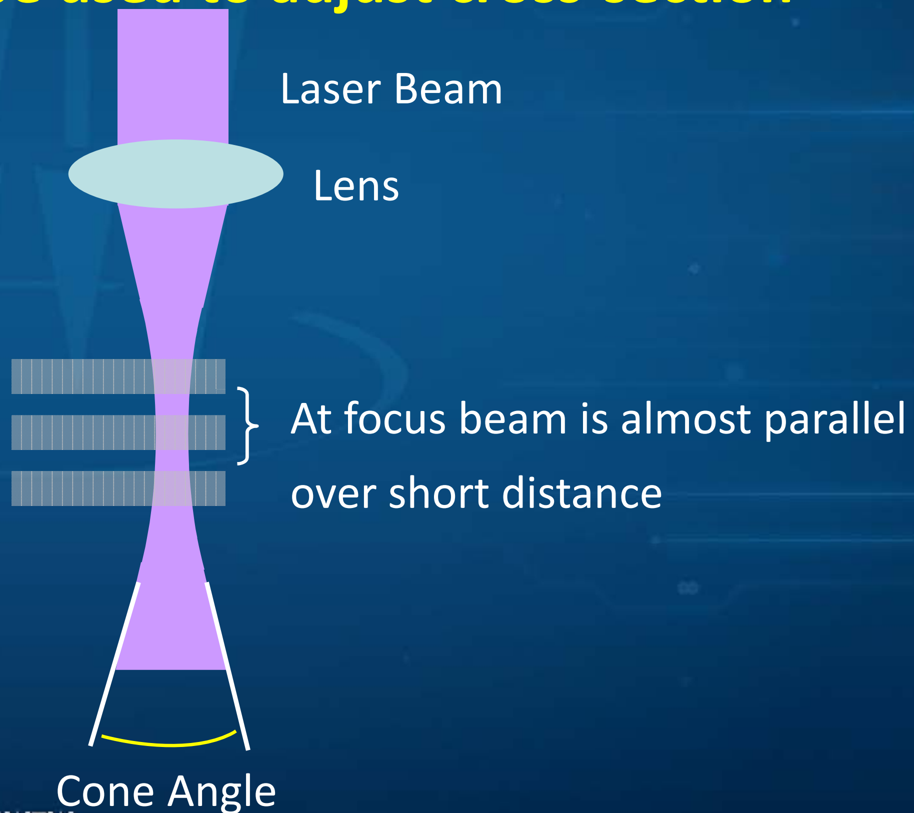
Other factors (speed, quality, cost) further refine choice

Advanced Laser Drilling

Hole Cross-sectional Shape to Aid Scrub Characteristics

- **Laser drilling parameters can be used to adjust cross-section**
  - Beam focus height
  - Beam cone angle
  - Laser power

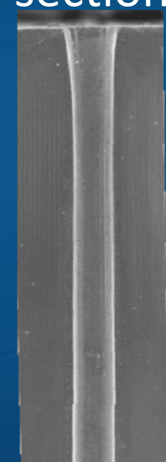
Focus Deep - positive taper
At Focus - no taper
Focus High - negative taper

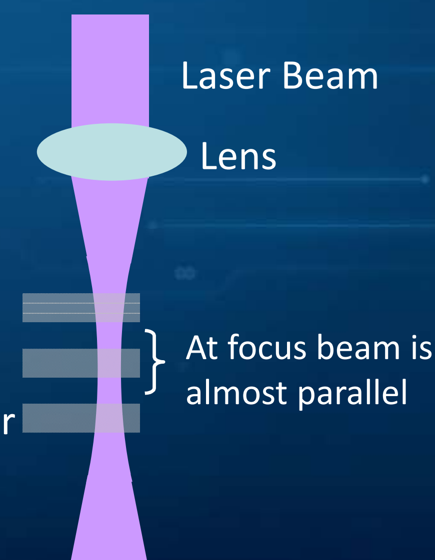


Advanced Laser Drilling

Hole Cross-sectional Shape to Aid Scrub Characteristics

- **Careful adjustment of parameters can produce cross-sections**
  - Small positive taper near top then long parallel section
  - Small positive taper aids insertion of probe
  - Long parallel section aids probe positioning

