5-22-1995

Direct Measurement of Optical Constants of Metals from a KrF Excimer Using Polarization Methods

Suleyman Turgut
Rochester Institute of Technology

Bruce W. Smith
Rochester Institute of Technology

Recommended Citation

Suleyman Turgut, Bruce W. Smith, "Direct measurement of optical constants of metals from a KrF excimer using polarization methods", Proc. SPIE 2439, Integrated Circuit Metrology, Inspection, and Process Control IX, (22 May 1995); doi: 10.1117/12.209235; https://doi.org/10.1117/12.209235

Direct measurement of optical constants of metals from a KrF excimer using polarization methods

Suleyman Turgut*, Bruce W. Smith

Microelectronic Engineering Dept.
Rochester Institute of Technology
Rochester, N.Y. 14623-5604
*Currently with Intel Corporation, Santa Clara, CA 95052

ABSTRACT

A simple null modulation-polarization method of measuring optical constants of metals has been adapted for operation with a KrF 248nm excimer laser. The approach requires only 3 optical components to extract the real and imaginary parts of the index of refraction (n,k). Experimental results will show good agreement to reference values for several metals (Cr, Au, Al) and Si.

1. INTRODUCTION

To account for the absorption of electromagnetic radiation in materials, the index of refraction is specified as a complex entity (n_c), the sum of real and imaginary parts:

$$n_c = n_r + ik$$

where n_r is referred to as the real index of refraction and k is the extinction coefficient. The measurement of these optical constants in the deep UV is commonly performed using UV spectroscopic ellipsometry, requiring a broadband source, detector and computer algorithms. A simplified technique [1] has been adapted for operation with a monochromatic source and three optical components. Two measurements are required to extract these two values, the principal angle of incidence (θ) and the corresponding principal azimuth (ψ). The principal angle of incidence is defined as the angle of incidence that produces a minimum reflection of the p component of the electric field (component of the electric field that is parallel to the angle of incidence, which is defined as the plane passing through the reflected and incident beam). The principal azimuth is defined by:

$$\tan(\psi)=R_p/R_s$$

where R_p and R_s are the reflected amplitudes of the normal components of the electric fields. Since this quantity is usually very difficult to measure, an alternative method exists: adjust the azimuth (axis of the polarizer) at the principle angle of incidence to give a null or minimum. Consequently, the two optical constants can be found using the following two relations:

$$k = \tan(\psi) \quad \text{and}$$

$$n\sqrt{1+k^2} = \sin(\theta)\tan(\theta).$$

The schematic of the optical setup that is used is shown in Figure 1.

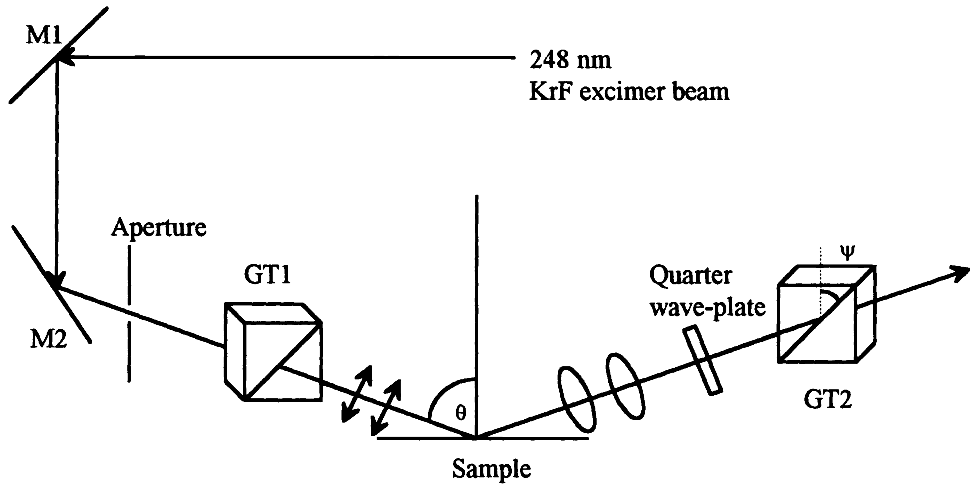

Figure 1. Schematic of 248 nm ellipsometric technique.

Calcite Glan-Taylor polarizing prisms have been utilized, with an asymmetrical usable full field angle of approximately 5° at 248 nm. The partially polarized output of the excimer laser is reflected off two mirrors and passed through an aperture and through a Glan-Taylor (GT1) polarizer who's axis is oriented so as to provide a linearly polarized electric field vibrating 45 degrees to the plane of incidence (the plane of incidence defined as the plane passing through the reflected and incident beam). This linearly polarized beam is elliptically polarized upon reflection from the metallic film since the two normal components of the electric field (*s* and *p*) are reflected with a phase difference. Passing through the appropriately oriented quarter wave plate, the beam is transformed back to linear polarization by retarding the *p* component by 90 degrees with respect to the *s* component. Crossing the second Glan-Taylor (GT2) polarizer with the linearly polarized beam produces a null at the principal angle of incidence.

2. RESULTS

Several metal samples were used in the above set up and the results are presented in Table 1.

Metal	Experimental (n,k)	Reference [2] (n,k)
Ti:W	0.23, 1.80	NA
Cr	0.90, 2.25	0.85, 2.01
Si	1.65, 2.75	1.58, 3.60
Au	1.32, 1.43	1.22, 1.49
Al	0.18, 2.61	0.19, 2.94

Table 1. Optical constants of films at 248 nm.

As is evident the experimental values are relatively close to the reference values, with differences ranging from 1-11%. The error can be attributed to a number of factors. First, the accuracy in determining the angle of incidence and azimuth was +/-1 degree. Secondly, the surface preparation and cleanliness of the metal has been known to produce variations in the quoted experimental data.

3. CONCLUSION

A simple null modulation-polarization method of measuring optical constants has been shown to successfully extract the real and imaginary parts of the index of refraction for several films. The technique uses a KrF excimer laser and only 3 optical components. Experimental results show good agreement to reference values for several metals (Cr, Au, Al) and Si.

REFERENCES

[1] Jenkins, F.A., White, H.E., Third Edition, 1957, 526
[2] Weaver, J.H., Krafka, C., Physik Daten, Optical Properties of Metals, Fachinformationszentrum Energie, 1981