Progress and future of NanoFrazor lithography

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NanoFrazor lithography, also known as thermal scanning probe lithography (t-SPL), has been developed at IBM Research Zurich since 2008 and was commercialized in 2013 by the startup company SwissLitho. Since 2014, several commercial NanoFrazor systems have been installed at research facilities in Europe, Asia and America. The young technology continuously improves and already enabled applications that have not been possible before. This paper summarizes recent advances of the technology and provides an outlook of future possibilities and applications.

Core of the technology is a heatable probe tip, which is used for patterning and simultaneous inspection of complex nanostructures. The heated silicon tip creates arbitrary high-resolution nanostructures by locally confined decomposition and evaporation of resist materials like PPA without the need of proximity corrections. The patterning depth of each single indentation of the tip can be controlled with better than 1 nm resolution, which enables direct patterning of 3D nanostructures with unmatched accuracy. This 3D patterning allows simple and superior fabrication of nanooptical components, like tapered waveguides, blazed gratings or spiral phase plates.

The patterning speed of t-SPL outperforms other scanning probe lithography technologies by a factor of 1000 or more. A scan speed of 20 mm/s with an indentation rate of 500 kHz has been demonstrated with a single cantilever. The written nanostructures are inspected by the cold tip already during the patterning process. This high speed online metrology capability enables turnaround times of seconds and significantly improves accuracy and reliability of the t-SPL process. Furthermore, new stitching and overlay methods have been developed that achieve sub-5 nm accuracy without the use of artificial marker structures.

Various pattern transfer methods using reactive ion etching, lift-off, plating, directed self-assembly and more have been developed in combination with the NanoFrazor. For example, parallel lines down to 11 nm half-pitch have been successfully transferred using a hard mask stack.
The t-SPL process does not use high energy charged particle, which are known to damage or charge up delicate materials during the lithography process. For sensitive electronic, magnetic or optical devices this can result in superior device performance. For example, InAs nanowire transistors have been fabricated using high resolution lift-off and the unique overlay capability of the NanoFrazor. The absence of trapped charge in the thin gate oxide led to improved switching behavior of the transistor.