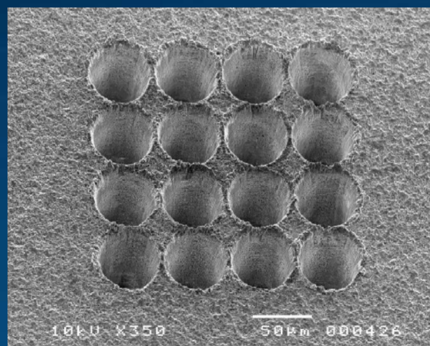




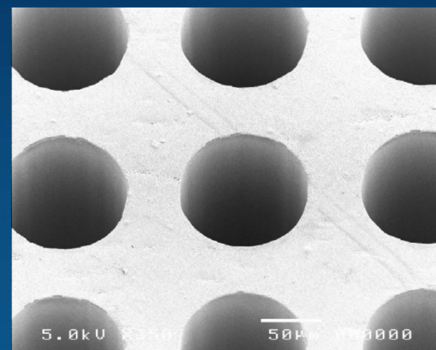
- **Other profiles possible**
  - allows some influence on scrub, wear etc

- **Low Taper is required for very fine pitch**

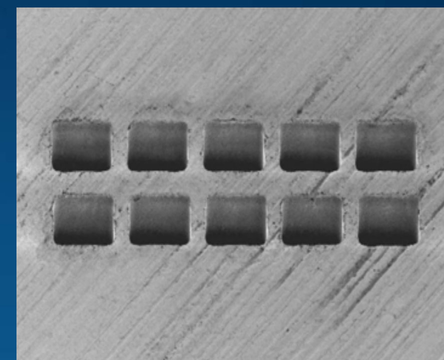
Laser Drilling Examples



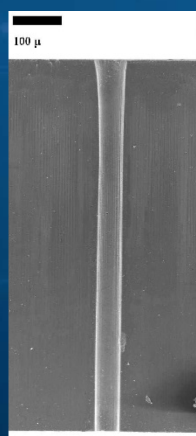
2 mil dia hole, alumina



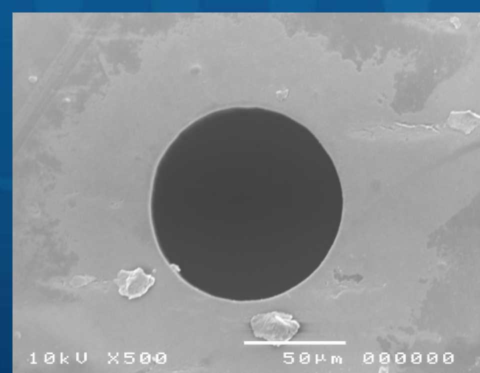
4 mil diameter hole, polyimide



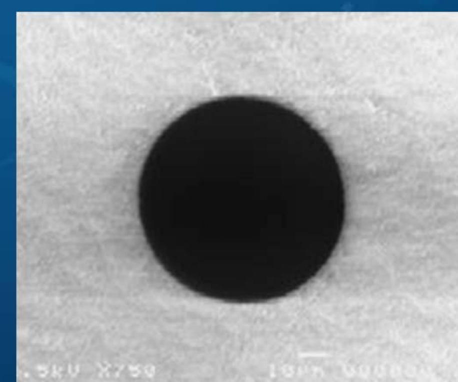
2.4 mil rectangular, SiN



2 mil dia hole, polyimide

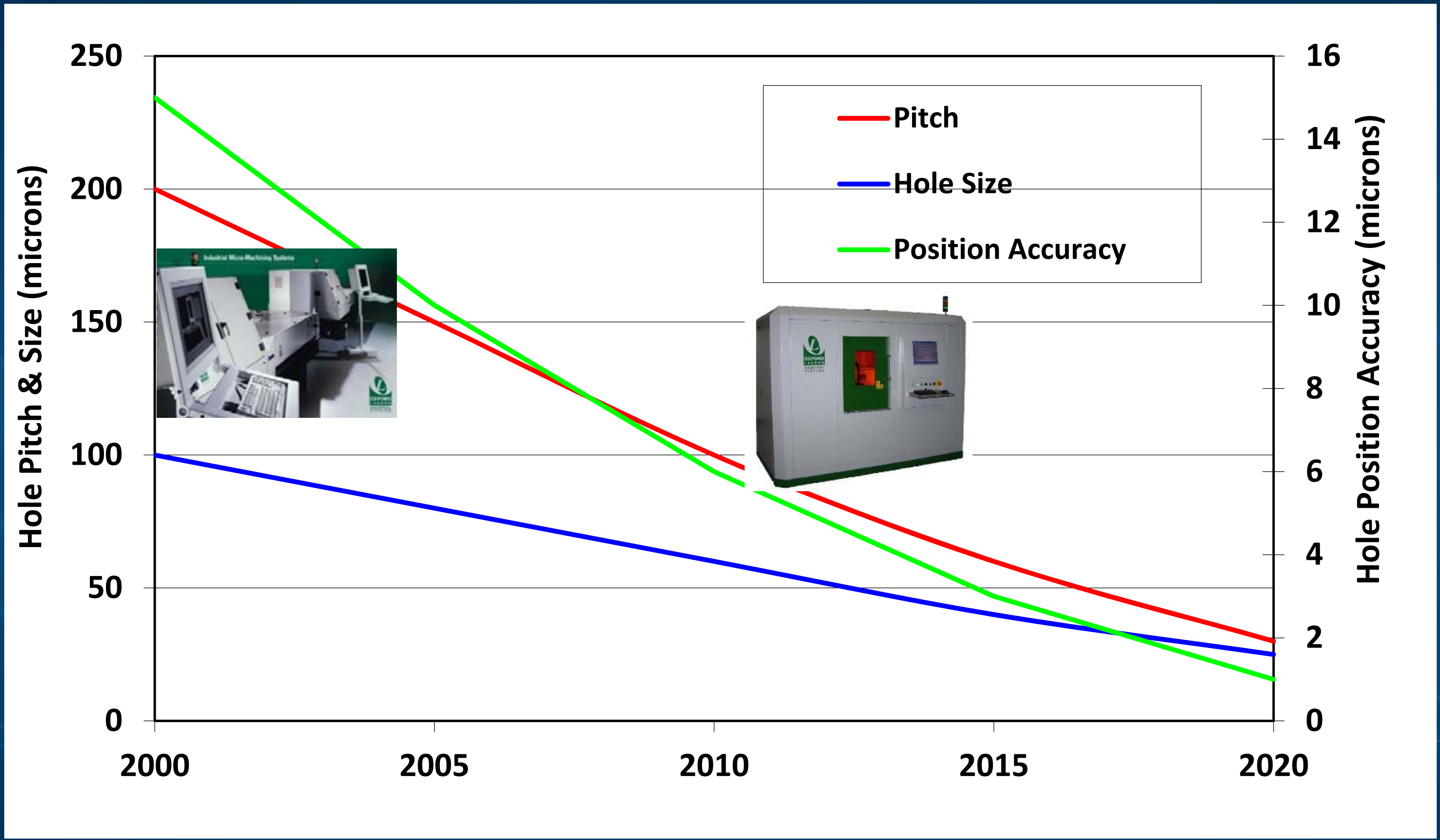


3.2 mil dia hole, polyimide



3.2 mil dia hole, SiN

Oxford Lasers Tool Roadmap



Tool capability supports industry roadmap for guide plates

Vertical Probe Card Challenges - ITRS 2013

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Vertical Probe Card Delivery Interval

"often longer than time between chip design and availability of wafers"
ITRS 2013

Drilling Cycle Time

	Time for 20,000 Holes
– mechanical drilling typically >15 secs/hole	83 hours
– Laser ProbeDrill - 6 secs/hole typical	33 hours

– Active laser development program road mapping 4 secs/hole using-house tools and leveraging over 20 years experience in laser applications development.

