Strategies to extend resolution limits for direct write lithography

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Direct write technologies including optical and thermal lithography techniques enable advanced micro and nanolithography in a wide range of applications, many of which are impractical with conventional methods. Further innovations, including parallelization, online layout conversion, resolution range expansions keep the lithography solutions by Heidelberg Instruments at the forefront of this technology.

The ever-expanding resolution range possible with direct writing now covers a seamless transition from the micro to the nanoscale. This is made possible, e.g. by pushing the resolution limits of the DWL66+ system beyond the currently specified 300 nm minimum feature size by optimizing exposure and process parameters. The high resolution, extending even down to 10 nm with thermal nanolithography with the NanoFrazor. The high resolution capabilities are seen in practice in applications for nanoantennae, quantum electronics, and micro- and nanophotonics, especially when combined with grayscale lithography.

DMD™ based direct write lithography with the MLA 150 is a state-of-the art process in almost every clean room. To enhance resolution, we introduce a novel exposure mode with a very fine pixel grid that enables L&S resolution of 450 nm (see Table 1). Furthermore, in collaboration with IMS Chips, an exposure strategy was developed to enable smaller lines and spaces using the VPG system. By tuning system performance and process, we were able to extend the range of written features down to the limits of typical high-res i-line lithography.

Advancements in layout handling have led to even higher versatility and automation possibilities. A big challenge in photonics and flat optics, including metasurfaces, is the increasing size of designs, some of which mean unwieldy amounts of data. On the other hand challenges in panel- and wafer-level packaging, as well as heterogeneous integration arise the need to combine multiple materials, z-levels and resolutions in the same design. Solutions to these challenges a jour range from smart splitting with the NanoFrazor, online conversion with the MLA300 and automated overlay with many direct write tools.

Pushing the limits of micro and nanolithography is possible due to the high reliability and flexibility of direct write methods. New challenges and limitations arise with advancing research needs, which are being addressed by increased automation, process optimization and materials libraries. Examples from applications and comparisons between different optical and thermal lithography methods will be presented.

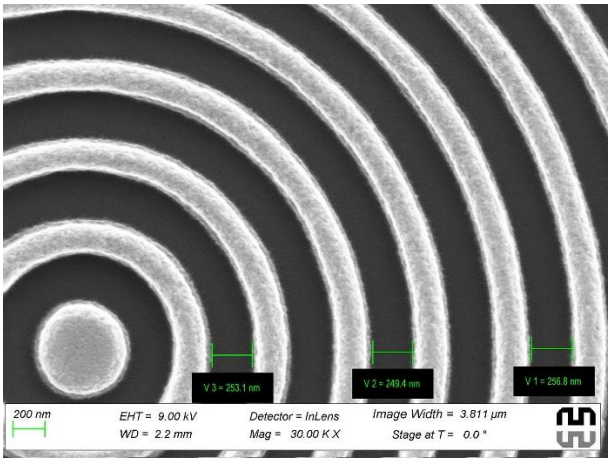

Figure 1: Concentric rings with 500 nm pitch, written using a DWL66+.

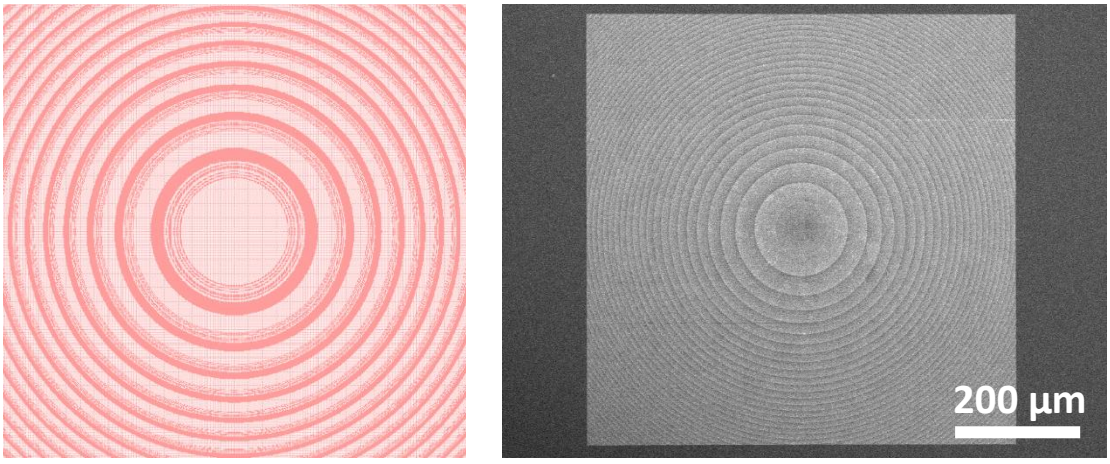

Figure 2: (left) Example of a relatively small metalens design with 1'904'400 rectangular elements. (right) The metalens design as patterned without interruptions using the NanoFrazor

Table 1: Specified parameters versus improved performance with optimizing methods

Tool	Parameter	Specification	Optimized Result
DWL 66^+	Minimum feature size	0.3 µm	0.2 µm
MLA 150	Minimum feature size	0.6 µm	0.45 µm
VPG 300 DI	Lines and spaces	0.5 µm	0.3 µm
NanoFrazor	Write speed	1000 μm^2/min	10000 μm^2/min