Assessing the Mask Clamping Ability of a Low Thermal Expansion Material Chuck

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Extreme Ultraviolet Lithography (EUVL) is one of the leading candidates for Next-Generation Lithography in the sub-30 nm regime. Successful implementation of this technology will depend upon advancements in many areas, including the quality of the mask system to control image placement (IP) errors. For EUVL, the nonflatness of both the mask and chuck is critical due to the nontelecentric illumination during exposure. The focus of this research is to assess the clamping ability of a low thermal expansion material (LTEM) chuck, both experimentally and with the use of numerical simulation tools, i.e., finite element (FE) modeling and simulation.

The EUVL Mask Standard, SEMI P37, specifies the flatness of the mask frontside and backside surfaces to be within 30 to 100 nm peak-to-valley (p-v). An updated EUV Mask Chucking Standard, SEMI 4584, requires chuck flatness to be approximately 32 nm p-v within the quality area. Recent technological advances in polishing and finishing techniques have placed these specifications within reach. Figure 1 shows the LTEM chuck developed at the Fraunhofer IOF, which has a flatness of about 50 nm within the quality area after pin structuring. The UW Computational Mechanics Center has investigated the nonflatness of the Fraunhofer chuck, as well as a number of EUVL reticles. The initial flatness data has been used as input into the FE models to subsequently simulate the response of the reticle during e-chucking (see Fig. 2). The numerical models predict the final nonflatness of the chucked reticle, which is then compared to actual experimental data.

All chucking experiments were performed in a cleanroom (within a vacuum chamber mounted on a vibration isolation cradle) to minimize the effects of particle contamination (see Fig. 3). In fact, particle effects were not visible in any of the interferograms while chucking. During these experiments, the chuck was supported on a three-point mount and the reticle was lowered onto the chuck surface using a customized lifter. A Zygo interferometer was used to measure the flatness of the reticle before and after chucking. Repeatability studies have been conducted and the ability of the Fraunhofer chuck to flatten extremely bowed reticles has been assessed.

Excellent agreement was found between the experimental chucking data and the corresponding numerical simulations. Figure 4 shows how closely the numerical prediction matched the experimental results, with a final chucked reticle flatness of 142 nm and 126 nm p-v, respectively. Results of this investigation demonstrate the ability of the Fraunhofer chuck to provide the necessary clamping pressure to flatten the reticle to the required specification. In addition, the modeling tools developed here can be used to optimize the chuck design parameters in order to facilitate the implementation of EUV lithography.

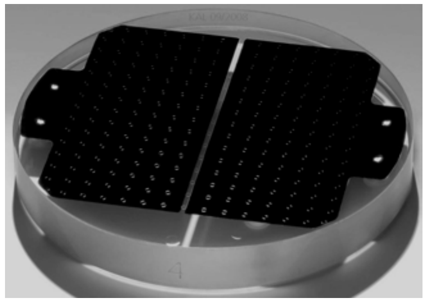


Fig. 1. EUV mask chuck prototype developed at Fraunhofer IOF.

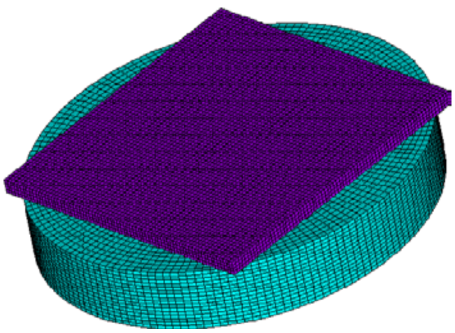
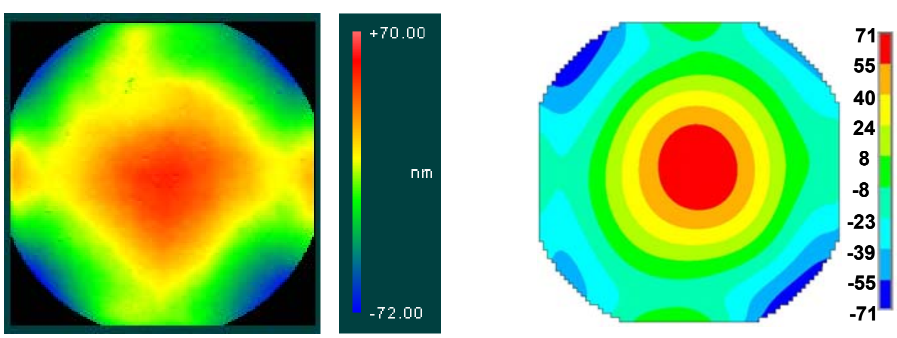


Fig. 2. Full 3-dimensional FE model of an EUV reticle on the Fraunhofer chuck.

Fig. 3. UW-CMC experimental setup in the cleanroom.



(a) (b)

Fig. 4. (a) Experimentally measured interferogram of a chucked reticle with a peak-to-valley of 126 nm, and (b) corresponding FE simulation with a predicted peak-to-valley of 142 nm.