MOL Solutions Inc
Optical & laser measurement
モル株式会社

# Advanced Laser Precision Manufacturing & Functional Surface Engineering

Advanced Laser Precision
Manufacturing & Functional
Surface Engineering

INTELLIGENT LASER

LSTR

MICROPLASMA

モル株式会社
MOL Solutions Inc.
www.mol-solutions.com

## Advanced Manufacturing Starts with Materials

**Our core expertise in laser-material interaction combines lasers, optics, materials science and precision control to develop verifiable, repeatable and production-ready processes.**

MOL Solutions specializes in advanced laser precision manufacturing and functional surface engineering. We integrate advanced laser sources, optics and beam engineering, precision motion stages, galvo scanners, encoders, vision and high-speed synchronization, from process development and metrology validation to production integration. For glass, SiC, ceramics, metals, PI, ABF and polymers, we enable microdrilling, precision cutting, selective material removal, microstructuring and high-aspect-ratio machining while reducing heat-affected zones, microcracks, debris, recast layers and distortion.

For semiconductors and advanced packaging, our capabilities include ultraprecision laser processing, through-glass vias (TGVs), localized redistribution layer (RDL) repair, ultrathin copper foil and battery copper processing, and SiC micropillars and microchannels for thermal management. Integrated source, optical, motion, process-window and software design delivers speed, precision, long-term stability and production scalability.

Beyond micromachining, LSTR uses laser interference to rapidly generate engineered periodic micro- and nanostructures that control adhesion, wettability, capillary flow, friction, optical response and thermal interfaces. Micro Plasma enables maskless, atmospheric-pressure direct writing for selective activation, fine cleaning, thin-film deposition and etching. Together with functional coatings, these technologies form a flexible hybrid surface modification platform.

Connecting R&D resources in Japan and Europe, MOL brings optics, laser processing, real-time metrology and intelligent control into production. Starting with customer materials and process needs, joint development, machining trials and system integration deliver practical solutions that improve yield, process efficiency and design freedom, advancing next-generation precision manufacturing from innovation to production.

## Advanced Lasers & Functional Surface Engineering

Explore precision laser processing, TGVs, LSTR, SiC thermal management and Micro Plasma by technology area.


01 Advanced Laser Manufacturing & Surface Engineering 04-08

Laser-material interaction, laser sources, beam engineering, precision motion, high-speed synchronization and hybrid surface modification

02 Ultraprecision Laser Processing 09-15

Laser sources, beam engineering and ablation-threshold control for low thermal impact, microcrack suppression, via geometry and selective processing

03 Breakthrough High-Speed TGV Drilling 16-18

Temporally shaped laser pulses create open through-holes before uniform chemical enlargement, improving via profiles and thick-glass productivity

04 LSTR: Laser Surface Texturing & Roughening 19-26

Multi-beam interference creates uniform, engineered periodic micro- and nanostructures for adhesion, wetting, friction, optics and thermal interfaces

+ SiC Microchannel Cooling

SiC micropillars, ILORA monitoring, surface activation and nanodiamond coating concepts for hybrid thermal management

05 Micro Plasma: High-Resolution Plasma Printing 30-37

Atmospheric-pressure, maskless direct writing for micron-scale activation, precision cleaning, deposition, etching and microstructuring

# 01

## Advanced Laser Precision Manufacturing & Functional Surface Engineering

Advanced Laser Precision Manufacturing & Functional Surface Engineering Company

**Laser-material interaction, integrating sources, beams, motion, processes and intelligent control**

## Precision Processing Starts with Material Understanding

MOL Solutions combines advanced laser sources, optical and beam engineering, high-speed precision motion, laser processes, micro- and nanoscale surface structures and intelligent control. We deliver precise, efficient and scalable laser processes for semiconductor, advanced packaging, optoelectronic and high-end electronics manufacturing.

**Beyond equipment integration, MOL's core strength is a deep understanding of laser-material interaction.**

## Integration from Laser Source to Production

For glass, SiC, PI, ABF, metals, ceramics and other advanced materials, MOL precisely controls wavelength, pulse duration, fluence and processing strategy to enable microdrilling, cutting, etching, microstructuring and high-aspect-ratio machining while reducing thermal impact, microcracks, debris and material damage.

### Application Capabilities

| Material × Wavelength × Pulse | Fluence & Process Strategy | High Aspect Ratio, Low Damage |
|---|---|---|
| GLASS | SiC / Silicon Carbide | PI / ABF / Packaging Materials |

## Advanced Optics & Beam Engineering: Controlling Material Interaction

**MOL designs complex optical paths and advanced beam-control systems. Beam shaping, diffractive optical elements (DOEs), Bessel beams, top-hat beams, multi-beam configurations and specialized focusing optics precisely control the spatial distribution and interaction of laser energy.**

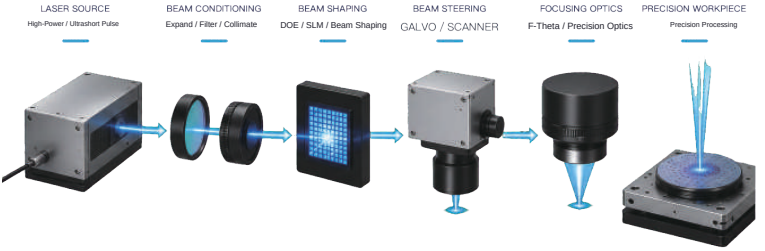
Beam shape, energy distribution and interaction depth are tailored to each material and process, improving speed, precision and quality while minimizing thermal impact. Integrating laser sources, optical design, beam shaping and process recipes turns laser energy into controllable, repeatable and scalable precision manufacturing.




## High-Speed Precision Laser Manufacturing: Speed, Accuracy & Stability

**Advanced semiconductor processes require micron-scale precision, high throughput and long-term stability.**

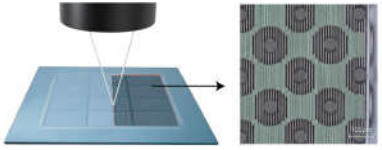
MOL synchronizes precision stages, galvo scanners, encoders, vision and laser control to coordinate pulses, scanning and processing position. With approximately 1 µm positioning repeatability and 1-1.5 G acceleration, its motion platform reduces travel and settling time between processing sites to increase production throughput.



## High-Speed Laser Interference Structuring: Engineered Functional Interfaces

**Precision laser microstructuring and micro- and nanoscale surface modification enable engineered adhesion, wettability, capillary flow, friction, bonding, thermal interfaces and optical properties.**

Applications include Cu adhesion on ABF/PI, RDL, underfill flow control, keep-out-zone (KOZ) overflow barriers, bonding interfaces, SiC cooling structures and advanced packaging.



