Experimental determination of Image Placement Accuracy in EUV Lithography

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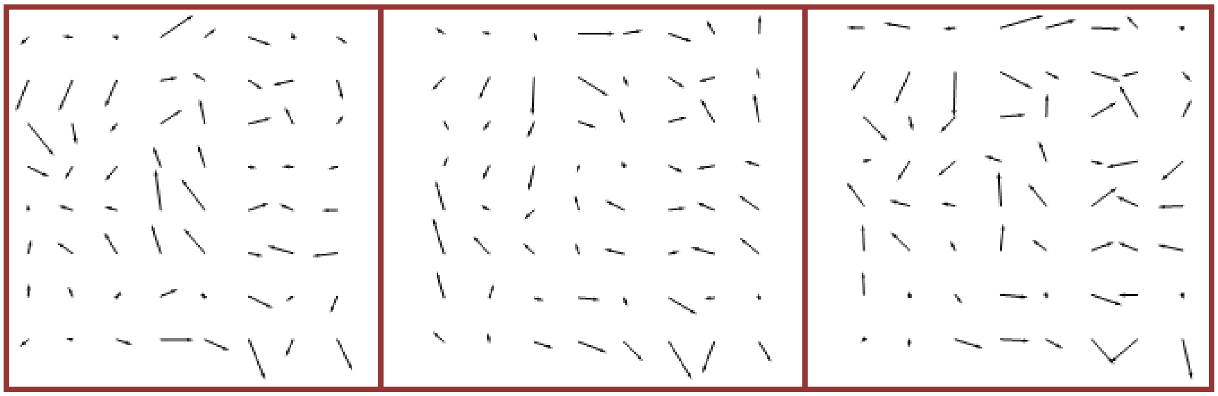
ABSTRACT

Image placement and overlay error specifications on the ITRS roadmap continue to get tighter with each successive technology node. Some of the primary contributors to this error in EUV lithography are reticle and chuck surface non-flatness and chucking flatness non-uniformity. In this paper we have studied these effects with the help of special EUV reticles that can be imaged in four different orientations and that contain an array of Image Placement (IP) fiducials (ASML XPA and IPRO) for IP error measurements. The chuck and the mask contributions to the placement error can be identified and separated by printing the array of marks with the mask chucked in different orientations (0, 90, 180 and 270 degrees).

The first set of experiments consisted of imaging the rotatable reticle with the ASML EUV Alpha Demo Tool at Albany in a Rohm & Haas XP4502J resist following cycles of clamping and unclamping in order to test the repeatability of reticle chucking. The resist images of the XPA fiducials were readout using the Wafer Stage Accuracy test in an ASML Twinscan XT:1700Fi 193nm Step and Scan exposure tool. Preliminary experimental data (Figure 1) suggests an image placement error contribution of ~1.2nm (RMS) due to the as-chucked reticle flatness. The chucking repeatability based on the three repeats was found to be 0.8nm (max. vector). Typically, IP errors tend to be higher at the corners of the reticle where the chucking force is less uniform and the non-flatness of the reticle substrate is typically greater. In the first set of experiments, the reticle that was exposed had an 8x8 array of IP fiducials distributed over the central 80x80mm of the reticle surface, where the non-flatness of the reticle was 60nm (based on interferometric flatness measurements). A reticle non-flatness of 60nm would result in IP errors of the order of 1.5nm (max. error). These errors are of the same order as the systematic errors present in the tool and would be extremely difficult to assign ambiguously. To address these concerns, we have fabricated a second rotatable reticle, with a larger array of IP fiducials (17x17), spread over a larger surface area (Figure 2) of the reticle (127x127mm). In this paper, we will discuss in detail the experimental results from the printing of both these reticles. We will also discuss the modeling procedures required to separate the systematic effects from the chuck and reticle contributions to image placement errors.



Set 1 Set 1 Set 1

FIGURE 1: Average residual error of 3 sets of exposures (1,2 and 3), each preceded by a unclamp/reclamp operation

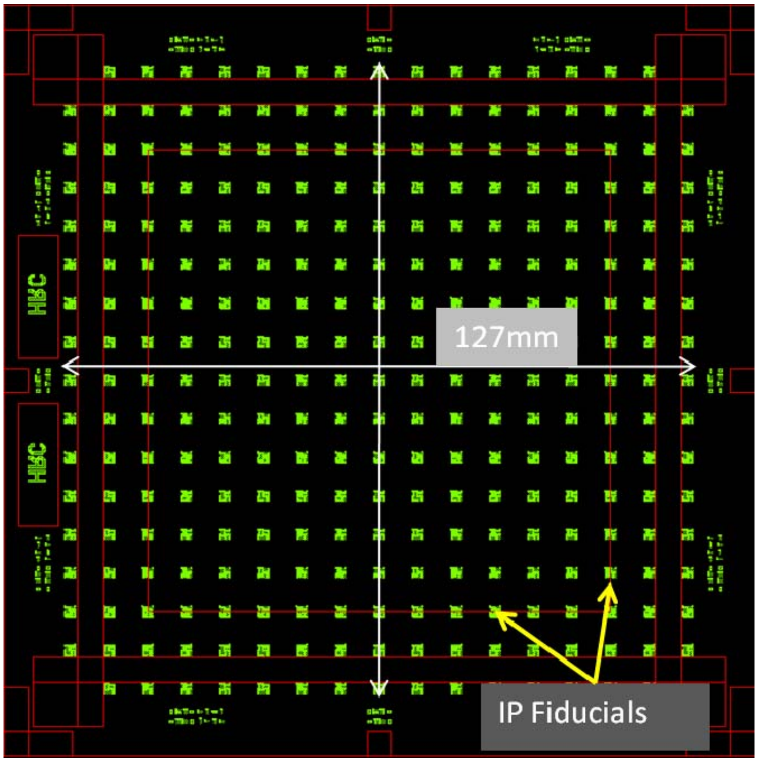


FIGURE 2: Reticle 2 with IP fiducials (ASML XPA mark) distributed over the central 127x127mm of the reticle