MASKLESS ALIGNER TECHNOLOGY AND THE MLA300 DRIVE EFFICIENT

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DEVELOPMENT AND PRODUCTION IN MICRO STRUCTURES

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HEIDELBERG INSTRUMENTS

Content overview

Paradigm shift in designing and manufacturing of microelectronics

Agility and flexibility through digital integration have become the new mantra for almost any industry. Consequently, there is a growing demand for state-of-the-art solutions which allow for scalable, versatile, and seamless integration with existing MES (Manufacturing Execution Systems) as well as legacy equipment.

The shift from traditional mask lithography production processes to highly automated, digital processes can be observed almost everywhere – most obviously in fields such as semiconductors, advanced packaging, highly integrated sensors as well as control elements. Here, the overall need to meet the specific micro-electronics application requirements with precision, versatility and high yields continue to challenge traditional lithography solutions.

The introduction of Maskless Aligner (MLA) technology by Heidelberg Instruments (HIMT) in 2015 has triggered a transformation that keeps evolving, even with respect to industries which are usually not associated with high-tech — such as precision gears used in clockworks.

Advantages of direct laser print over traditional mask technology

Systems based on HIMT's maskless aligner technology (MLA) provide extremely high exposure speed, front- and backside alignment, warpage compensation, high resolution, and high accuracy. Their ability to expose on any substrate size, ranging from tiny semiconductor pieces to full 8“ wafer panels, makes MLA technology suitable for a wide range of applications.

In volume production as well as in R&D, direct laser writing can speed up the prototyping and significantly reduce fabrication costs. Time and money are not the only decisive factors. Today, many manufacturers and product developers select the maskless aligner approach because of its accuracy, ease of use, efficient processes, scalability, and minimization of risks.

Most MLA users report the following advantages:

- With MLA-technology there is no need to make new mask sets during the development and process optimization phase, or should different masks be required to compensate for line-width bias from processing
- The elimination of traditional mask management and storage, such as verification, cleaning, checking for wear and defects, saves time and money
- Integration and automated digital processes eliminate the need for wafer steppers and other very costly equipment
- Worries about legacy products subject to availability guarantees or disproportionally small product series become a thing of the past
- The risk of breaching design confidentiality by data leakage during external mask production, or storage after a production run, no longer exists
- Development cycles and time-to-market become shorter
- Significant yield increase
- Operational and maintenance costs are significantly lower

Another major advantage: The patterning performance no longer depends on the nature and quality of the photoresists as the write head has multiple options for wavelengths *(375 nm resp. 405 nm)* and resolutions. The real-time autofocus system enables fast adaption to almost any quality of substrate surface as the automatic compensation for warpage and surface corrugations even allows the use of lower grade substrate material.

Modifications and corrections are made within the design file and real-time digital processing takes care of immediate exposure.

Evolution of maskless aligner systems and the growing power within

Customer feedback on previous direct-write systems prompted the development of the Maskless Aligner and subsequent launch in 2015. Now called the MLA150, it brought dramatic changes to many research facilities and in recent years has established itself as an indispensable, reliable working system – for microfabrication in numerous cleanrooms and as a reference system. Today, more than 200 MLA150s by Heidelberg Instruments are operated in some of the most prestigious universities and research institutes like Harvard, Stanford, ERPF and Georgia Tech. The system has become a de-facto-standard for R&D applications and rapid prototyping in laboratories around the world.

Compared to conventional mask aligners, the MLA150 has similar cycle times for exposures, but it comes with significantly lower costs as there is no need for masks or frequent replacement of mercury lamps. Academic research and commercial R&D benefit from the system's flexibility, accuracy of exposed structures, high reproducibility, and fast prototyping, while appreciating the ease of handling.

Game changer – MLA300

It was only a matter of time until industrial users were asking for an MLA-System to facilitate small to medium volume production. So, Heidelberg Instruments developed the industrial version of the Maskless Aligner. After extensive beta-testing, the MLA300 was officially launched in 2019, making it the first and only maskless aligner for industrial production with a resolution of 1.5 µm. It immediately attracted tech companies and the first production-ready machines were sold within a month.