**Advanced German LSTR technology extends surface engineering to efficient, large-area micro- and nanostructure manufacturing.**

LSTR combines multiple laser beams to rapidly generate highly uniform periodic micro- and nanostructures. Compared with point-by-point scanning, it is well suited to large-area, high-throughput functional surface manufacturing.

Engineered structures tune adhesion, wettability, fluid flow, friction, optical response and thermal interface properties, creating new process opportunities for next-generation semiconductors and advanced packaging.



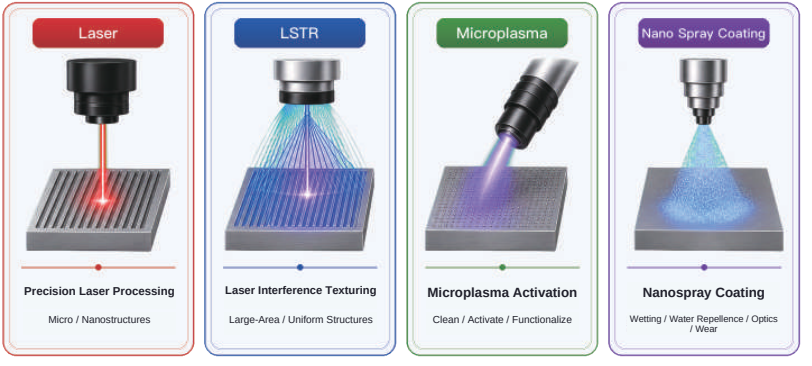
**Laser Interference Microstructure**

| | |
|---|---|
| **Adhesion & Bonding** ADHESION | **Wetting & Capillarity** WETTABILITY |
| **Friction & Optics** FRICTION / OPTICS | **Thermal Interfaces** THERMAL |

## Hybrid Surface Modification: From Microstructures to Coatings

**MOL combines laser processing, LSTR, Micro Plasma and functional coatings in a multifunctional surface modification platform.**

From laser microstructuring and activation to micro/nanoscale functionalization and specialty coatings, the complete process is tailored to the material and application, adding physical, chemical, thermal and interfacial functionality.




01 **LASER / Microstructuring**

02 **MICROPLASMA / Surface Activation**

03 **COATING / Functional Layers**

04 **FUNCTION / Hybrid Interfaces**

# 02

## Ultraprecision Laser Processing

Extreme precision laser processing

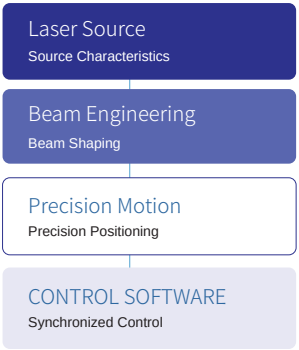
**Precise control of energy, thermal impact, sidewall geometry and selective material removal**

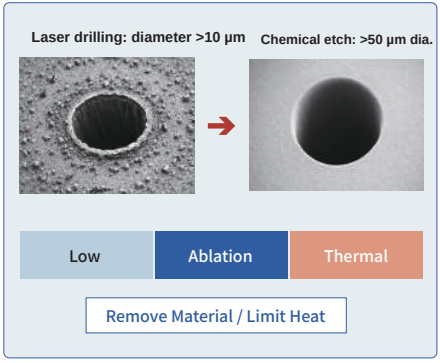


## MOL Ultraprecision Laser Platform: From Source to Control Software

**MOL Solutions considers ultraprecision laser processing a core technology for next-generation semiconductors and advanced manufacturing.**

Beyond integrating a laser source, MOL combines source characteristics, advanced optics and beam engineering, process technology, precision motion and high-speed synchronized control software. Optimized, material-specific conditions deliver laser energy with greater precision and stability.




### Ablation Threshold & Energy Control

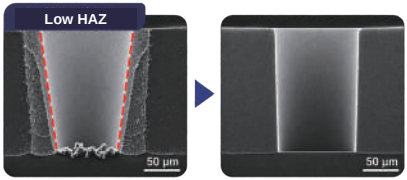
**Precise ablation-threshold control is essential: materials respond differently to laser wavelength, pulse duration and fluence.**

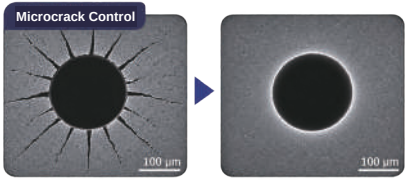
Using its expertise in laser-material interaction, MOL optimizes pulse energy, fluence, repetition rate, pulse overlap, scan speed and focus position to remain within the appropriate material-removal window. This maintains processing efficiency while limiting unnecessary melting and heat accumulation, a foundation of ultraprecision laser processing.

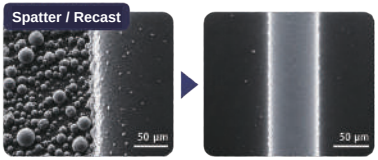
## Low Thermal Impact & Microcrack Suppression: Localized Energy, Less Brittle-Material Damage

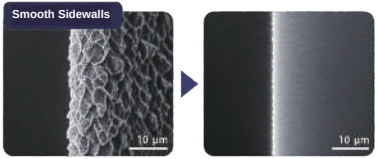
**For brittle materials such as glass, ceramics and SiC, MOL develops processes to control the heat-affected zone (HAZ) and suppress microcracks.**

Optimizing wavelength, pulse conditions, beam profile, focus position and toolpath confines energy to a small processing zone. Reduced heat diffusion and thermal stress help suppress microcracks, chipping, discoloration and distortion. This is especially important for high-reliability TGVs, glass microholes, ceramic micromachining and SiC microstructures.




## Low Spatter, Low Recast & High Surface Quality: Localized Energy, Less Material Damage

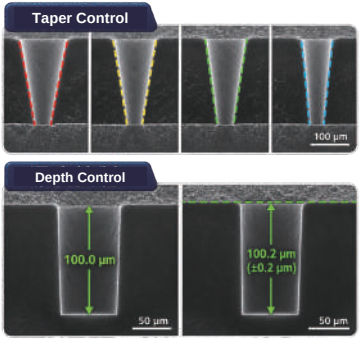
**Debris, recast layers and surface quality are key performance indicators in MOL's precision laser processes.**

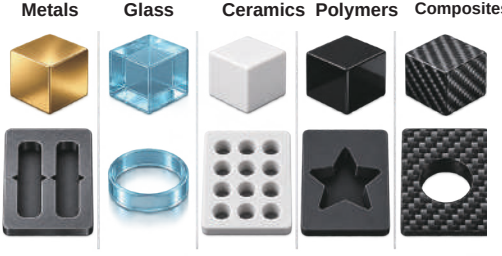
Joint optimization of pulse energy, scan strategy, pulse overlap, processing sequence and assist gas reduces spatter, molten droplets, residue and recast. Cleaner sidewalls and cut surfaces reduce subsequent cleaning, polishing and secondary processing.

