SUSS LI SERIES: DIRECT LASER WRITING TECHNOLOGY FOR FAST PROTOTYPING IN ACADEMIC AND INDUSTRIAL R&D

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Artwork generation by laser direct writing on resist is a highly versatile complement to traditional mask-based lithography. This technology results also particularly cost effective when fast turnaround must be achieved in research activities and small productions.

The Laser Imager addresses a wide range of applications, such as microelectronics, microfluidics, diffractive optics, MEMS, conformal micro-patterning, microwave integrated circuits (MICs), and graphene and nanotube technology.
In R&D, for example, the LI Series equipment stands for flexibility and ease of use, resulting in a key enabling technology for the fastest optimization of all research processes. Due to the combination of its optical apparatus and its high precision stage movement controls, the same tool can be used first to produce a pattern and then for inspecting the results. The system transforms a laser beam into a controlled writing tool, reaching a sub-micrometric resolution over large areas.
Particularly effective is the use of direct laser writing technology within a complete process transfer from product optimization to high volume production. The layout of a microelectronic device, for example, can be quickly optimized by modifying a software mask (i.e.a CAD file) for directly writing onto a resist coated substrate using the SUSS Laser Imager. Once the layout of the device is finalized, the same LI equipment can be used to produce the photolithography mask to then transfer the complete lithographic process to the high through-put mask aligners.
For micro-optics, laser writing, with its grey-scale lithography capability, ideally complements the manufacturing processes of optical devices. This technology allows for the definition of high-quality masters from whom micro-lenses and diffractive optical elements can be effectively replicated.

When employed in micro-parts fabrication, the extensive customization possibilities of the SUSS LI tools offers the option to include additional laser sources, with wavelengths tailored to specific process requirements. For example, a second 375 nm laser would allow the effective patterning of thick layers such as SU-8 resists, typically for fabricating high-quality micro-mechanical parts, for example in the watch industry.

The new Laser Imager from SUSS MicroTec is a versatile direct writing tool with a cost/performance ratio optimized for each specific application. In this view, each unit is unique, including a combination of standard and customized features matching the requirements of the user in R&D activities or specialty industrial productions.

TECHNOLOGY AND FEATURES

Laser direct imaging is based on the possibility of exposing a photoresist film, deposited on a substrate, by means of focalized laser radiation and defining the desired pattern by moving the focus spot and the substrate in a variety of write modes, allowing the user to select the patterning strategy best suited for each specific design.

Besides the possibility of selecting among different write modes, a host of other features makes up the unique capabilities of the Laser Imager.

- **Surface tracking:** the laser spot can follow and remain in focus on the substrate surface even if this is slightly concave, convex or uneven. The focusing system exerts no pressure on the substrate, allowing patterning on delicate substrates like thin free-standing membranes or soft samples. The laser writing process can be performed also on slightly tilted substrates (max 2 degrees).

