System for calibration of EUV detectors

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Abstract— The paper presents the project of a system for detectors investigation applied in the metrology of extreme ultraviolet radiation. The main task of the work is to determine detector responsivity and its spatial non-uniformity. At the setup, a laser-plasma source with a gas-puff target will be used. Basing on measured parameters of the source, the requirements for optical elements and measurement method have been specified. A special investigation procedure of the spatial non-uniformity of detectors responsivity is described. The preliminary results of silicon photodiode investigations are also presented and discussed.

The technology of EUV radiation (λ=13.5 nm) is the next step in semiconductor lithography development [1]. Applying lighting of this wavelength, the structures of dimensions not smaller than 35 nm can be produced. The main issue of this work is an absolute measurement of radiation energy. Detector responsivity influences the performance of measurement instruments. The results of detector research made at the Physikalisch Technischen Bundesahnshalt showed that the responsivity of detectors could deteriorate during their exploitation [2]. The changes in detectors are caused by ageing due to storage conditions.

The lab setup consists of a radiation source, metrology chamber, and a scanning mechanism (Fig. 1)

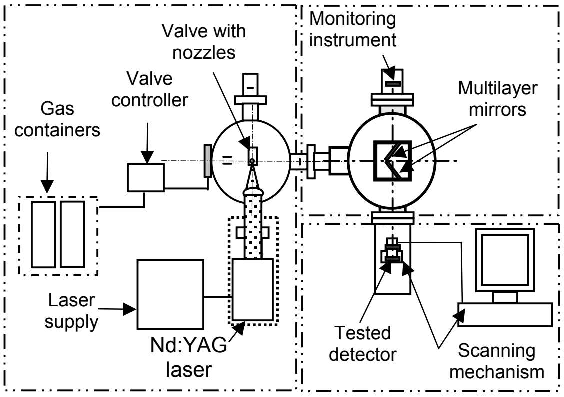

Fig. 1. Scheme of the setup.

In the source, the gas puff target is irradiated with the radiation generated by an Nd:YAG laser [3]. Radiation parameters (irradiance of the order of 4 GW/cm^2) and gas density are sufficient for hot plasma generation. The main elements of the source are an Nd:YAG laser and a vacuum chamber with equipment. In the chamber, an electromagnetic valves setup with a positioning system was mounted. The valve serves to create a gas target made up of two areas of gases. The gas target with two streams is created by an outflow of a working gas (for example xenon, krypton, argon) surrounded by buffering light gas (helium, hydrogen) in a concentric manner. Details of the valves system are described elsewhere [4]. The main task of the buffering gas is to maintain high density of the working gas. The double-stream configuration of a gas torch provides high density of the gas target.

The spectrum of source emission depends on the used gas. For the xenon gas, the spectrum consists of two strong lines: 11 nm and 13.5 nm in the EUV wavelength range (Fig. 2).

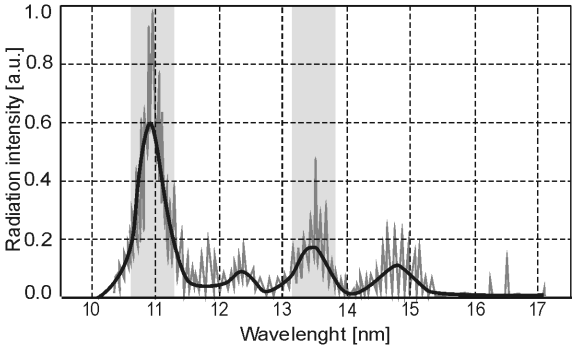

Fig. 2. Xenon gas emission characteristic.

The preliminary investigations of the source showed that efficiency and stability depend on the conditions of plasma generation. The conditions relate to the changes of delays of opening time of gas nozzles with reference to an

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Nd:YAG laser pulse, energy of the laser pulse, pressures of the gases in the valve, pressures of the remaining gases in the source chamber and the position of the Nd:YAG laser focus on the target.