## Microhole & Sidewall Control

**MOL precisely controls taper angle, sidewall roughness and machining depth in microhole and microgroove processing.**

Beam shaping, depth-of-focus management, multi-step machining and finishing reduce the taper typical of laser-drilled holes, producing more vertical and smoother sidewalls. Precision Z-axis and laser-energy control also enable blind holes, microgrooves, cavities and 3D microstructures, extending lasers beyond cutting and drilling into precision microstructure manufacturing.



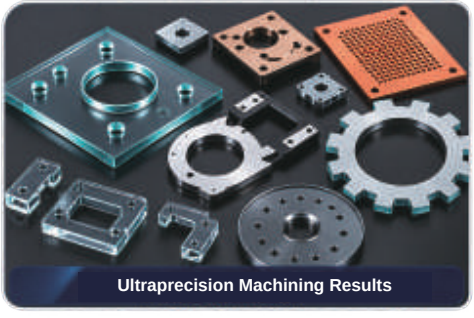

## Selective Multi-Material Removal

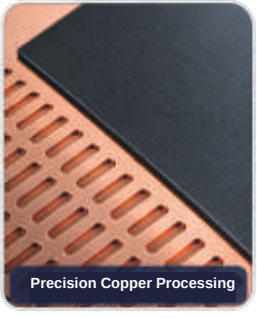
**Differences in wavelength-dependent absorption and laser-energy response enable selective processing of specific materials within multilayer structures.**

Upper layers can be removed while minimizing damage to underlying structures. Applicable materials include metals, glass, ceramics, SiC, polymers, PI, Cu and functional films, with potential applications in RDL, advanced packaging, microelectronics and precision optoelectronics.

## Multi-Material Processing: From Development to Production

**These capabilities support glass microholes and TGVs, precision cutting of complex glass shapes, ceramic microholes and square holes, SiC microstructures, ultrathin copper foil cutting and selective multi-material laser processing.**

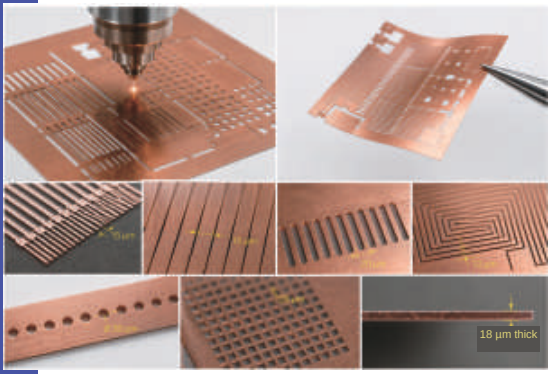

Ultraprecision Machining Results


Precision Copper Processing

Glass/ TGV —— Ceramic —— Sic —— Cu FOIL

For each material and application, MOL selects the wavelength and source, designs beam delivery, shaping, processing optics, motion and control software, then establishes the process window and parameters through material trials. This integrates process development with production equipment delivery.

# Precision Copper Laser Processing & RDL Repair




**As advanced packaging moves toward higher density and finer lines and spaces, microscopic redistribution layer (RDL) defects increasingly affect package yield.**

Cu bridges, nodules, protrusions, localized overplating and shorts can arise during fabrication. Scrapping an entire high-value AI/HPC or advanced package because of a local RDL defect carries a substantial manufacturing cost.

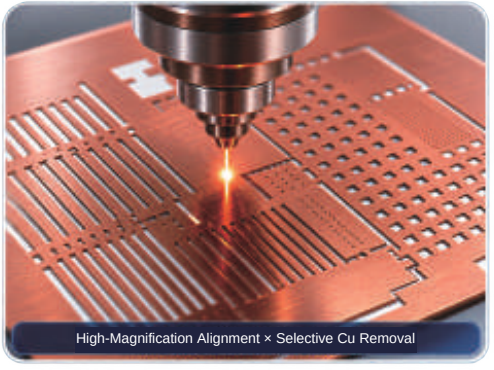
MOL develops specialized laser processes for copper and applies them to RDL repair. Advanced optics, high-magnification vision alignment, precise energy control and high-speed precision motion locate microscopic defects, then selectively remove excess Cu responsible for shorts and other circuit anomalies.

MOL RDL repair combines high selectivity and positioning accuracy with low thermal impact and material damage. Energy is confined to the defect area to protect intact Cu lines, surrounding dielectrics and adjacent structures while controlling HAZ and debris. Applications include Cu bridge removal, short repair, localized Cu trimming, nodule removal and protrusion correction. Repairing localized defects that could otherwise cause scrap can improve RDL yield, reduce scrap costs and increase the manufacturing value of advanced packages.



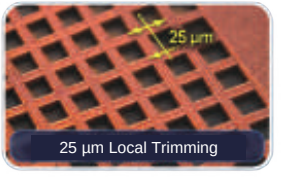
Beyond RDL repair, this technology supports precision copper processing: ultrathin foil cutting, battery electrodes and current collectors, Cu tab cutting and trimming, and cutting, micromachining and localized trimming of copper foils, leads, terminals, connectors and busbars.

MOL integrates specialized lasers with advanced optics, vision, precision motion and process control in an advanced copper processing platform. From micron-scale RDL repair to copper foil and battery components, it combines precision, low thermal impact and process flexibility for semiconductors, advanced packaging, electronics and new-energy applications.


