High transmission pellicles for EUVL reticle protection

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Reticle particle defects continue to remain one of the principal challenges facing high-volume implementation of Extreme Ultraviolet Lithography (EUVL) [1]. Organic pellicles for reticle protection have traditionally been employed for optical lithography, but as they are highly opaque near 13.5nm wavelengths, they are unsuitable for EUV exposures. The EUV pellicles must satisfy a number of critical criteria such as transmission, robustness during handling, thermal and maintaining reticle imaging fidelity [2]. The high transmission requirement is especially a concern for EUVL where improvement in wafer power density is a top priority.

In this paper, we show a novel method of fabricating full-field EUV pellicles. Our approach involves attaching a 50-100nm Si membrane to a wire mesh [Fig 1]. The pellicle is then mounted at a desired stand-off distance from the reticle. Transmission performance is verified at actinic wavelength at the LBNL synchrotron facilities. The cell shape of the mesh is hexagonal for increased robustness. We have generated meshes with linewidths between 1-3um which is potentially capable of reducing non-uniformity to <1%. This is a greater than 5-fold improvement over what was previously reported by our group [3-4]. Since the pellicle is fabricated from Si, in addition to mitigating defects, we show that this pellicle solution can also help reduce OoB radiation.

The full-field EUVL scanner Advanced Demo Tool (ADT) by ASML, installed at IMEC, Belgium, has been utilized for first-ever actinic imaging of EUVL reticles with pellicles. Pellicles with varying stand-off distance, wire-mesh linewidths, and transmissions were evaluated. The impact to CD uniformity and linewidth roughness were determined. We find that, in general, a minimum stand-off distance of 5-6mm between pellicle and reticle is necessary, along with aforementioned mesh linewidth < 3um, to achieve desired imaging specs.

The impact to resist imaging is quantified through modeling and validated experimentally [Fig 3]. However, as we show through modeling, illumination non-uniformity is directly proporational to mesh linewidth. Decreasing stand-off distance dramatically degrades uniformity due to the severely increased apodization of the pupil by the mesh.

Thermal modeling verification of the pellicles has been completed. The instantaneous power induced rise in temperature is within operating range. Additionally, the full-field pellicle is tested on a linear motor assembly in a vacuum environmental chamber [Fig 2] to simulate the effects of reticle stage acceleration. A vacuum environment ensures that the mass loading of air is not a dominant contribution. The track length is sufficient to accelerate and decelerate at >5g and mimic sustained scan velocity of 2m/s. We demonstrate that the pellicles are robust enough to handle vacuum pump-down cycles and repeated high-volume manufacturing reticle stage motion.

References:

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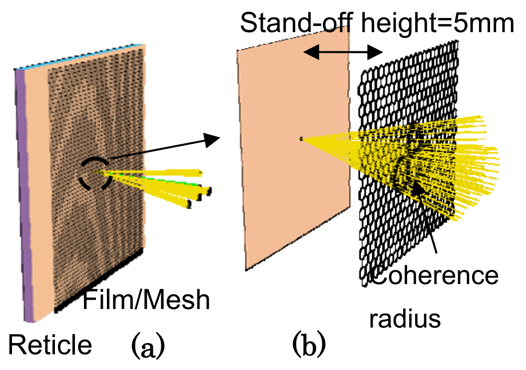

Figure 1: (a) Wiremesh with thin film (b) effect of partially coherent illumination at the mesh ($\sigma = 0.5$ is used in this schematic) .

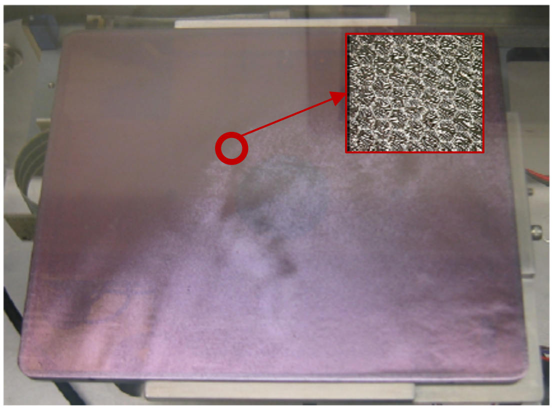

Figure 2: Full-field EUVL pellicle mounted on a mechanical scan stage. Insert shows cell structure.

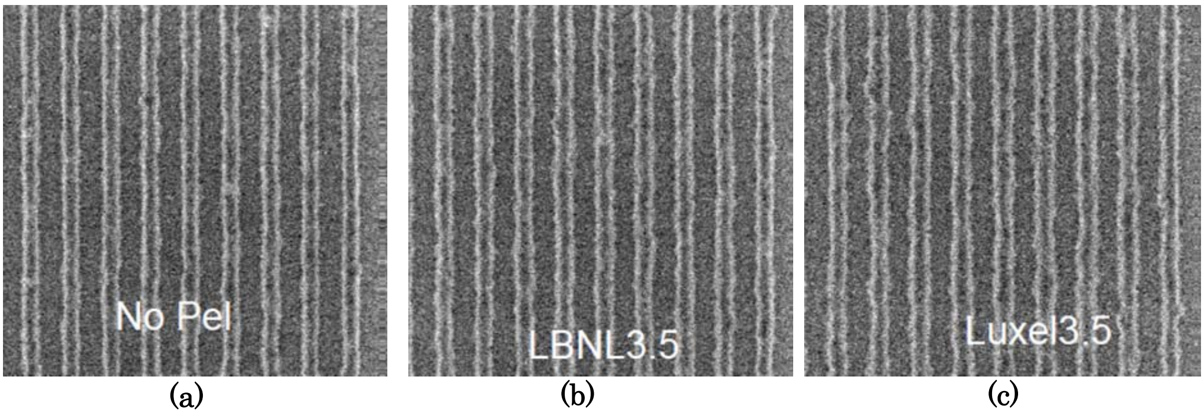

Figure 3: 35/70nm Line/Pitch SEM resist images of 3 cases (a) no pellicle, (b) 3.5mm stand-off pellicle with 66.3% single-pass txm, (c) 3.5mm stand-off with 73% single-pass txm.