40 nm Pitch Extreme Ultraviolet Interferometric Lithography

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Interferometric lithography (IL) can generate periodic patterns to characterize photoresist materials and to create templates for self-assembled geometries. Extension to the EUV region around 13.4 nm provides the environment for the development of the imaging materials, such as advanced photoresists needed for the Next generation Lithography at the 20nm node and below. Our activity is based on the novel EUV-IL beamline described in [1-2] with the specifications listed in Table 1; an example of a 42.5nm pitch printed in PMMA is shown in Fig. 1. The beamline and the EUV-IL system were commissioned in 2006; we have recently completed several characterization studies, and as a result modified several key components to improve resolution and usability.

The quality of the image is affected by several factors, some intrinsic to the exposure setup (e.g., mask quality) and some extrinsic (vibrations). "Resolution", in the sense of the smallest printable features, is not a well defined figure of merit. The best way to describe the performance of an interferometer is in terms of its Modulation Transfer Function, MTF, that is, of the modulation observed in the interference pattern at various pitches; the extrapolation of the MTF to zero yields the ultimate patterning ability, but not the "usable" limit -- for this the resist must be taken into account. In an EUV-IL system, vibrations can significantly reduce the MTF of the exposure process. The interferometer itself is mounted on a stable and massive base, but some vibrations may still be coupled to the mask through the beamline and other inevitable mechanical connections. We have successfully reduced these external sources of vibrations, but it is clear that in order to obtain the ultimate resolution possible with EUV-IL it is necessary to mechanically clamp the mask to the wafer. An extreme example of fixed vs. free mount exposures is shown in Fig. 2. We have developed a simple method based on using uniform soda lime glass spheres (200-800 μm) mounted on the silicon frame of the interferometer to allow a firm gap setting without compromising our ability to step-and-repeat. The mask is designed so that different pitches can be imaged at the same gap.

Another important area is the uniformity of illumination. We have studied in detail the performance of several mirrors by mapping the wavefront quality. In the case of an EUV-IL system it is necessary that the *phase* in addition to the *intensity* be highly uniform. In addition, the gratings have a finite size, and the diffraction of the edge of the grating window will affect the final interference pattern. In other systems [3] often the laser beam is actually wider than the gratings, so that the effect is not observed. A gradual change of the transmission can eliminate this unwanted diffraction result. We have investigated another method, i.e., to gradually change the duty cycle at the edge of the grating, following to the gradual and smooth average transmission, with promising results. This change in duty cycle can be achieved by varying the exposure shape and dose in the EBL mask patterning step.

The EUV-IL system can expose different pitches at the same time, and also introduce a variable image modulation by performing double exposures overlapping the interference pattern with the transmitted zero order. We will present the first results of these modulated exposures for some prototypical resist materials.

Table 1: Specifications of EUV beamline at University of Wisconsin

Imaging System Specifications:	
2.5" x 2.5" travel stage	Automated matrix exposure control
Wafers up to 8"	PMMA requires exposure ~ 10 sec @ 200mA
In-situ mask gap adjustment	Maximum beam size: 3/8" dia.
Vacuum ~ 10^{-6} Torr	Power density = 210 mW/cm^2
Pump down in <5 minutes	

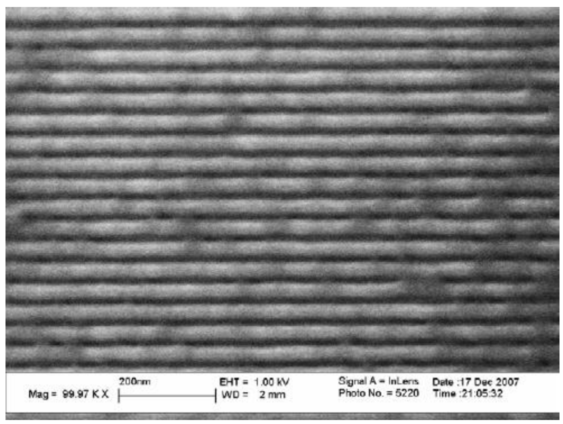
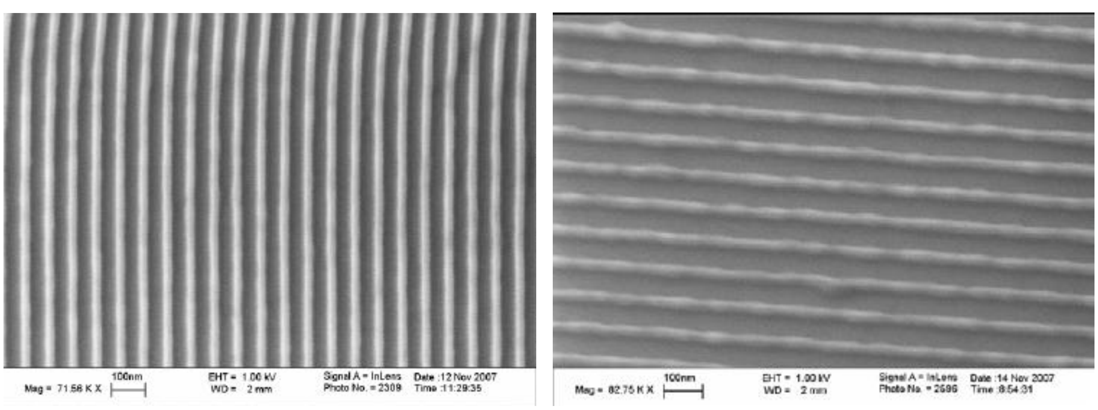


Fig.1. SEM image of 42.5 nm pitch grating on PMMA resist after EUV-IL exposure.



(a) (b)

Fig.2. 70 nm pitch grating SEM image of (a) fixed and (b) free mounted EUV-IL exposure.

References:

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