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Flatness characterization of EUV mask chucks

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Abstract

For future extreme ultra violet (EUV) lithography at a wavelength of about 13 nm, flatness of the mask surface is an issue, since out-of-plane deviations sensitively transfer to in-plane distortions. Electrostatic clamping devices of extreme flatness and high stiffness are required. At Fraunhofer IOF, manufacturing processes for EUV mask chucks made from low thermal expansion materials are investigated. Since the chucking surface is finally structured into a pin array, flatness characterization is not trivial. The paper reports on flatness characterization of a mask chuck prototype at various stages of surface manufacturing. We present measurement results obtained with sophisticated commercial tools based on optical and tactile principles and discuss limitations encountered in both cases as well as possible strategies for improvement.

Keywords: EUV; Lithography; Electrostatic chuck; Mask chuck; Pin chuck; Flatness characterization

1. Introduction

For future manufacturing of micro-electronic devices at the HP 32 nm node and beyond, cost and efforts for immersion based optical technologies increase dramatically (i.e. double exposure) or even fail completely and EUV lithography is considered an appropriate alternative for high volume production [1]. In EUV steppers, clamping of the mask proceeds similarly as with Si-wafers in e-beam lithography via electrostatic chucking in vacuum, albeit a thin backside metallic coating to the mask has to be applied, since it is made from an insulating, low thermal expansion material (LTEM) substrate.

Of central importance for chucking is an extremely flat chuck surface, to prevent from pattern distortions arising from uncontrolled mask bending, since out-of-plane deviations (OPD) sensitively transfer to in-plane distortions (IPD) under non-telecentric illumination conditions. The EUV Mask and Chucking Standards, SEMI P37 and SEMI P40, specify the non-flatness of the mask front side and backside, as well as the chucking surface, to be no more than 50 nm peak-to-valley (PV) [2,3]. From Finite Element Modeling the consequences of particle induced distortions from the interface between chuck and mask and correlations of OPD versus IPD are well understood [4]. In our own work, we have previously focused on design considerations for a suitable EUV mask chuck and have also described the manufacturing details of a prototype in quite detail [5]. Here now, results from characterizing the chuck surface flatness of this prototype with different techniques will be presented.

To monitor the complete process flow, the surface was completely reworked, i.e. the previous pin structure was removed in favor of a fresh flat surface, which was then restructured with pins again. Fig. 1 shows the chuck after restructuring. Pin structure covers slightly more than the $(152\ \text{mm})^2$ mask area, but there is mask overhang at the corners.

2. Measurement means

The flat chuck surface was characterized by optical interference measurements, using a 12-in. phase-shifting interferometer of the Fizeau type (Zygo) equipped with a 640×480 pixel camera and a $\lambda/30$ (PV) reference flat at $\lambda = 632.8$ nm.

On the pin structured surface, 1-dimensional tactile height measurements with a profiler (Talysurf) as well as

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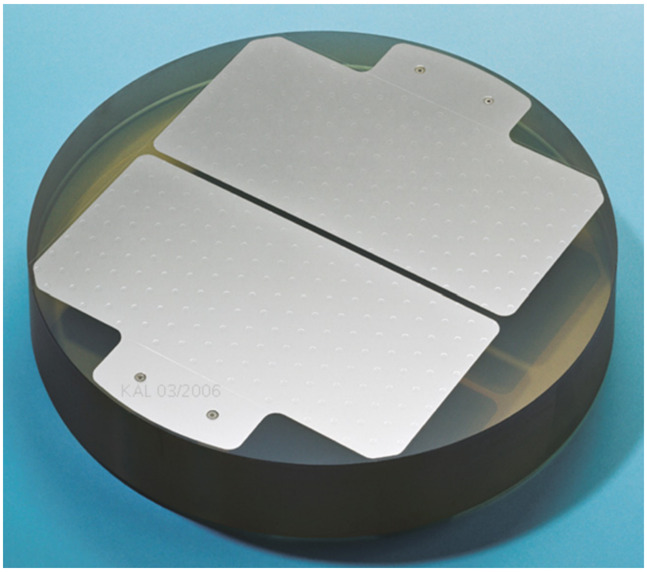

Fig. 1. EUV mask chuck prototype.