High-Magnification Alignment × Selective Cu Removal



15 μm Line Width



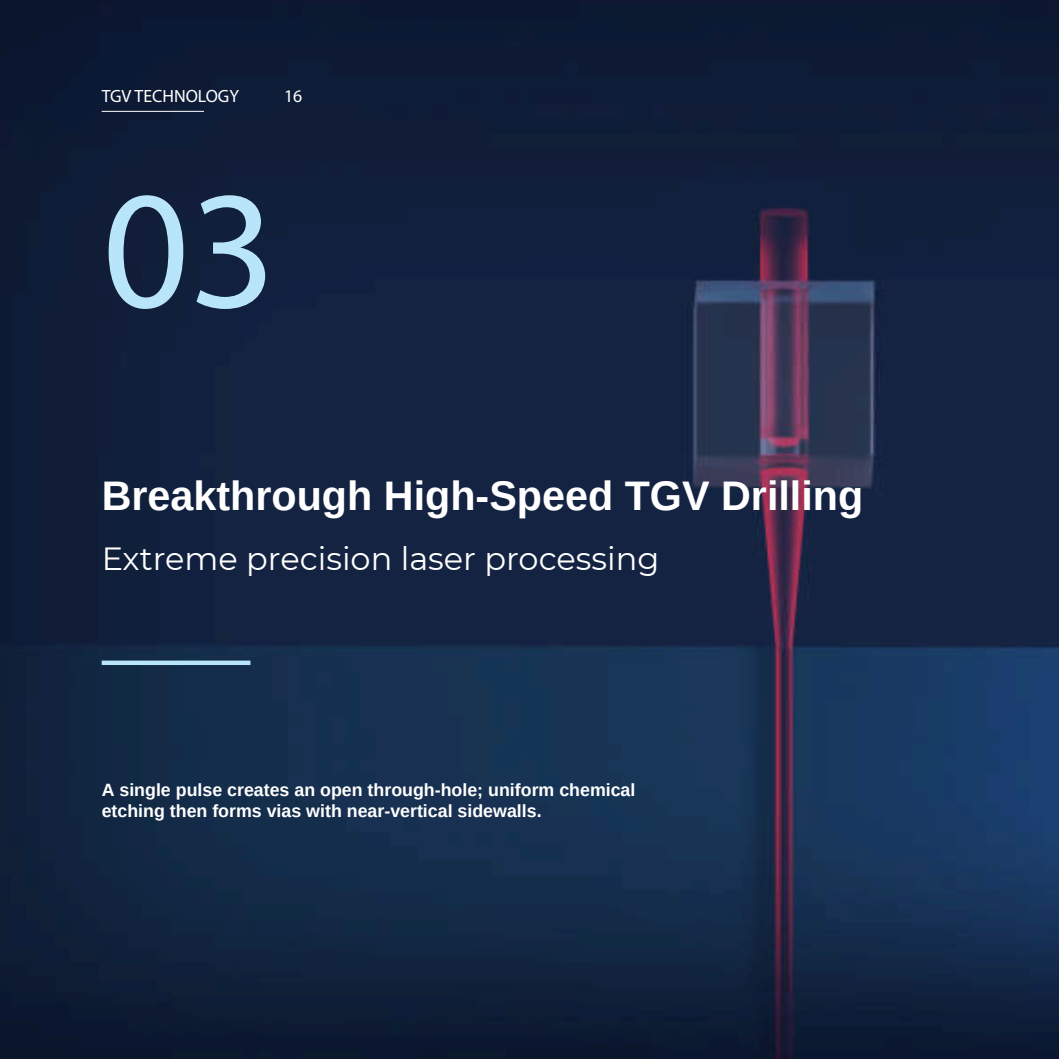
25 μm Local Trimming

# 03

## Breakthrough High-Speed TGV Drilling

Extreme precision laser processing

**A single pulse creates an open through-hole; uniform chemical etching then forms vias with near-vertical sidewalls.**



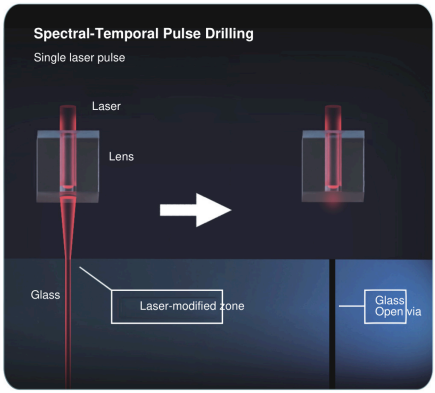
## Open Through-Holes First, Uniform Chemical Enlargement Next

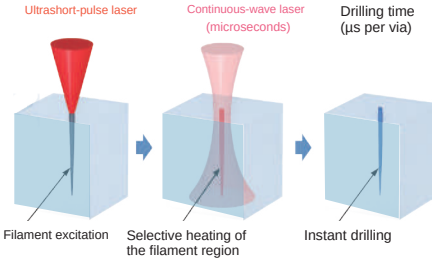
**MOL's through-glass via (TGV) technology combines temporally shaped laser drilling with chemical etching, providing a high-speed, high-quality microhole process with production potential for thick glass substrates.**

Before etching, specialized laser pulses create fully open microholes directly in glass. Subsequent chemical etching enlarges the holes uniformly, addressing the speed and profile-control limitations of conventional glass microhole processes.

Conventional laser-induced deep etching (LIDE) creates a modified channel through laser filamentation, without an open through-hole. Etching must then progress inward from both surfaces. In thicker glass, slower chemical reaction and material exchange near the center can extend etch time and produce constricted bottleneck or pincushion profiles.

MOL takes a different approach. Specially designed temporal pulse shaping creates an initial open through-hole of approximately 10-20 µm with one pulse. Etchant can enter the entire via from the outset, giving the upper, central and lower regions more uniform etching conditions. This can shorten etch time and produce straighter, more parallel and consistent sidewalls.



## Design Target: Up to ~20,000 vias/s

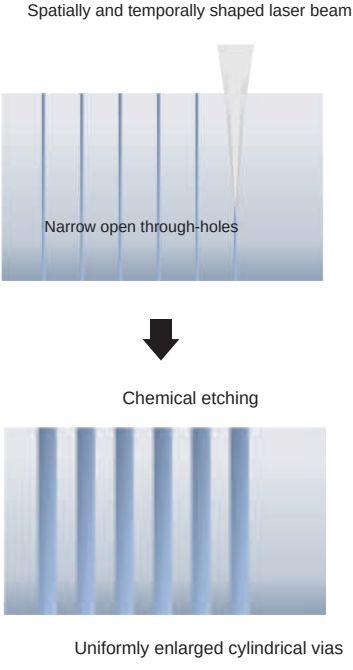
**MOL targets one initial through-hole per laser pulse, with a laser-drilling rate of up to approximately 20,000 vias/s.**

For via diameters >50 µm in glass thicker than 0.5 mm, creating open through-holes before uniform chemical enlargement has the potential to reduce total process time, improve sidewall verticality and increase production efficiency.

## Reengineering the Laser-Etch Process

**MOL's TGV value extends beyond faster laser drilling.**

It redefines how laser drilling and chemical etching work together. Single-pulse through-hole formation, uniform chemical etching and near-vertical sidewall control could provide more efficient, scalable TGV processing for high-density glass-core and glass-interposer interconnects in next-generation AI/HPC packaging.