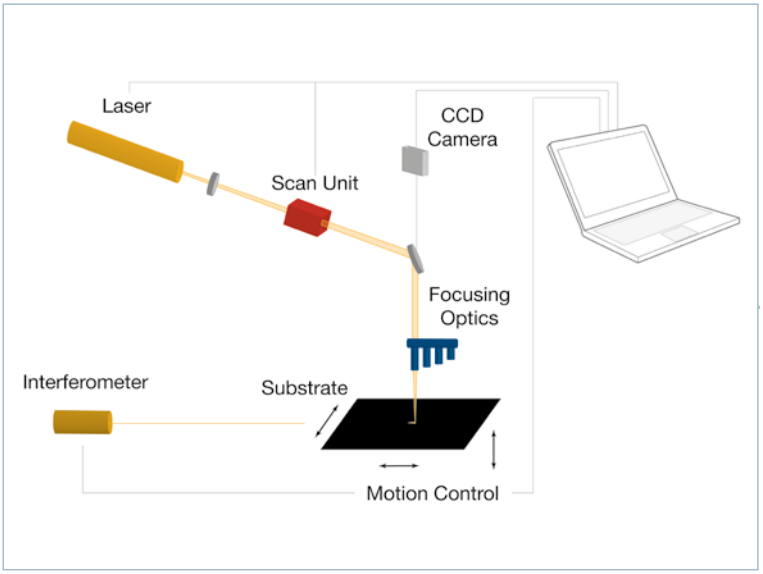

Figure 1 *Sketch of the SUSS LI equipment: the laser beam, after passing through the scan unit, is scanned on the substrate surface via a set of focusing lenses capable of achieving different resolutions. At the same time, the XYZ stage is moved synchronously with the scanned beam. In the* ***Pro*** *Series an additional interferometer allows for submicron control of the relative position between beam spot and substrate*

This characteristic is especially useful if small samples with non-parallel surfaces are used, or when they are glued on a larger carrier plate.
No dead area: the laser beam can pattern substrates of any size and shape, remaining in focus up to their edges. This feature is especially useful in R&D activities if small chips or irregularly shaped samples are used.

- **Wide selection of minimum linewidth and patterning speeds:** by simple mouse clicks, the user can define the minimum laser spot size used for patterning (from submicron to 8 µm) and the positioning resolution for each pattern element (from 0.1 µm to 2 µm). Furthermore, the automatic lens exchanger allows the user to select in a few seconds the most suited resolution for each specific part of the layout, optimizing system through-put.

- **Possibility of hosting one or two lasers for micro-lithography.** Normally, a 405 nm laser is installed, corresponding to the h-line of the mercury lamp used in mask aligners. This gives the tool a full compatibility with the most popular photoresists used in traditional micro-lithography. But a 375 nm laser can be added, well suited for thick SU8 resist or other thick UV-sensitive photo-polymers. Of course, wavelength selection requires only a mouse click.
  It is also possible to host **an additional laser source for surface processing or micro-ablation**. A nano-, pico-, or femto-second laser can be installed in addition to 405/375 nm lasers, making the Laser Imager a unique combined tool for both micro-lithography and laser processing.

- **Bottom-side alignment capability:** an optional back-side microscope, combined with a chuck adapter, allows also for back-to-front pattern alignment.

- **Extremely long lifetime for the 405/375 laser sources.** These are directly modulated (no acousto-optic modulator) and have a practically infinite lifetime (a warranty of 4 years is given for the laser sources).

- **Fully customizable substrate chucks,** capable to host samples of any size and shape, with thickness up to 10 mm.

- **Wide range of resist thickness,** from 0.3 to 100 µm. Therefore, the same tool can be used for ultrafine submicron patterns on thin resist (e.g. for micro-electronics, micro-optics) as well as in low resolution applications on thick resist (e.g. for microwave circuits, PCB, solar cells, MEMs, micro-fluidics). The user can also set the beam focus above or below the resist surface, for controlling the *sidewall* shape.

- **Possibility of surface photoluminescence mapping,** with 405/375 nm pump wavelength.

With its particularly compact footprint and the minimal requirements posed on the cleanroom infrastructures (no compressed air required, no air cooling duct, no water), those tools are an optimal fit for any laboratory.

The unique capabilities listed above are complementary to a number of other traditional features that the user may expect in an advanced pattern generator:

- Multilayer patterning, with manual/automatic top-side overlay alignment.
- Videomicroscopy and surface metrology.
- Grey level lithography.
- Simple and intuitive Windows™ user interface.
- Minimum or null maintenance.

TOOL DESCRIPTION

The Laser Imager is composed of three parts: the Write Unit (with dual beam XY laser interferometer in the *Pro* versions), the Control Unit and the powerful PhotonSteer control software.

Figure 2 *The SUSS LI8* ***Pro*** *model: The Write Unit contains the laser source(s), the chuck for the different substrates, and the XYZ stages that move the substrate under the focused laser beam. A rack cabinet contains the Control Unit*

As mentioned above, the Write Unit hosts normally a 405 nm laser (60 or 200 mW) for general purpose lithography. An additional 375 nm laser (50 mW) can be included, as well as another laser for surface microprocessing.

