Testing of Reflective Quarter Wave Retarder in EUV Range.

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Abstract

The high demand to understand the optical, electronic, and structure properties of materials has fostered to extend the investigation down to shorter wavelengths in the far ultraviolet (FUV) and extreme ultraviolet (EUV) range. This has pushed scientists to investigate and design new optical tools as wave retarder (QWR) which, coupled with other techniques, can provide valuable information about physical, like magnetic and optical properties of materials. For that purpose we have designed and studied an EUV QWR based on multilayer structures with a protective capping layer to avoid oxidation and contamination to improve stability and reflectivity efficiency.

Introduction

In the visible and near-UV spectral region, circular and linear polarized radiation can be realized easily through an optical polarizer combined with a quarter-wave plate [1] however, as we move toward the shorter wavelengths, it is difficult to find adequate materials since all materials become highly absorbing for that range .Aluminum is a good candidate material that has been used for a long time for multilayer optical tools in the EUV range because of its high reflectivity performances [2,3]. Several studies have been done to use quarter-wave retarders based on single layer of aluminum reflective coatings However, for wavelengths shorter than 160 nm the presence of aluminum oxide Al_2O_3 due to the strong reaction with air strongly influences the optical properties of the film. The oxide layer has very high absorption in vacuum ultraviolet range reducing the reflectance of the aluminum in this region. [4] Then some protective cap layer structure is required to avoid oxidation without affecting the resulting performances.

Objective

- Designing and testing an EUV polarimetric apparatus based on Al multilayer structures working as QWR in a wide spectral range (88-160 nm).
- Investigate two different protective capping layer of TiO_2 and Tb deposited on the top of Al layer by the technique of electron beam evaporation to avoid oxidation and contamination to improve stability and reflectivity efficiency.
- Such design could be particularly useful as analytical tools in EUV-ellipsometry field where the system can be a relatively simple alternative to Large Scale Facilities and can be applied to test different optical components by deriving their efficiency and their phase effect, i.e. determining the Mueller Matrix terms.

Experimental Realization

The EUV reflectometer facility available at CNR-IFN Padova, Italy is shown in Fig. 1. A four-reflection linear polarizer has been designed using gold coated mirrors to test and evaluate QWR Figure. 2 (a)

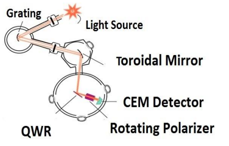


Fig.1 The used FUV-EUV normal incidence reflectometer Facility located in LUXOR, Padova, Italy

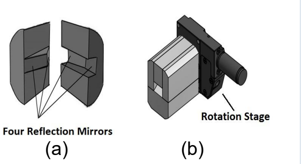


Fig. 2 (a) the Four reflection mirrors polarizer, (b) the whole device is attached to a rotational stage with positioning sensors.

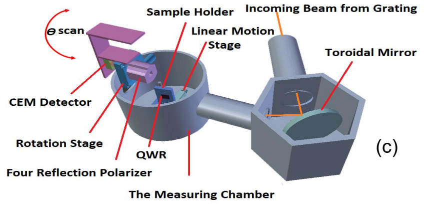


Fig. 2 (c)The setup arrangement for testing the QWR in the FUV-EUV facility at Padova.

The Spectral performances of the four reflection mirrors polarizer are shown in Fig. 3a while in Fig. 3c the relative transmitted intensity for a linearly polarized beam vs the rotation angle of the polarizer is shown.

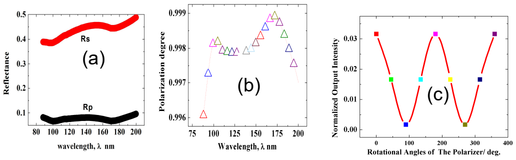


Fig. 3 (a) The calculated reflectance of Rs and Rp of unpolarized incidence beam versus wavelengths at incidence angle 60 (b) The linear polarization degree of the total four reflection mirrors versus wavelength, (c) The detector signal versus the polarizer rotation angle, the incident beam is assumed to be partially linearly polarized with stokes parameter [1, 0.9, 0, 0] at wavelength 121.6 nm.