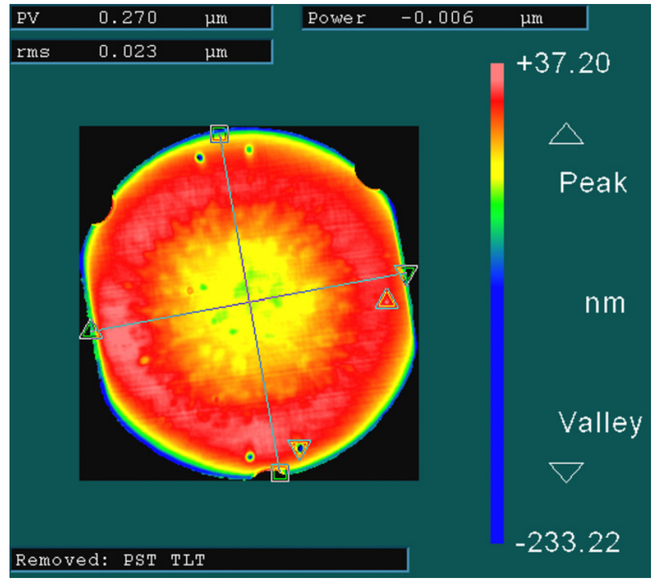

Fig. 2. Flatness of chuck surface before pin structuring (topview) (For interpretation of the references in color in this figure legend, the reader is referred to the web version of this article).

full 2-dimensional tactile height measurements (Panasonic UA3P) were performed. Both instruments use roller bearing guides for lateral probe scanning. While the former instrument detects height via laser beam deflection from a cantilever and scans on a straight line only, the latter has an atomic-force-type height sensor and can trace arbitrary curves in two dimensions. In our application, a meandering across the pin structured area at right angles was chosen.

Tactile calibration was done with a reference sphere (Talysurf) or a reference flat (Panasonic), respectively. In principle, resolution is estimated to about ±10 nm, and accuracy to about ±50 nm (for both instruments). However, both values depend sensitively on environmental conditions and calibration procedures and are not easy to control.

3. Chuck surface before pin structuring

Chuck flatness was achieved by optimized optical manufacturing technologies (lapping and polishing). The chuck surface just before pin structuring was measured by Fizeau-interferometry.

The results are shown separately in Fig. 2 for the complete chuck and in Fig. 3 for the relevant center area (the mask quality area). Note the high symmetry of the remaining surface deformation and the rather high flatness within the mask quality area, i.e. within the central (142 mm)^2 square, which amounts to about 70 nm (PV).

Clearly, this flatness value still exceeds SEMI P40 requirements by about a factor of 1.5, i.e. is not yet sufficient for production tools, but might be better (to our knowledge) than what is currently used in premature equipment for EUV technology tests and process optimization.

Further improvement appears feasible and straight forward, albeit time consuming.

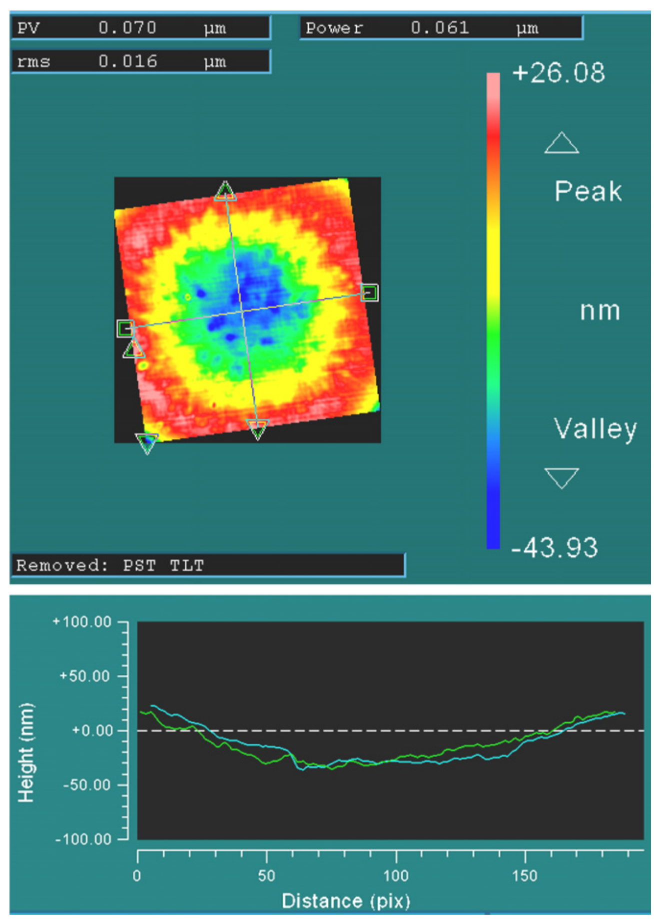

Fig. 3. Mask quality area before pin structuring (topview and cross profiles, respectively) (For interpretation of the references in color in this figure legend, the reader is referred to the web version of this article).