Since then, companies from quite diverse industries have found this direct writing system to be a cost-effective replacement for some of their traditional equipment, both in terms of technology and costs. Compared to mask-based systems the yield is higher while the costs for exposures are significantly lower; and there is no more expenditure on wafers, reticles (masks) and consumables such as the UV or laser source. The main benefit, however, is the system's modularity and flexibility. Users can easily customize products (incl. serial numbers and/or production tracking IDs) for their clients. They can perform on-the-fly compensations for distortions from other processing or lithography steps, or from die-shift in packaging applications.

Autofocus and auto-compensation

The system's real-time autofocus system compensates up to 150 µm of substrate surface variations. No matter if the challenge is residual warpage, surface corrugations, thickness variations of sintered materials or non-planarized layers from a conventional semiconductor fabrication processes – the auto-compensation reliably works for either. This capability is also an advantage for patterning different substrate materials. The system can even expand the scope of materials for processing — using lower-grade substrates and eliminating planarization steps can help a manufacturer reduce production time and costs.

Such dynamic compensation is quite useful in MEMS applications where the thickness variation of the top silicon layer influences the mechanical properties of the fabricated device: With a thickness map the structure geometry can be adapted to match each wafer by individually adjusting the feature size.

Further benefits of MLA300 for product development and manufacturing

- Full automation and integration with manufacturing execution systems (MES)
- Small footprint saves on costly space in the clean room: 1.20 m (W) x 2.35 m (L)
- Highly customizable to accommodate specific production needs
- In a mix & match environment it contributes to cost reductions while maintaining throughput: high-resolution (sub-micron) layers can be patterned by wafer steppers whereas lower resolution layers (1.5 µm and larger) are handled completely by the MLA300
- Built-in dose correction ensures that the nominal and exposed dose remain constant throughout the laser lifetime. Even with 24/7 production the laser lifetime should exceed 10 years

Modules for added performance and flexibility

In industrial manufacturing, production throughput is the most important metric. Therefore, engineers at Heidelberg Instruments have developed a concept of fully integrated exposure modules with ultra-compactly packed exposure optics. Up to four modules can be combined to either increase the system's throughput (identical modules), or versatility (with different resolution) and speed. The exposure modules boast multiple optical corrections, such as scaling, rotation and HIMT's patented optical substrate tracking technology which massively outperforms digital compensations of the data pattern. As a result, a 300 mm wafer can be exposed within minutes instead of hours. Furthermore, the optics show virtually no astigmatism, enabling users to produce new products with much tighter specifications, something that was impossible on their previous equipment. Moreover, the modular concept allows use of the same exposure for prototyping, process development and volume production.

Continuity and easy maintenance are of utmost importance – another reason why the MLA300 boasts a rapidly growing installation base: In event of a defect, an exposure module can be exchanged quickly and repaired off-site, while the system remains operational. Similarly, the system has been designed for minimal downtime when new modules are added as an upgrade, e.g., for production ramp-up. **Steffen Diez**

Request a demo to explore the possibilities of the MLA300 for your production!

Important infos in a nutshell

- Maximum exposure area: 300 mm x 300 mm
- Minimum feature size: 1.5 µm
- Minimum lines and spaces: 2 µm
- Maximum write speed: 5000 mm2/min (with one module at 405 nm)
- Unmatched uniformity and yield on warped or corrugated substrates
- Dynamic mask: Fast design adaptations to e.g. correct for die-shift
- Digital mask library: Easy management, seamless change of pattern
- Integration into production facilities and MES Systems

About Heidelberg Instruments

Heidelberg Instruments is a world leader in the development and production of high precision photolithography systems, maskless aligners and nanofabrication equipment.

HIMT systems are installed in industrial and academic facilities around the world. These are used for direct writing and photomask production in various areas of MEMS/NEMS - for Semiconductors, Quantum Computing, Flat Panel Displays, Photonics, 2D Materials, IOT and many other related applications.

With over 35 years of experience and more than 1,000 systems installed worldwide, HIMT can provide lithography solutions specifically tailored to meet all your micro- and nanofabrication requirements – no matter how challenging.

Download MLA300 fact sheet

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