Results

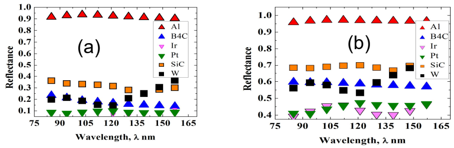
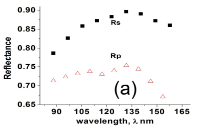


Fig 4. The reflectivity of different materials for (a) p- polarization and (b) s-polarization versus wavelength at normal incidence angle of 59^0.



$$|r_s| = |r_p|$$

$$\varphi = |\varphi_p - \varphi_p| = 90^0$$

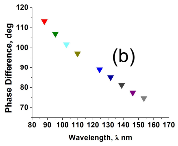


Fig 5. (a) The reflectance of Rs and Rp versus wavelength of capping layer of TiO_2 deposited on of Al at normal incidence angles 59^0. (b) Phase Difference of capping layer of TiO_2 deposited on Al layer versus wavelength at normal incidence angles 59^0. It can be seen that a phase difference of 90^0 degrees at wavelength 121.6 is obtained

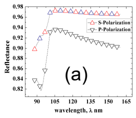


Table 1. Wavelengths with their correspondi incidence angles at phase difference about 9 for QWR with Tb capping layer

Wavelength	Working Incidence Angles
154.8	64.5
121.6	59
103.2	54.5
97	52.8
91	50.3

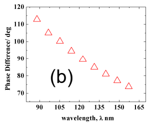


Fig 6. (a) The reflectance of Rs and Rp versus wavelength of capping layer of Tb with 2 nm thickness deposited on Al layer at normal incidence angles 59^0. (b) Phase Difference of a capping layer of Tb deposited on Al layer versus wavelength at normal incidence angles 59^0 it is clearly seen that a Phase difference of 90^0 degrees for wavelength 121.6 is obtained.

Testing procedure

The first three Stokes parameters S_0, S_1, and S_2 can be measured directly without the retarder, the equivalent Mueller matrix of the system and the output intensity are defined as

$$I_{out} = R(-\theta) * M(FRP) * R(\theta) * I_{in} \qquad S^{\sim} = \frac{1}{2}\left[\left(|r_s|^8 + |r_p|^8\right)S_0 + \left(|r_s|^8 - |r_p|^8\right)S_1\cos 2\theta + \left(|r_s|^8 - |r_p|^8\right)S_2\sin 2\theta\right]$$

Then the QWR can be inserted to the optical path as shown in Figure 1 to characterize its reflection and phase properties. In this way the fourth parameter is measured by rotating the measuring chamber to various angles.

$$I_{out} = R(-\theta)*M(FRP)*R(\theta)*M(QWR)*I_{in}$$

$$S^{\sim} = \frac{1}{2}\left[\left(\left(|r_s|^8 + |r_p|^8\right)X + \left(|r_s|^8 - |r_p|^8\right)y\cos 2\theta\right)S_0 + \left(|r_s|^8 + |r_p|^8\right)Y + \left(|r_s|^8 - |r_p|^8\right)X.S_1\cos 2\theta + \left(|r_s|^8 - |r_n|^8\right)(XY)^{\frac{1}{2}}\, S_3\sin 2\theta\right]$$

the X and Y refeer to the reflectifity intensity values of the QWR were

$$X = \frac{\left(|r_s|^2 + |r_p|^2\right)}{2} \quad \text{and} \quad Y = \frac{\left(|r_s|^2 - |r_p|^2\right)}{2}$$

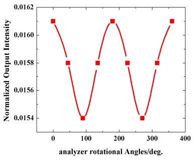


Figure 7. The CEM signal is plotted versus rotational angle of the polarizer, the beam is reflected by the designed QWR with Tb capping layer, the incidence beam is configured to have partially linear polarization at 45 with Stokes vector [1, 0, .9, 0] at wavelength 121.6 nm.

Conclusion

We have designed and studied QWR in EUV range covering a wide spectral range (88-160 nm) based on Al structures with two different protective capping layer TiO_2 and Tb. Based on the theoretical results, multilayers of Al/TiO_2 and Al/Tb deliver high reflectance for s and p polarization with a phase difference between the two orthogonal components around 90 deg. The design will be tested with the EUV reflectometer facility available at CNR-IFN Padova,. This solution can be a very promising laboratory system to test the properties of thin films and of interfaces in the EUV spectral range.

REFERENCES

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