# 04

## Laser Surface Texturing & Roughening

Laser Surface Texturing and Roughening

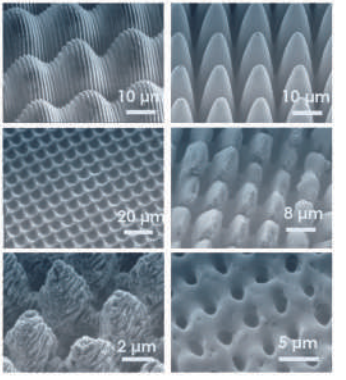
**Multi-beam interference rapidly creates uniform, engineered functional micro- and nanostructures over large areas.**

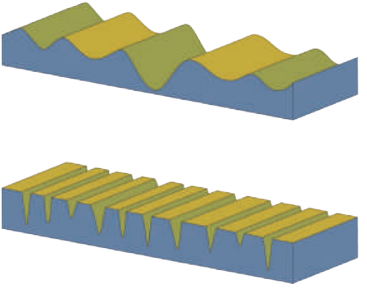
## Directly Write Periodic Micro/Nanostructures with Laser Interference

**LSTR goes beyond texture creation: engineered periodic micro- and nanostructures control functional surface properties.**

3D LSTR combines multiple laser beams to create a defined interference pattern. Modification occurs at intensity maxima, while other surface regions generally remain unchanged.

In one step, line, dot, crossed or hierarchical structures can be transferred onto metals, polymers, ceramics, composites, coatings and glass. Typical resolution ranges from approximately 300 nm to 30 µm.



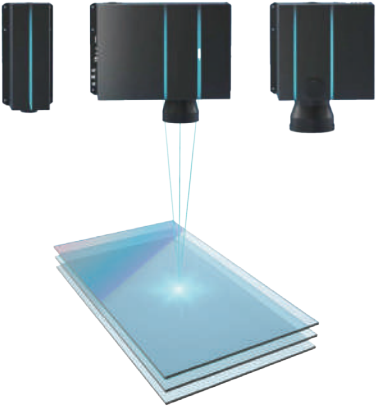



- Constructive and destructive interference forms periodic patterns
- Features smaller than the laser spot
- Parameters control pitch, geometry and surface function

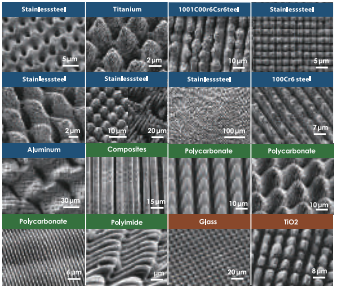
## From Laboratory Structures to High-Speed, Large-Area Manufacturing

**Unlike point-by-point scanning, an interference pattern creates periodic structures in a single exposure, enabling large-area, high-throughput functional surface manufacturing.**

Core modules support IR-to-UV lasers, varied geometries and software-defined structure adjustment. Processing speeds reach up to 3 $m^2$/min, with integration into CNC systems, industrial robots and roll-to-roll lines.



- Non-contact surface processing
- Typically no chemicals or cleanroom required
- Short- and ultrashort-pulse laser compatibility
- Modular integration with existing equipment




## Micro/Nanostructuring Across Materials

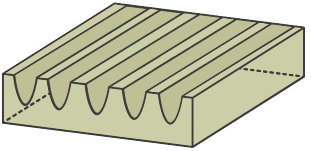
### 9 Material Classes | 18 Example Structures

Precision laser micro/nanostructuring creates holes, pillars, ripples and periodic arrays on stainless steel, titanium, aluminum, copper-chromium alloys, composites, polycarbonate, polyimide, glass and TiO2. Eighteen representative structures across nine material classes demonstrate versatile processing and geometric control, enabling application-specific wettability, friction, adhesion, optical response and thermal performance.

## Single-Scale & Hierarchical Structures for Tailored Surface Performance

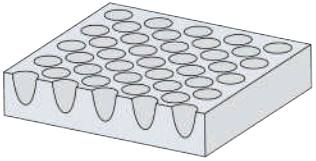
**Available geometries include lines, dots, crossed patterns and hierarchical micro/nanostructures combining multiple length scales. Each structure produces a distinct surface response.**

Control of pitch, depth, orientation and hierarchy precisely tunes roughness and geometry, providing scalable structure designs for optical, electronic, bonding and biomimetic surfaces.



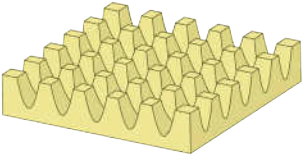
### Grooves

Increase capillary force and surface area for microelectronic and optical applications.



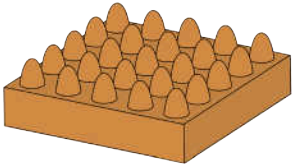
### Holes

Lower surface potential for antifouling, antifogging or anti-icing applications.



### Crossed Grooves

Requires two laser passes; MOL BIONICS multi-cross technology offers an alternative.



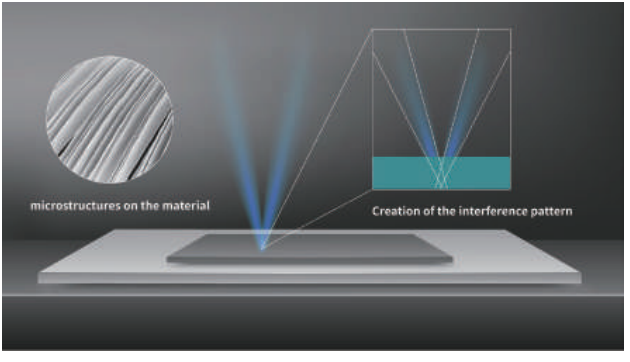
### Pillars

Surface roughening and increased area for heat transfer and medical applications.

## Microstructures for Adhesion, Wetting, Friction, Optics & Heat Transfer

**LSTR uses engineered structures to change physical and interfacial behavior, beyond simply adding texture.**

Structures can tune adhesion, wettability, fluid flow, friction, optical response and thermal interfaces, with potential functions including anti-icing, improved biocompatibility, decoration, antireflection, anti-fingerprint performance and wear resistance.