During the first part of research the influence of the composition of the gas target as well as the time delay between the synchronization signal for gas nozzles opening and an Nd:YAG laser pulse (He, H, Ar) on EUV radiation intensity were investigated. The nozzle time delay results directly in the change of a density profile of the working gas in the target. The preliminary results showed that, for Xe working gas, the time delay of 800 μs is the most optimal for maximum source intensity. However, the stability for this particular value of time delay is very low. The comparison of the registered EUV source intensity at the wavelength of 13.5 nm for different time delays and for selected buffering gases is presented in Fig. 3.

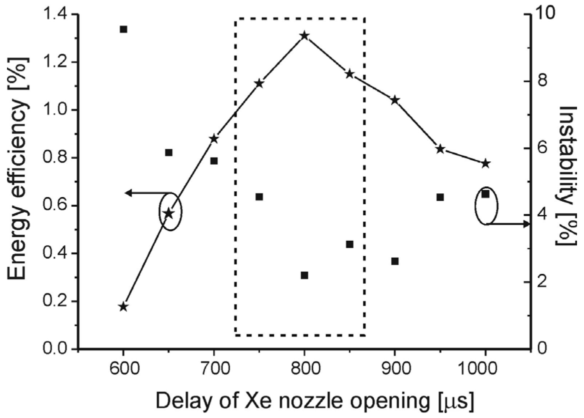

Fig. 3. The relative intensity of the EUV radiation source vs. time delay of nozzle opening for some composition of gas target [5].

The obtained results show that the conditions of plasma generation in the source fundamentally determine the metrology parameters of the laboratory setup for detectors calibration. The operation conditions of the source must be a compromise between high efficiency and good stability. For the selected conditions, the radiation energy of the source is 1 mJ/sr/pulse and the stability is 5%.

The measured stability of source radiation influences the accuracy of a calibration procedure. For this reason, a special testing procedure is prepared. It is based on responsivities comparison of a tested detector with a reference one. The calibration setup uses an optical beam splitter consisting of two multilayer mirrors. The reflectivity of the multilayer mirror is optimized for a wavelength of 13.5 nm and an incident angle of 45° – Fig. 4. Additionally, to determine the used radiation spectrum, the system is prepared to mount an absorption filter. The filters minimize radiation outside the measurement range. For example, the filter consists of Si_3N_4/ Zr / Si_3N_4 layers of the thickness of 150 nm/ 100 nm/ 150 nm, respectively attenuates the radiation with wavelength shorter than 13.5 nm.

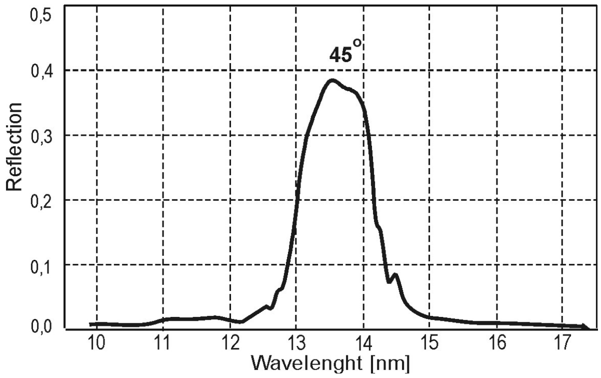

Fig. 4. The relative intensity of the EUV radiation source vs. time delay of nozzle opening for some composition of gas target.

The system determines spatial non-uniformity of detector responsivity. A special scanning construction was prepared. It consists of a holder with a pinhole, XYZ translation stage, and a movement driver.

The preliminary research of the scanning mechanism was made at the relevant laboratory setup – Fig. 5.