Vertical Probe Card Delivery Interval

"often longer than time between chip design and availability of wafers"
ITRS 2013

Drilling Yield

- right first time
- no tool breakage
- requires excellent process stability (**hole tolerance & position**)
- process stability important especially in high pin count

- **Hole Tolerance**
  - Optimized drilling strategies based on 20 years experience
  - Advanced, proprietary optical trepanning and scanning drill heads
- **Hole Position Accuracy**
  - Careful choice of best components, e.g. granite & air-bearings
  - Stable laser beam pointing - laser choice, beam delivery design

Vertical Probe Card Cost

"Fine pitch or high pin count probe cards are too expensive" ITRS 2013

New Generation Laser Tools

- **Higher Yield**
- **Faster Drilling Cycle Times**
- **Sub-contract vs. in-house tool capability**
  - Depends on in-house capability and culture towards manufacturing vs. assembly
- **Tool capability**
  - older tool designs and non-optimized tools e.g. pcb drilling tools
    - have same or higher running costs compared to new generation tools but lower capability and capacity

Vertical Probe Card Cost

"Fine pitch or high pin count probe cards are too expensive" ITRS 2013

In-House vs. Sub-Contract

In-House	Sub-Contract
Short turn-around	Low capital investment
Full control of critical process	Low training investment