· Higher adhesion and bond strength

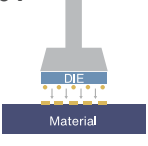
· Hydrophilic, hydrophobic and capillary flow control
· Friction, wear and electrical contact performance

· Antireflection, decoration and thermal interfaces

## Surface Engineering for Semiconductors & Advanced Packaging

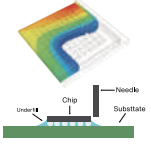
**Apply engineered LSTR structures to underfill flow, bonding interfaces, glass substrates, electronic connectors, cooling structures and precision surface treatment.**

**01**



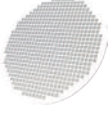

**Higher bond strength**

**02**



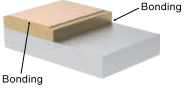

**Faster underfill flow**

**03**



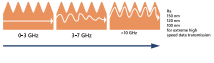
**Stronger circuit adhesion to glass**

**04**



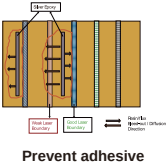

**Tune Cu foil or film roughness for stronger bonding**

**05**



**Uniform roughness for improved high-speed signal transmission**

**06**



**Prevent adhesive overflow**

**07**



**Control contact angle**

**08**



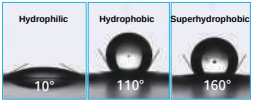
**Tune hydrophilicity and hydrophobicity**

## LSTR with Precision Laser Interference

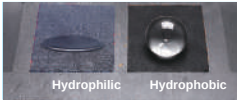
**Applications span AI chips, advanced packaging, SiC power devices, glass substrates, silicon photonics, co-packaged optics (CPO) and medical devices, offering fast, precise and scalable functional surface engineering.**

## Surface Energy Engineering

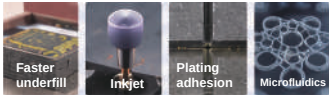
**a. Tune wettability and contact angle**




**b. Control surface energy by region**

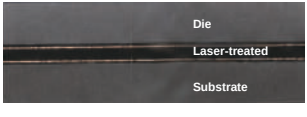



**c. Applications**

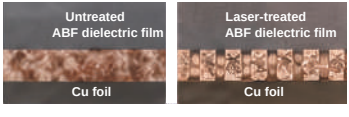



## Bonding Engineering

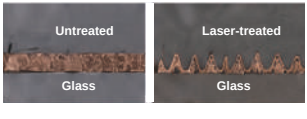
**a. Stronger die bonding**



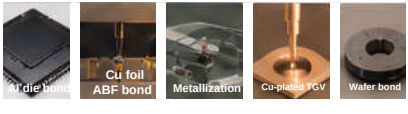

**b. Stronger ABF-to-Cu foil bonding**




**c. Stronger plated-circuit adhesion on glass**

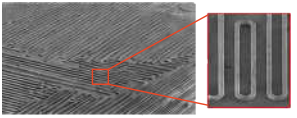



**d. Enhanced interlocking across applications**

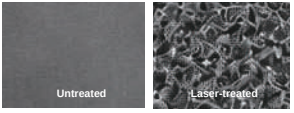


## Thermal Engineering

**a. Machine microchannels in SiC wafers**

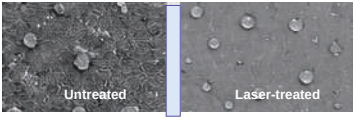


**b. Tune roughness to increase heat-transfer area**

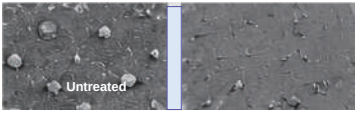



## Antifouling Surfaces

**a. Prevent surface contamination**

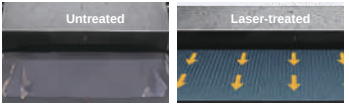



**b. Reduce adhesion of foreign particles**

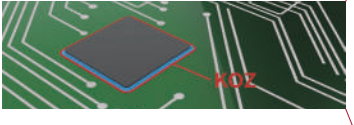



## Fluid Control Engineering

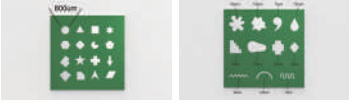
**a. Create channels to accelerate underfill flow**

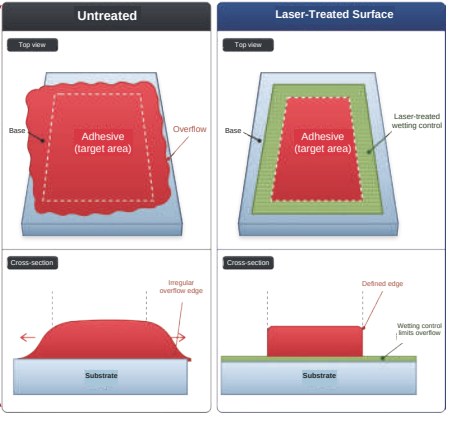



**b. Confine fluid flow to meet KOZ requirements**



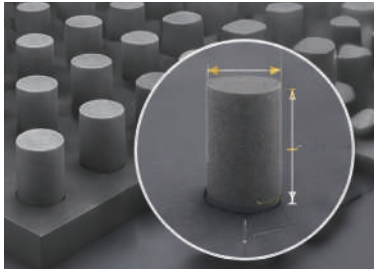

**c. Enable coating of small, irregular geometries**



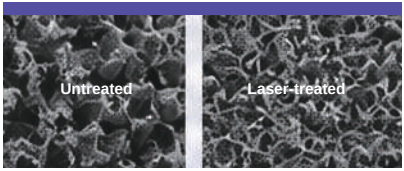



## Thermal Engineering: SiC Micropillars

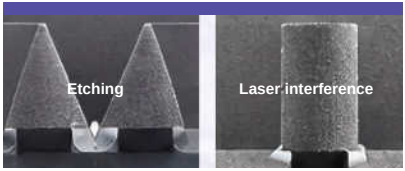
**Laser interference microstructuring forms dense SiC micropillar arrays with near-90° sidewalls, increasing effective surface area and coolant-to-surface heat exchange. Unlike conventional etching, which tends to form V-grooves, it produces well-defined, dimensionally uniform pillars for advanced thermal management and liquid cooling of AI GPUs, power modules and high-heat-flux devices.**



**More surface area for better cooling**




**High-speed machining of 3D microstructures**




Thermal resistance
30-50% lower

Higher heat flux
**2-3×**

Improved cooling
**Significant**

High reliability
**Long service life**

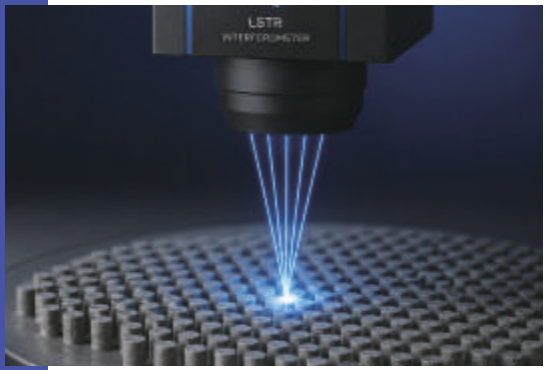
# Laser Interference for SiC Microchannel Cooling

**SiC offers high thermal conductivity, hardness and high-temperature stability for high-heat-flux environments. Its hardness and brittleness, however, make precision machining of high-aspect-ratio micropillars challenging.**

MOL coordinates the laser source, precision optics, beam profile, fluence, focus and high-speed precision motion to create dense SiC micropillars, microchannels and customized 3D cooling structures.

