

## **Commissioning a new EUV Fresnel zoneplate mask-imaging microscope for lithography generations reaching 8 nm**

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We are bringing online the first of a new generation of high-resolution EUV microscopes dedicated to current and future generations of EUV lithography. The new microscope, called the SEMATECH High-NA Actinic Reticle review Project (SHARP), will become operational near the end of 2012. A dedicated research system, years ahead of commercial tools, SHARP is designed to flexibly emulate various illumination partial coherence conditions and rotating azimuthal planes of incidence, while offering a range of illumination angles (6 to 10°) and numerical apertures (NA) values (0.25 to 0.625 4×NA).

During eight years of research with the SHARP's predecessor, the SEMATECH Berkeley Actinic Inspection Tool (AIT) demonstrated the essential need for high-quality EUV-wavelength imaging for mask research. Owing to the wavelength-specific reflective properties of EUV reticles, imaging with EUV light is the only faithful way to understand the physical response of defects, repairs, and pattern optical proximity corrections. These EUV optical properties limit the effectiveness of all non-EUV inspection technologies; the differences between EUV and non-EUV measurement technologies are likely to increase in future nodes.

SHARP is designed as a high-performance replacement for the AIT. SHARP's all-EUV optical design uses a synchrotron bending-magnet source with tunable wavelength and bandwidth spanning a continuous EUV spectral range. Efficiency improvements to the beamline and illuminator are projected to increase the delivered flux density by nearly 100× relative to the AIT. A novel, three-mirror, Fourier-synthesis illuminator converts the low-divergence input beam into a programmable range of incidence angles, from 1–19°, focused onto the mask. The ~1-kHz angle-scanning is powered by a 1-mm-diameter, multilayer-coated MEMS mirror that scans pupil-fill patterns during exposure. SHARP's condenser is an ellipsoidal mirror with 10× demagnification, designed to concentrate the beam onto a 5–100-μm mask region. The ellipsoidal mirror can be programmed to scan through small (500 μrad), angular range, to increase the illumination uniformity and area. SHARP's high-resolution imaging system relies on Fresnel zoneplate lenses, which serve as diffraction limited, small-field objectives, patterned using e-beam lithography into an array of various NA values, angles of incidence, magnifications, and azimuthal angles (for emulation of lithography-tool imaging across a ring field). SHARP is also equipped with an in-situ visible-light microscope to simplify mask navigation, and a pair of photodiodes to compare the incident and reflected EUV power.

We report the results of in-progress calibration, optimization, and performance testing, including imaging resolution, aberration characterization, illumination coherence-control and uniformity, among other performance metrics. We will also discuss SHARP's mechanical design, which uses a vibration-isolated internal platform and a shared rigid frame that connects the independent mask and zoneplate stages for nm-scale stability during exposures. Specified for relevance down to 8-nm CD and beyond, we anticipate that SHARP will serve the development of EUV lithography for years to come.

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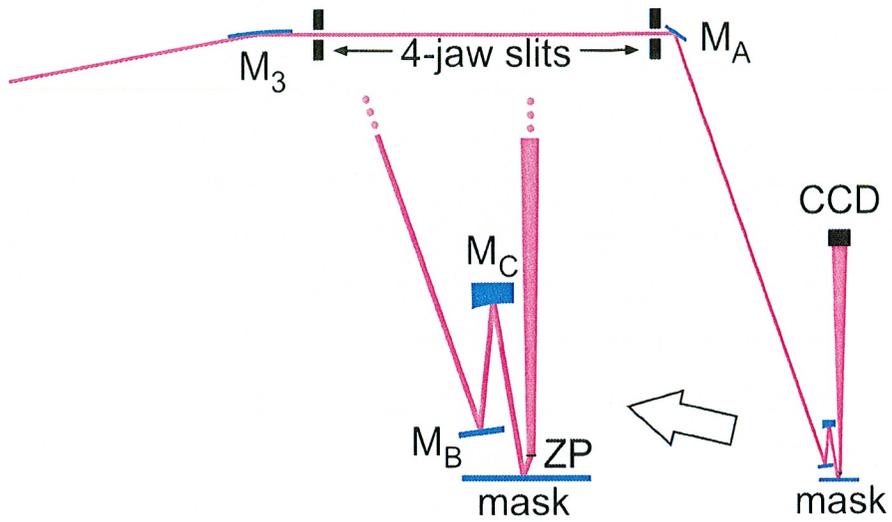


FIGURE 1. The beam path through the SHARP microscope. Inset detail shows a schematic of the  $M_B$ ,  $M_C$ , the mask and the zoneplate (ZP) lens positions. The intermediate focus is on  $M_A$ .

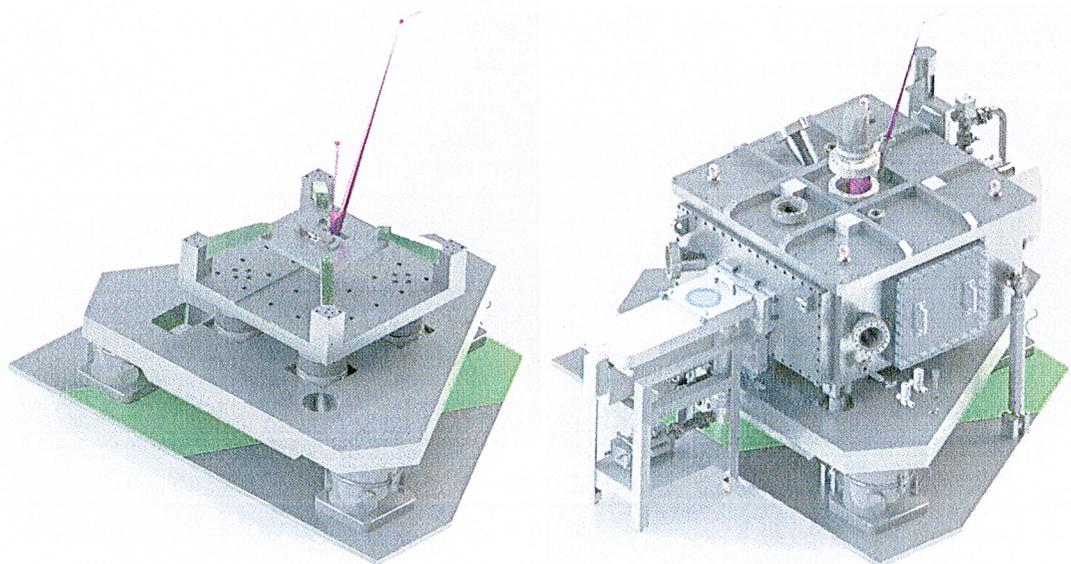


FIGURE 2. (Left) CAD model of SHARP's vibration-isolation system. (Right) Model of the assembled system. The beam path is shown in magenta. The green stripe represents the location of a buried grade beam.

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