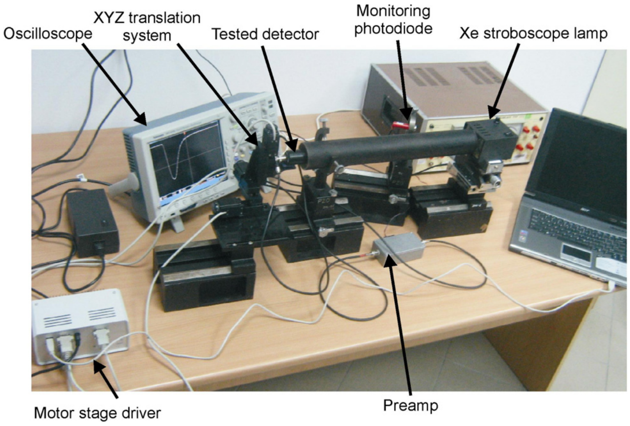

Fig. 5. Laboratory setup to investigate the spatial non-uniformity of detectors responsivity.

The main task of the investigation was to verify the procedure with a moving pinhole. The results yielded also guidelines for designing a scanning unit operated in a vacuum. A stroboscope lamp was applied as a source,. That is why the whole measurement does not relate to the EUV wavelength range. The comparison of photodiode responsivity and lamp emission is presented in Fig. 6. The silicone photodiode was prepared for the testing procedure.

The diameter of the pinhole and the movement step were equal to 1 mm. The stability of lamp intensity was independently controlled by a monitoring photodiode.

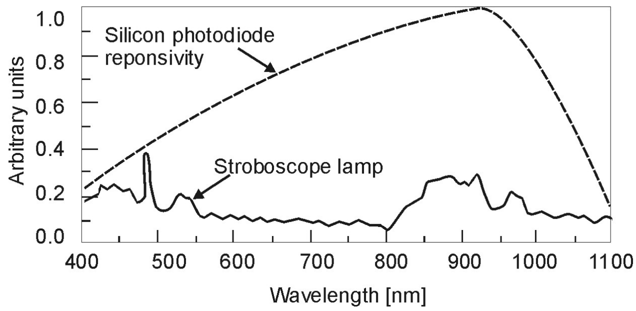

Fig. 6. Emission spectra of a xenon stroboscope lamp with spectral responsivity of a silicon photodiode.

The spatial responsivity non-uniformity of the investigated photodiode was determined from the measurements– Fig. 7.

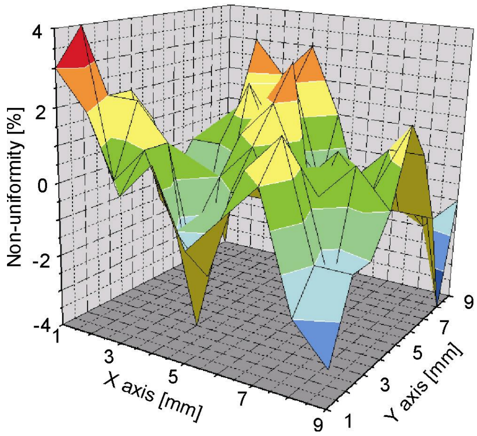

Fig. 7. Spatial non-uniformity of photodiode. responsivity .

The measured non-uniformity in Fig. 7 is about 4%. In the case of manufacturer's data, the non-uniformity is equal to 2% for the wavelengths 254 nm, 162 nm, 122 nm, and 10 nm. Thus, this difference can result mainly from the ranges of an investigation wavelength.

The paper presents the project of a system for calibrating detectors in the EUV wavelength range. The experimental results provide an opportunity to determine optimal parameters of the source operation. The results showed that source efficiency and stability depend on the conditions of plasma generation. For this reason, a special construction of the beam splitter was designed. The system is able to measure spatial non-uniformity of detector responsivity. The described scanning unit made it possible to determine photodiode non-uniformity in the spectrum of a stroboscope lamp. The research verified the testing procedure with a moving pinhole and provided guidelines for designing a scanning unit operated with an EUV radiation source (vacuum conditions).

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