Correct answer depends on company strategy and culture

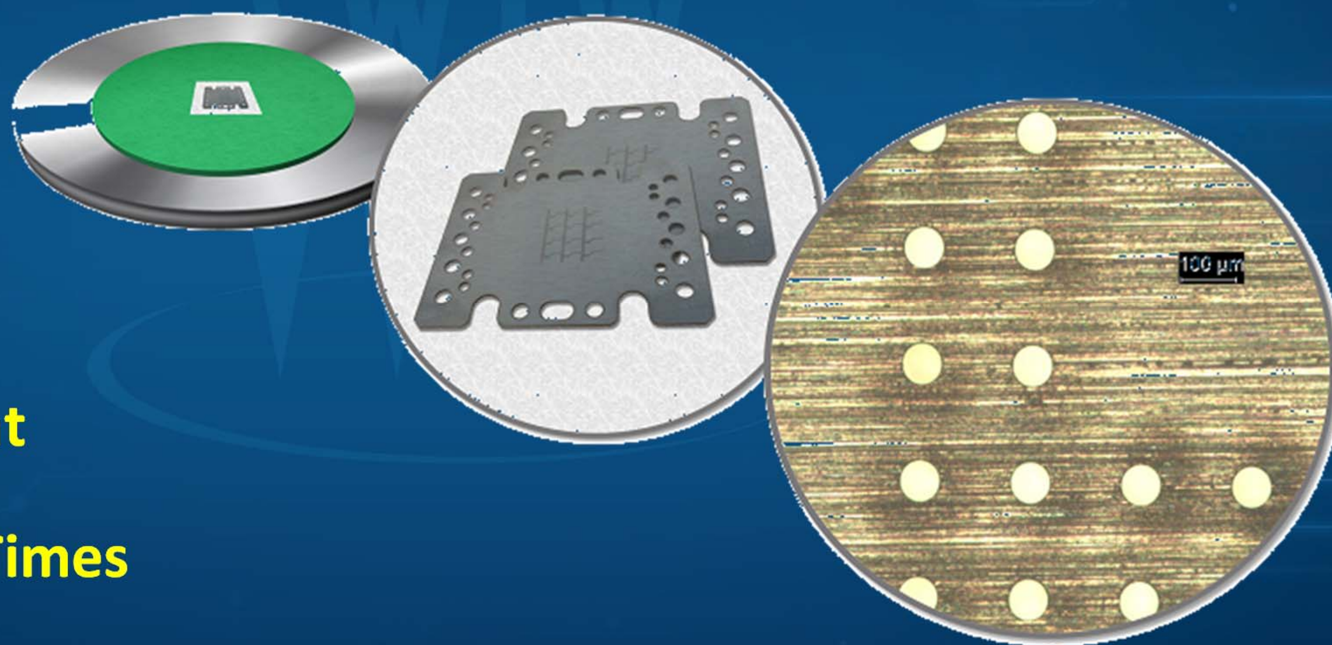
Other considerations

- Supplier (equipment or sub-contract) must be involved in development
  - to support new generation probe cards
- Metrology equipment
- Number of tools available
  - multiple tools reduce risk and increase flexibility

Advanced Laser Drilling

To meet current and future demands

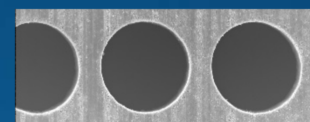
- Materials
- Fine pitch
- Small holes
- High pin count
- Faster Cycle Times



Advanced Laser Drilling

Materials

- **Lasers can drill most materials including**
  - Silicon Nitride, Alumina etc
  - Photoveel II and Photoveel II S and other new ceramics
  - Kapton, Vespel, Cirlex etc
  - Silicon, Glass, Metals



Silicon Nitride

Kapton

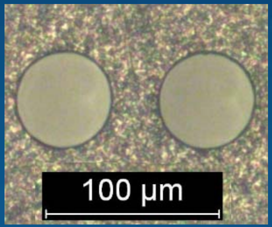
Glass

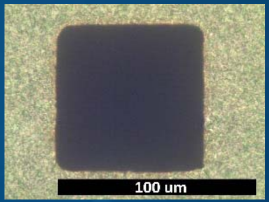
- **Requires appropriate choice of laser and process parameters**

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 30 micron holes round and square**

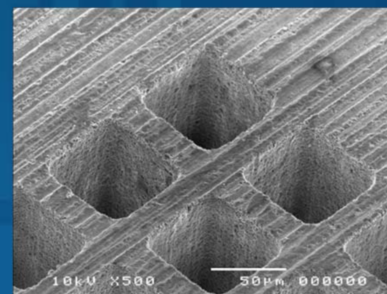


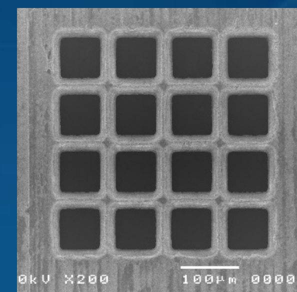


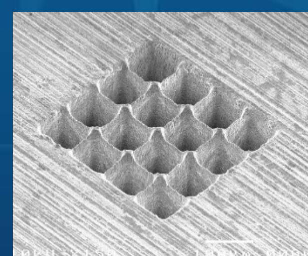
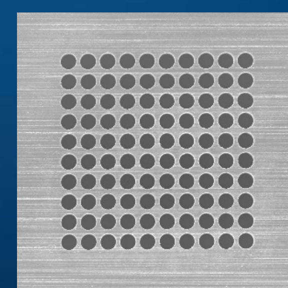
Advanced Laser Drilling