Precise laser parameters and multi-step machining reduce taper, V-grooves, microcracks, debris, recast and HAZ, targeting near-vertical sidewalls, flat bottoms and uniform pillar geometry.

Precision etching or post-treatment can further improve surfaces beyond laser-only processing, balancing throughput and microstructure quality.




MOL integrates ILORA real-time optical monitoring to stabilize micropillar processing. Non-contact laser reflectometry continuously acquires SiC reflection signals. Intensity and waveform analysis tracks material removal, machining depth and surface condition in real time.

ILORA monitors pillar height/depth consistency, local machining anomalies and signals associated with microcracks, surface damage or nonuniform processing, extending offline inspection to inline/in-situ real-time process monitoring.

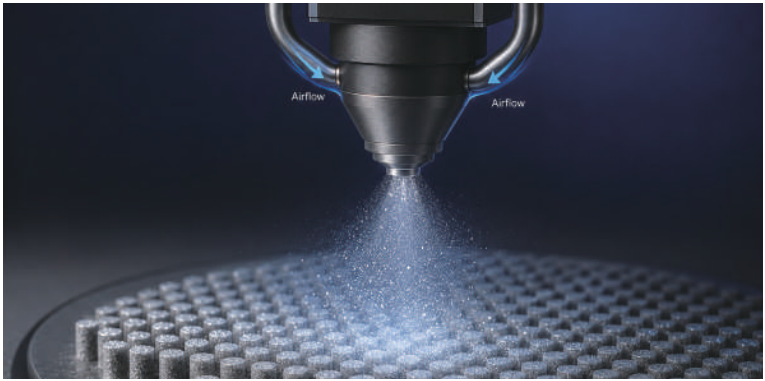
Measurements can be linked to laser power, pulse energy, focus, scan speed and pulse overlap for compensation and optimization. This supports development toward closed-loop control: Measurement > Analysis > Process Adjustment > Verification. The aim is to reduce variation and improve pillar-array uniformity, yield and traceability.

## Surface Activation × Nanodiamond Coating × SiC Microstructures

**MOL extends SiC micropillars beyond geometric machining into integrated surface engineering, including the concept of nanodiamond coatings.**

After micropillar machining, localized Micro Plasma activation can treat pillar tops, sidewalls and surrounding areas to increase surface energy and wettability, improving bonding between SiC and subsequent functional materials. Selective treatment helps improve coating uniformity and adhesion reliability on high-aspect-ratio structures.

MOL further explores a nanodiamond coating concept that adds a thermally conductive functional layer to activated SiC micropillars. It combines SiC's thermal conductivity, the pillars' increased effective area and diamond's heat-transfer properties in a hybrid thermal management structure. ILORA could also extend to downstream processing, using optical-signal changes to help assess surface condition, coating uniformity and local anomalies across the full process flow.



# 05

## High-Resolution Plasma Printing

Micro Plasma

**Atmospheric-pressure, vacuum-free and maskless direct writing for micron-scale selective activation, cleaning, deposition and etching.**



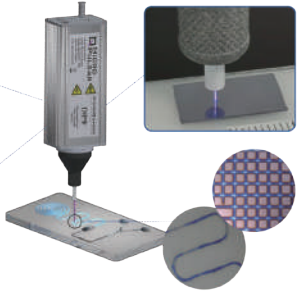
## Atmospheric-Pressure Direct Writing for Selective Surface Treatment

**Next-generation heterogeneous integration needs effective surface modification; conventional methods often lack precision and speed.**

Micro Plasma combines atmospheric-pressure microplasma with direct-write plasma printing. Treatment is confined to micron-scale areas at relatively low temperatures, without vacuum or masks.







## Functions & Features

### Activation
Modify surface energy for bonding, printing and coating.

### Thin-Film Deposition
An open precursor system deposits polymers, metals, metal oxides and hybrid layers.

### Precision Cleaning
Remove micron-scale organic contamination for surface preparation.

### Etching
Selective layer etching for microstructuring and fine patterns.

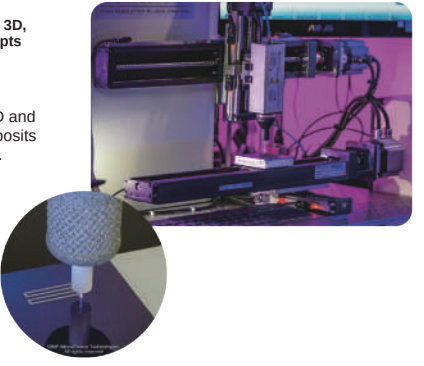
### Microstructuring
Micro- and nanotexturing creates tailored functional surface properties.

### Additive Manufacturing
Integrates with 2.5D and 3D additive manufacturing for high-resolution features.

## Micron-Scale Patterns & Gradients, from 2D to 3D

**Create simple or complex patterns in 2D, 2.5D and 3D, including continuous gradients. Direct writing adapts toolpaths to the design.**

Activation, thin-film deposition, fine cleaning and etching support simple and complex 2D, 2.5D, 3D and graded structures. An open precursor system deposits polymers, metals, metal oxides and hybrid layers.



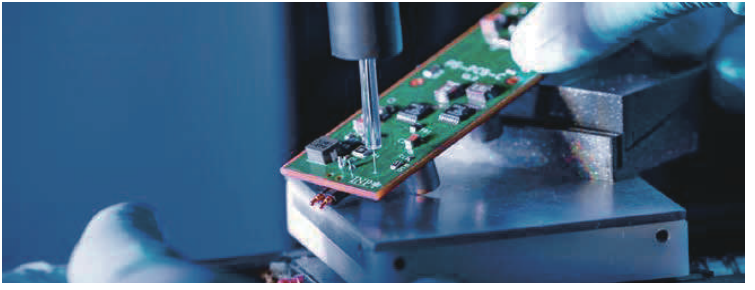
## Line Widths from 30 µm: Precise, Multi-Material & Modular

**The high-resolution plasma printing system uses advanced multi-material direct writing for fast, sustainable, scalable and modular processing.**

| 30 µm | 10-80x | <20 µm | 2-33× | 12-20× |
|---|---|---|---|---|
| Current line width | Finer than comparable plasma systems | In development | Lower gas use | Lower power use |

## Micron-Scale Treatment without Vacuum or Masks

**Heterogeneous integration requires controlled surface modification at micron scales. Atmospheric-pressure microplasma and direct-write printing localize treatment to specified areas, supporting low-temperature, vacuum-free and maskless high-resolution surface modification and microfabrication.**



| Atmospheric pressure | No vacuum | Maskless | Area-selective |
|---|---|---|---|
| ATMOSPHERIC | NO VACUUM | MASKLESS | AREA SELECTIVE |

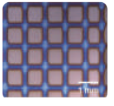
## Open Material Selection for Tailored Functional Layers

**Open precursors and plasma gases enable processes tailored to the substrate, pattern and functional layer.**

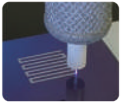
Activation, deposition, fine cleaning and etching support simple and complex 2D, 2.5D, 3D and graded structures. An open precursor system enables polymer, metal, metal oxide and hybrid-layer deposition.

