Ultra-broadband spectrometry in the extreme ultraviolet (EUV)

Application Note

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The research group EUV Technology at RWTH Aachen University, TOS - Chair for Technology of Optical Systems (RWTH-TOS), works on compact stand-alone setups that utilize extreme ultraviolet (EUV) radiation for nanometrology and nanostructuring purposes. EUV radiation offers unique properties with respect to these applications including its short wavelength on the order of 10 nanometers as well as its strong and element-sensitive interaction with materials of all kinds. Compared to the utilization of ultraviolet and visible light, the properties of EUV radiation enable significant progress in the fields of nanoscience and semiconductor technology.

A stand-alone EUV spectrometer realized at RWTH-TOS allows for ultra-broadband spectrometric characterizations of samples in the EUV spectral range [1-5]. Typical samples are ultrathin layer systems with down to sub-nm thickness, nanostructured surfaces as well as novel material compositions related to semiconductor technology. The spectrometer allows for measurements of reflectance as well as transmittance in the wavelength range from approximately 2 nm to 18 nm. It is based on the emission of a gas discharge-produced plasma source emitting broadband spectra in the EUV spectral range. These spectra range approximately between wavelengths of 2 nm to 20 nm depending on the fuel gas(es) utilized in the source (see Fig. 1) [6].

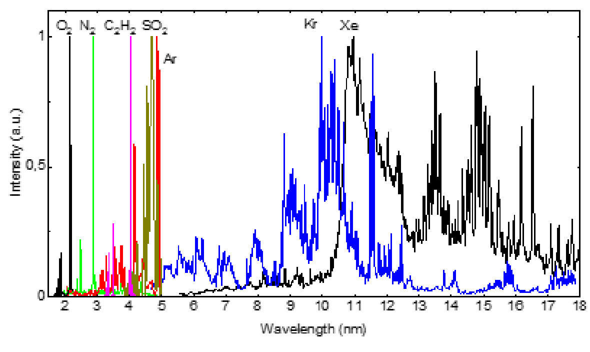

Fig. 1 Emission spectra of a discharge-produced plasma operated with different fuel gases ranging approximately from 2 nm to 18 nm wavelength [6].

In order to capture a wide wavelength range of the EUV spectra emitted by the plasma source, the EUV-sensitive Newton SO CCD camera model DO940P-BN from Andor Technology with a rectangular wide format back-illuminated CCD sensor (2048 x 512 x 13.5 µm pixels 27.6 mm x 6,9 mm) is integrated into the stand-alone EUV spectrometer. Despite the comparably large size of the CCD sensor, it is still not capturing the full spectral dispersion produced by the utilized flat-field spectrograph (see Fig. 2). For this, the camera needs to be translated along the dispersion axis (x-axis). In order to guarantee the optimum focus distance and angular orientation with respect to the spectrograph, a translation along the beam axis (y-axis) as well as a rotation in the x-y plane is necessary.

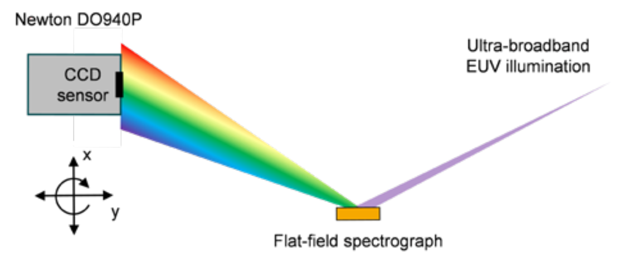

Fig. 2 Schematic depiction illustrating the necessity to move the CCD sensor along the dispersion direction of the flat-field spectrograph.

Since EUV radiation cannot propagate under ambient pressure conditions, experimental investigations involving EUV radiation need to be conducted under vacuum conditions. Conducting the above-mentioned movements therefore poses a significant challenge regarding the hardware implementation. To meet this challenge, the CCD camera is mounted in a hanging position to a highly robust positioning module consisting of a cross-translational stage enabling a travel of several centimeters in both orthogonal directions and a rotational stage between the cross-translational stage and the CCD camera. The positioning module including the camera is connected to the main vacuum setup by a flexible vacuum bellow. The positioning module can withstand forces created by the vacuum pulling on it as well as the weight of the vacuum components hanging on the stage (see Fig. 3). [7]

