A Laser-Plasma Clean Soft X-Ray Source for Projection Microlithography

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Within a National Project on nanotechnologies, at the ENEA Research Centre in Frascati a micro-exposure tool for projection lithography at 14.4 nm has been developed. The laser-plasma soft X-ray source is equipped with a patented debris mitigation system developed in the frame of a European Integrated Project, in order to preserve the collecting optics. A 90-nm-resolution patterning has been achieved on resist by this laboratory-scale tool based on a Schwarzschild-type projection optics. Also results of fluorescent material exposures will be shown.

Laser produced plasmas are widely used as soft X-ray radiation sources to be applied in many different fields, ranging from spectroscopy and fundamental plasma physics, imaging techniques, like microscopy and microradiography, to radiobiology and metrology. Microlithography is one of the most technologically challenging applications of soft X-rays, with particular reference to the extreme ultraviolet (EUV) spectral region (5-50 nm). The worldwide importance of EUV lithography (EUVL) is essentially due to the EUVL potential to extend optical projection lithography to higher resolution in manufacturing of integrated circuits, thanks to the shorter wavelength and to the availability of high-reflectivity-at-normal-incidence mirrors [1].

Beside the huge effort carried out by international consortia to raise EUVL at industrial level, also laboratory-scale facilities have been realised to be exploited both for components test and metrology, and for diverse applications.

Within a National Project on nanotechnologies, at the ENEA Research Centre in Frascati a micro-exposure tool (MET) for projection lithography at 14.4 nm has been developed. It is based on a laser-produced-plasma solid-tape-target soft X-ray source, in turn driven by two different XeCl excimer lasers with distinctive pulse characteristics. The spectral efficiency in the EUV spectral region is optimised working with a laser intensity around 10^{10} W/cm^2, which allows a maximum conversion efficiency of about 0.7%/eV over a 2π solid angle.

The huge emission of fast atoms and particulate from the plasma is strongly attenuated by a patented debris mitigation system (DMS), in order to guarantee a long lifetime of the expensive elliptical mirror that acts as collector of the emitted EUV and X-ray photon bursts. Mitigation factors up to ~ 800 and ~ 700 have been obtained for atoms and particles, respectively, which are at the fore-front of this matter. This very efficient DMS requires a shift from the conventional 13.5-nm wavelength for the projection lithography to 14.4 nm, where the Mo-Si multilayers maintain the same integrated reflectivity also after multiple reflections.

The clean radiation is properly shaped by the illumination optics up to the reflective mask, where the patterns to be reproduced are. The projection optics is a low-cost suitably designed Schwarzschild objective (SO) with a numerical aperture NA=0.23 and magnification M~1/10. The SO alignment has been carried out through the Foucault technique, using both visible and ultraviolet light. We used a novel procedure to overcome the limitations related to the diffraction limit of the alignment wavelengths.

We achieved 90-nm-resolution patterning on resist by this laboratory-scale tool based on a Schwarzschild-type projection optics. Also fluorescent materials have been exposed and the relevant results will be presented. The obtained results are among the best ever achieved by laboratory-scale EUVL METs.

Possible advanced applications in microelectronics, biology and photonics that are foreseen for our MET will be also discussed.

[1] Kemp K. and Wurm S., C.R. Physique **7**(8), 875-886 (2006)

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