EUV optics cleanliness qualification using spectroscopic ellipsometry

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Background & Motivation

Goal: predict EUV reflectance loss due to carbon deposition using visible-light ellipsometry

Methodology

Change in polarization after reflection supplies thickness and optical constants of contamination layer

1. Principle of EUV reflectance loss

(a) Calculated relative EUV reflectance loss for different types of carbon films

(b) Reflectance loss normalized by density only

- Reflectance attenuation scales with density and thickness only
- In typical EUV optics contamination (< 5 nm) type of carbon is irrelevant for reflectance loss determination

2. Estimating the carbon density from the optical constants

Bruggeman’s effective medium approximation (BEMA):
- Mix carbon with voids
- Describe refractive index and density

3. Estimation of EUV reflectance loss

Good agreement obtained between densities measured by GIXR and estimated values using the BEMA and CM model.

3. Application for ultrathin carbon films

Trajectory of ellipsometric angles, \( \Psi \) and \( \Delta \) at 600 nm

1. Predict reflectance loss: EUV reflectometry and grazing incidence X-ray reflectivity (GIXR) used as reference
2. ‘nd’ allows estimation of product of density and thickness (nd) (BEMA)
3. Reflectance loss can be estimated by \( \Delta R/R \approx \xi d \)

4. Application for ultrathin carbon films

Trajectory of \( \Psi \) and \( \Delta \) reveals type of carbon

Conclusions

1. EUV reflectance loss due to carbon deposition is mainly determined by the carbon layer thickness and density and not by its composition.
2. All published experimental carbon densities and refractive indices are well described by Bruggeman’s effective medium approximation (BEMA).
3. For EUV induced carbon, the predicted reflectance loss based on the BEMA agrees well with the experimental data with an accuracy of \( \pm 1\% \), thus enabling qualification of the cleanliness of EUV optics.