Fine Pitch

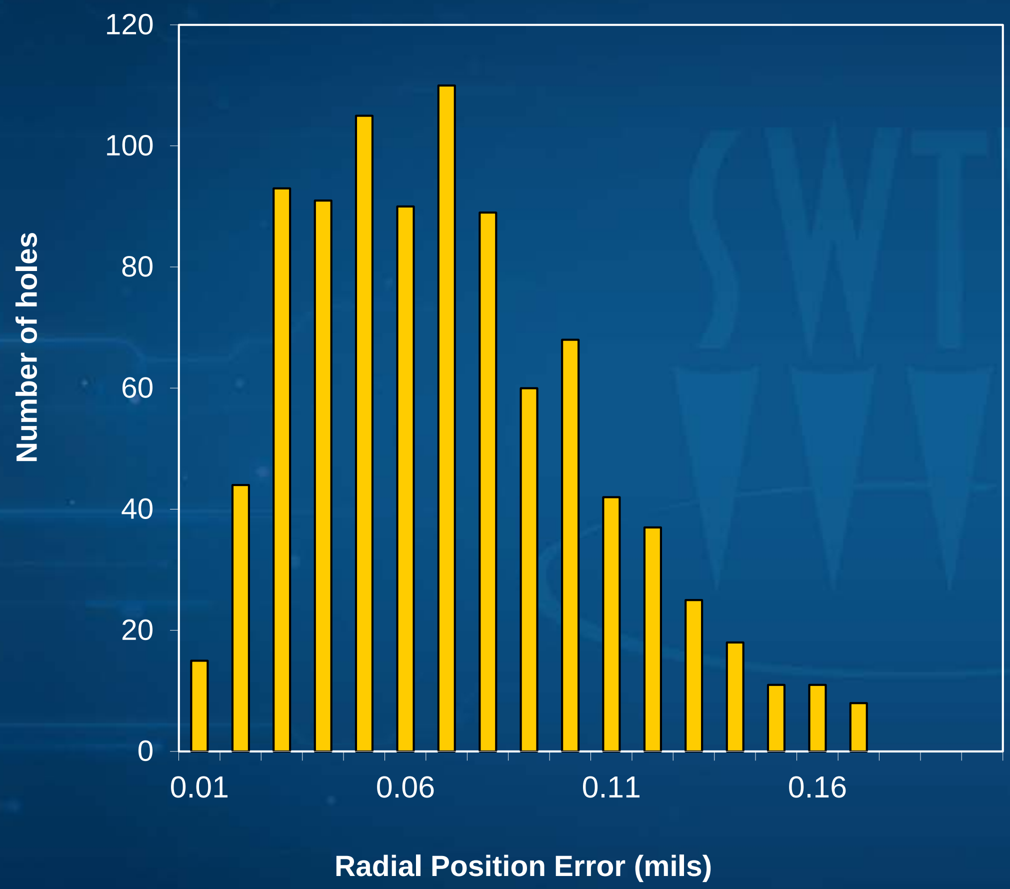
- **Requires**
  - Small holes (see previous slide)
  - Low thermal impact on material
    - no micro-cracks
    - no Heat Affect or melting
  - Low taper (see next slides)
    - to prevent hole entries merging
- **Hole pitch of 40 - 45 microns**
- **Wall thickness of 10 - 15 microns**





Laser Drilling - Position Accuracy



Radial position variation (+/-2σ)

= 0.15 mil (3.8 micron)

Measured with Mitutoyo SQV 404 PT
Resolution 0.004 mil (1micron)
Accuracy 0.07 mil (1.8 micron)

Advanced Laser Drilling

High Pin Count (>20,000)

- **At 6 secs per hole, 20,000 holes = 33 hours**
- **Requires excellent process stability**
  - maintain hole positioning (<5 micron radial)
    - excellent laser beam pointing characteristics
    - stable beam delivery system
    - excellent motion control system
  - maintain size tolerance (<0.5 micron)
    - stable laser power
    - accurate focus control over large substrates
    - excellent motion control system

Conclusions

- **With the correct choice of laser tool (laser, optics, motion system) and optimized process strategies then lasers can address some of the challenges for Vertical Probe Cards outlined in ITRS 13.**

- **<u>Latest generation tools</u> can meet the current and near-future requirements**
  - hole size (30 micron)
  - fine pitch (40 micron)
  - position accuracy (<5 micron).

- **<u>Next generation tools</u> are expected to meet**
  - hole size 20 micron
  - pitch 30 micron
  - position accuracy 2.5 microns.