Extreme ultraviolet interference lithography towards high- and hyper-NA lithography

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To ensure the continuous downscaling of semiconductor devices following Moore's law, extreme ultraviolet (EUV) technology was adopted by industry as the next generation lithography platform owing to its high resolution and throughput.. The successful introduction of the first EUV scanners in high-volume manufacturing and the upcoming introduction of high-NA tools has sparked a lot of research in the field of EUV photoresists and related materials. More recently, the intention of industry to investigate hyper-NA as a viable solution to continue scaling beyond what high-NA scanners can offer brings up several issues that need to be solved, before such an endeavor materializes. Most importantly, a lot of research is needed on materials capable of reaching hyper-NA resolutions down to 6 nm half pitch (HP).

EUV interference lithography (EUV-IL) is a powerful photolithography technique capable of producing high-resolution periodic patterns. The EUV-IL tool at the Paul Scherrer Institute has shown record resolution of 6 nm HP[1]and has been used over the years in a large array of projects and most specifically in the research field of EUV materials, before EUV scanners were available. The tool is capable of producing high-contrast and focus-independent aerial images and is compatible with most materials and substrates. In its standard configuration, transmission diffraction gratings are used to create mutually coherent beams which, in turn, interfere and create a high-contrast aerial image.

We will illustrate the main capabilities of the EUV-IL end station and showcase its use in the development of photoresists for future lithography nodes. We will also present a recent addition to our setup where we use mirrors to deflect the beams and create the interference pattern instead of diffraction gratings. Due to its higher efficiency, this method is less prone to drifts and vibrations leading to very high resolutions down to 5nm HP. This important addition to the toolbox of our EUV-IL end station enables it for developing and evaluating the next generation EUV materials. We will also present our recent work on resistless lithography, where we show EUV patterning without the use of a photoresist and discuss the potential of such a technique[2]. The planned upgrade of our end

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[1] D. Fan, Y. Ekinci, *Photolithography reaches 6 nm half-pitch using extreme ultraviolet light,* J. Micro/Nanolith. MEMS MOEMS **15**, 033505 (2016).
[2] L.-T. Tseng *et al., Resistless EUV lithography: photon-induced 1 oxide patterning on silicon,* Sci. Adv. In Press (2023).

station in the coming years in terms of stability and throughput together with the scheduled SLS 2.0 synchrotron upgrade, which will provide higher flux and better temporal coherence, will make out EUV-IL tool an important asset for the future of EUV lithography.