A large choice of write areas is available, from 2"x2" to 13"x13", with an allowed substrate size at least 2" wider that the write area.

Substrate motion is achieved through a XY stage equipped with state-of-the-art linear motors having 10 nm resolution and a Z stage with 100 nm resolution. If the laser beam is kept still, the XY motion system provides for defining the trajectories of the focused spot on the substrate surface. This corresponds to **stage-scan, vector** and **contour** modes. Such modes are well suited for patterning long straight or curved lines or for specific applications (photochemistry, trimming, etc.). Any linear XY stage movement can be programmed, with position-synchronized beam on/off and a maximum drawing speed of 10 mm/s. But in most applications, with generic complex and dense patterns, the default **beam-scan** mode is used: the whole pattern is converted into a bitmap image and divided into parallel strips. The laser beam is scanned on the substrate while this moves along each strip (Y direction), orthogonal to the scanning direction (X). The bitmap pattern is obtained by modulating the beam during each scan. After completing one strip, the stages move to the beginning of the next strip and the process is repeated. All strips are precisely aligned to each other, with no visible stitching error between adjacent strips, thanks to a proprietary **zero-stitch technology** used in the tool. The surface patterning speed in beam-scan mode depends on the resolution set by the operator, and can range from 5 mm^2/min to 160 mm^2/min.

In all LI systems, XY metrology relies on state-of-the-art optical encoders embedded in the linear motors, with an absolute positioning precision around 1/10000 of the motion value. For

	LI2	LI4	LI6	LI8	LI6 *Pro*	LI8 *Pro*	LI12 *Pro*
Substrate Size	100x100mm	150x150mm	200x200mm	250x250mm	200x200mm	250x250mm	350x350mm
Write Area	50x50mm	100x100mm	150x150mm	200x200mm	150x150mm	200x200mm	300x300mm
Autofocus and Surface Track	No		yes				
Setup	TableTop		Stand Alone				
# Focusing Optics	2		4				
Automated Lens Exchanger	No		Yes				
Auto Multilayer Alignment	No		Optional		Yes		
Double Write Speed	No		Optional		Yes		
Laser Interferometer	No				Yes		

Figure 3 *Summary table of the different models in the SUSS LI Series and of their main characteristics*

more demanding application and for achieving low sensitivity to environmental temperature variations, the **LI *Pro*** range of Imagers is recommended. All LI *Pro* tools are equipped with dual-beam XY laser interferometer, in addition to the embedded optical encoders, and guarantee submicron positioning precision over the full motion range.

All Imagers include substrate video monitoring through the focusing objective, with red light illumination, image averaging, frame grabbing and metrology tools.

The amount of energy used for resist exposure can be selected in a wide range, from a few mJ/cm^2 to several thousands of mJ/cm^2. This corresponds to a wide selection of resist thickness, from a fraction of micron to about 100 µm.

The **Control Unit** is an easy serviceable rack cabinet hosted below the write head. Therefore, it does not require any additional floor space.

The **PhotonSteer** package includes all necessary software drivers and the user interface for managing the Imager through the Control Unit. A layout editor is also included (CleWin5), with format converters to/from GDSII, DXF, CIF, Gerber, etc

No special facility or safety measure is required for system installation. Only a standard 220-230 V or 110-115 V grounded wall plug is required. The system enclosure protects the user form any laser stray light and interlocks switch off the laser beam or the whole system in case of intentional access to the interior of the system.

CONCLUSIONS

SUSS MicroTec's LI series, with its versatile surface laser patterning technology, lends itself as an ideal tool for the many requirements of academic and industrial R&D laboratories. With their primary focus on flexibility, robustness, ease of use, and large spectrum of possible customization, the several models within this product range allow to provide always the most suited solution for each specific user application.

Dr. Claudio Arnone is President and R&D manager at MICROTECH srl, Italy. He graduated in Italy in 1978 and later he carried out pioneering work on laser processing at MIT-Lincoln Laboratory. Co-founder of MICROTECH in 1992, now actively collaborates with SUSS MicroTec in the field of laser writing.