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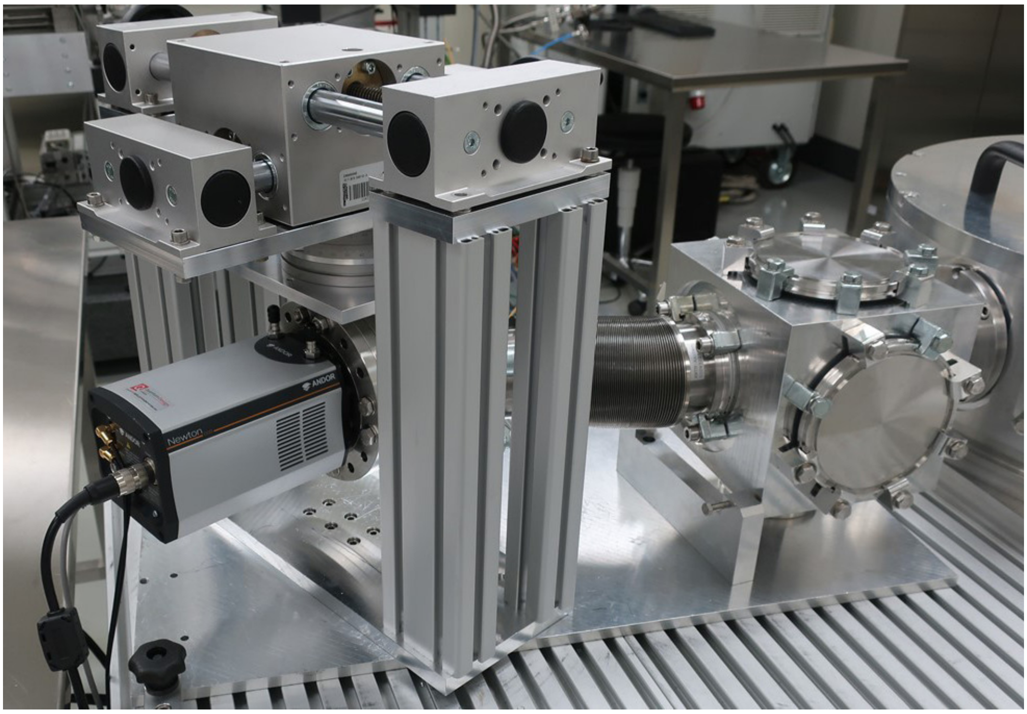

Fig. 3 Newton DO940P-BN CCD camera mounted on a highly robust translational stage connected to a vacuum chamber by a flexible edge-welded bellow.

In summary, the CCD camera mounted on the presented positioning module enables ultra-broadband spectrometry in the EUV. The setup ensures an accurate alignment of the camera with respect to the dispersion and focusing properties of a flat-field spectrograph while maintaining vacuum conditions. The setup has overall demonstrated an excellent robustness and usability [4,5].

References

[1] S. Danylyuk et al., "Multi-Angle Spectroscopic Extreme Ultraviolet Reflectometry for Analysis of Thin Films and Interfaces," Phys. Status Solidi C 12(3), 318–322 (2015).

[2] M. Tryus et al., "Optical and structural characterization of orthorhombic LaLuO3 using extreme ultraviolet reflectometry," Thin Solid Films 680, 94–101 (2019).

[3] L. Bahrenberg et al., "Laboratory-based EUV spectroscopy for the characterization of thin films, membranes and nanostructured surfaces," Proc. SPIE 11147, 111471X (2019).

[4] L. Bahrenberg et al., "Characterization of nanoscale gratings by spectroscopic reflectometry in the extreme ultraviolet with a stand-alone setup," Opt. Express 28(14), 20489–20502 (2020).

[5] S. Schröder et al., "Accuracy analysis of a stand-alone EUV spectrometer for the characterization of ultrathin films and nanoscale gratings," Proc. SPIE 11517, 115170S (2020).

[6] J. Vieker et al., "Metrology and irradiation systems for accelerated testing of EUVL components," Proc. SPIE 11517, 115170T (2020).

[7] L. Bahrenberg et al., "Nanoscale grating characterization through EUV spectroscopy aided by machine learning techniques," Proc. SPIE 11325, 113250X (2020).

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