### POLYMER LAYERS

Examples: (tetrahydrofuran-2-yl)methyl methacrylate, 1,2,4-trivinylcyclohexane, PEG, ethylene



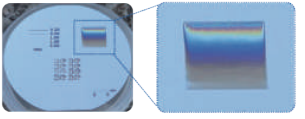




### GLASS LAYERS

Example: HMDSO





### METAL LAYERS

Silver and gold; no nanoparticle inks



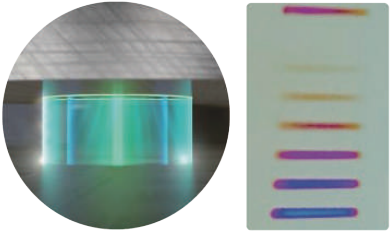


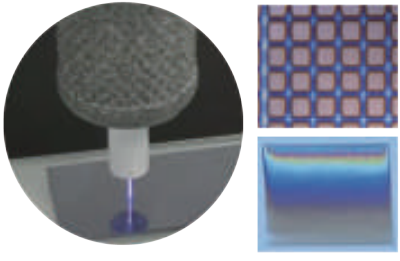
### METAL OXIDE LAYERS

E.g., alumina; hybrid layers also supported

PLASMA GAS | Ar · Ar+$N_2$ · Ar+$O_2$ · He · Ne

## Technology Comparison





### Other Technology: ALD*

**Atlant3D DALP®**

· Minimum resolution: 400 µm

· Temperature: 120-300 °C

· 3 mm wide × 40 mm long line: 3-4 min

· Graded structures supported

### MOL Technology

**Micro plasma**

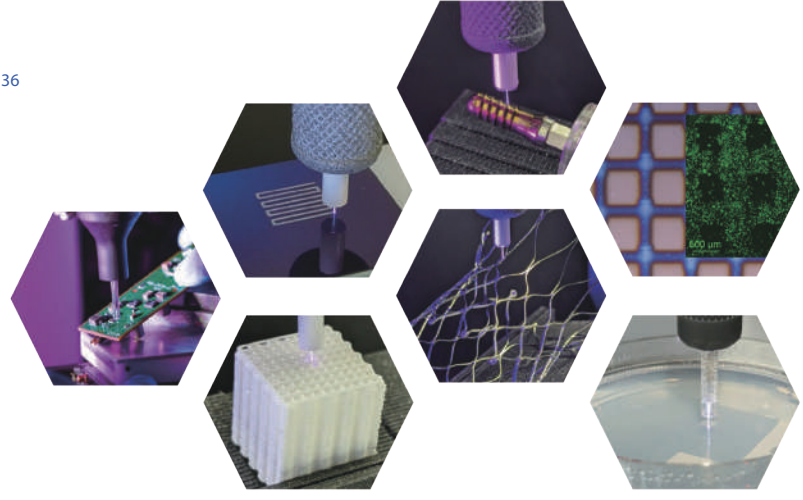
· Minimum resolution: 100 µm

· Temperature: 30-40 °C

· 3 mm wide × 40 mm long line: 3 s

· Graded structures supported

| Feature | Plasma Jets (Market) | ALD (Atlant3D) | Micro Plasma |
|---|---|---|---|
| Minimum resolution | 100 - 10,000 µm | 400 µm | 30 µm |
| Temperature | 30 - 40 °C | 120 - 300 °C | Low (<40 °C) |
| Speed (3 mm line) | 3 s | 3-4 min | Fast / selective |
| Sustainability | High gas / power use | Moderate | Minimal waste |




## Applications for Next-Generation Heterogeneous Integration

**High-resolution plasma printing supports heterogeneous integration, microfabrication, rapid prototyping and custom microplasma solutions, with material compatibility, reduced damage, complex geometries and in-situ treatment.**

### Life Sciences & Medical Devices

Surface activation for biosensors, microfluidic devices and medical equipment.

### Electronics & Semiconductors

Thin-film electronics, flexible circuits and heterogeneous integration.

### Advanced Materials

Tailored surface functionality for advanced material development.

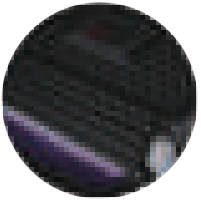
### Research & Academia

Microfabrication research, surface science and process development.

## Plasma Jet Processing Scales

**Existing plasma jets operate from centimeter to submillimeter scales, with differing jet sizes, treatment areas and application methods. Micro Plasma focuses on micron-scale direct writing and area-selective treatment for fine patterns, localized surface modification and heterogeneous integration.**

## Applications



Surfx 10-100 mm



plasmatreat 1-5 mm



MPG 500 µm–2 mm



Relyon Plasma 5 mm



Nadir s.r.l 1 cm2



Space Foundry 700 µm

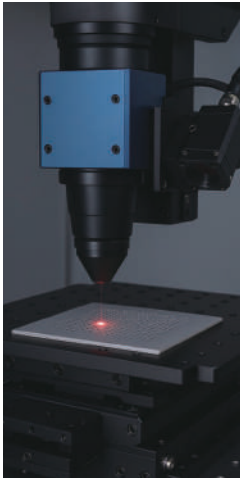
# TECHNOLOGY

## OPTICAL & LASER

### Next-Generation Laser Processing

Ultrafast laser through-hole processing for advanced semiconductor materials and precision micromachining.





### Precision Dispensing

Real-time optical droplet monitoring for ultraprecise, stable, high-speed dispensing control.

### 3D LSTR Technology

Laser-engineered microstructures improve bonding, wetting, thermal management and surface functionality.



# Note_

Date: / /

MOL SOLUTIONS Inc.

Finer features, tighter tolerances and higher throughput make precision lasers and optical metrology essential to manufacturing.

MOL Solutions delivers the precision metrology and laser micromachining needed to support this transition in real production environments.

*Precision in Every Step*

**MOL Solutions Inc**
Optical & laser measurement
モル株式会社

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