U. S. Department of Commerce
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National Bureau of Standards

Certificate of Analysis

Standard Reference Material 2530-2

Ellipsometric Parameters Δ and ψ and Derived Thickness and Refractive Index for a Silicon Dioxide Layer on Silicon

Serial No.

This Standard Reference Material (SRM) is issued primarily to evaluate the accuracy of ellipsometers. It consists of a 76-mm (three-inch) diameter silicon wafer on which a uniform silicon dioxide layer was grown, patterned, and partially covered with chromium as shown in Figure 1. SRM 2530 is certified for the ellipsometric parameters delta, Δ, and psi, ψ, at a wavelength of $\lambda = 632.8$ nm using the highly accurate ellipsometer built at NBS [1]. It is also certified for the derived values of thickness and refractive index of its silicon dioxide layer. This SRM may also be used as an aid in the calibration of various other optical and mechanical thickness monitoring instruments [2].

An ellipsometer measures the change in the polarization of light when it is reflected from a surface, and this change can be specified in terms of the ellipsometric parameters Δ and ψ [2]. The electric field vector of the light wave can be resolved into two components, one in the plane of incidence and one normal to the plane of incidence, and the reflection process introduces a relative phase change, Δ, between these two components and a relative amplitude attenuation, $\tan\psi$.

The certified parameters, Δ and ψ, are used to calculate the values for the thickness and refractive index of the silicon dioxide layer. These values can be derived by using either a one-layer or a two-layer model of the oxide film. The two-layer model assumes an interlayer beneath a stoichiometric layer of silicon dioxide; whereas the one-layer model does not include a discrete interlayer, but assumes a single dielectric layer for the oxide film. The two-layer model gave a better fit to the collective experimental data, as well as giving a value for the refractive index of the silicon dioxide layer that is independent of thickness. Therefore, the certified values of thickness and refractive index are based on the two-layer model. For more information, please refer to the accompanying document, NBS Special Publication 260-109, Preparation and Certification of SRM 2530, Ellipsometric Parameters Δ and ψ and Derived Thickness and Refractive Index of a Silicon Dioxide Layer on Silicon [3].

Under Supplemental Information, values of Δ and ψ are given as a function of angle of incidence for a two-layer model. Values of thickness and refractive index are also given based on a one-layer model of the oxide layer. These supplementary values are not certified, and therefore, no uncertainties have been assigned.

CERTIFIED VALUES

Separate certified values are provided for two areas designated "left side" and "right side" as shown in Figure 1. The areas are approximately 2.5 cm x 2.5 cm, located 0.5 cm to the left and right of the chromium overlayer. The following values are certified for SRM 2530-2, SN_____. Values after the plus/minus signs indicate total uncertainties associated with the certified values; these uncertainties are computed as one-standard-deviation limits to random error plus systematic error.

The following values of Δ and ψ were obtained at the wavelength of 632.8 nm and at an angle of incidence, ϕ, that is close to the principal angle [2] for this sample: ϕ = _____ ± _____ deg.

Left Side	Right Side
Δ = _____ ± _____ deg.	Δ = _____ ± _____ deg.
ψ = _____ ± _____ deg.	ψ = _____ ± _____ deg.

The derived certified value for the thickness of the silicon dioxide film, t_f, plus that of the silicon-rich interlayer, t_i, is:

Left Side	Right Side
$t_f + t_i$ = _____ ± _____ nm	$t_f + t_i$ = _____ ± _____ nm.

The derived certified value for the refractive index of the silicon dioxide film is the same for both sides:

n_f = _____ ± _____.

The following values were determined from a simultaneous fit of the data and are the same for both sides.

Interlayer Thickness and Refractive Index:

t_i = _____ ± _____ nm n_i = _____ ± _____.

Refractive Index of the silicon substrate, real and imaginary parts:

n_s = _____ ± _____ i_____ ± _____.

The overall direction and coordination of the technical aspects of this SRM were performed by G.A. Candela, D. Chandler-Horowitz, and J.F. Marchiando of the NBS Semiconductor Electronics Division.

This SRM was fabricated in the Semiconductor Processing Research Laboratory by D.B. Novotny of the NBS Semiconductor Electronics Division.

The ellipsometric measurements leading to certification were performed by B.J. Belzer of the NBS Semiconductor Electronics Division.

The statistical analysis was performed by M.C. Croarkin of the NBS Statistical Engineering Division.

The support aspects involved in the certification and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by R.W. Seward.

Gaithersburg, MD 20899
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Stanley D. Rasberry, Chief
Office of Standard Reference Materials

SN_____

SUPPLEMENTAL INFORMATION

Two-Layer Model:
Based on the above certified values for this SRM, the derived values for Δ and ψ as a function of angle of incidence, ϕ, are given below because some ellipsometers can be used only at discrete values of the angle of incidence.

	Left Side		Right Side	
ϕ(deg)	Δ(deg)	ψ(deg)	Δ(deg)	ψ(deg)
50				
55				
60				
65				
70				
75				

One-Layer Model:
For a one-layer model of silicon dioxide on silicon, the thickness and refractive index for the silicon dioxide layer for this SRM are calculated to be:

Left Side	Right Side
t_f = _____ nm	t_f = _____ nm

The refractive index of the silicon dioxide film is:

n_f = _____,

and the value for the refractive index of the silicon substrate is:

n_s = _____ i_____.

Cleaning and Handling:
The SRM should be stored in the clean wafer container supplied, and should be handled only with proper wafer tweezers. Even when the SRM is kept in its clean container, a film forms on the surface of the oxide. This unwanted film forms rapidly, usually at a rate of 0.1 or 0.2 nm per week, and can be removed by rinsing the SRM with reagent grade ethanol and then with deionized water. Both solvents, the ethanol and the water, can be blown off the wafer surface with clean nitrogen. The sample must then be permitted to stabilize in the atmosphere 20 - 30 minutes prior to continuing with the measurements. When the surface is prepared in this manner, the measurements are reproducible for several hours or more. If the SRM becomes excessively dirty from mishandling, improper storage, or any other reason, the wafer should then be cleaned using a semiconductor processing grade detergent and rinsed thoroughly with deionized water.

REFERENCES

1. Candela, G.A., and Chandler-Horowitz, D., An Ellipsometry System for High Accuracy Metrology of Thin Films; SPIE Vol. 480 Integrated Circuit Metrology II, p 2 (1984).
2. Candela, G.A., Chandler-Horowitz, D., Novotny, D.B., Vorburger, T.V., and Giauque, C.H.W., Film Thickness and Refractive Index Standard Reference Material Calibrated by Ellipsometry and Profilometry; SPIE Vol. 661 Optical Testing and Metrology, p 402 (1986).
3. Candela, G.A., Chandler-Horowitz, D., Marchiando, J.F., Novotny, D.B., Belzer, B.J., and Croarkin, M.C., Preparation and Certification of SRM 2530, Ellipsometric Parameters Δ and ψ and Derived Thickness and Refractive Index of a Silicon Dioxide Layer on Silicon, NBS Special Publication 260-109 (1988).

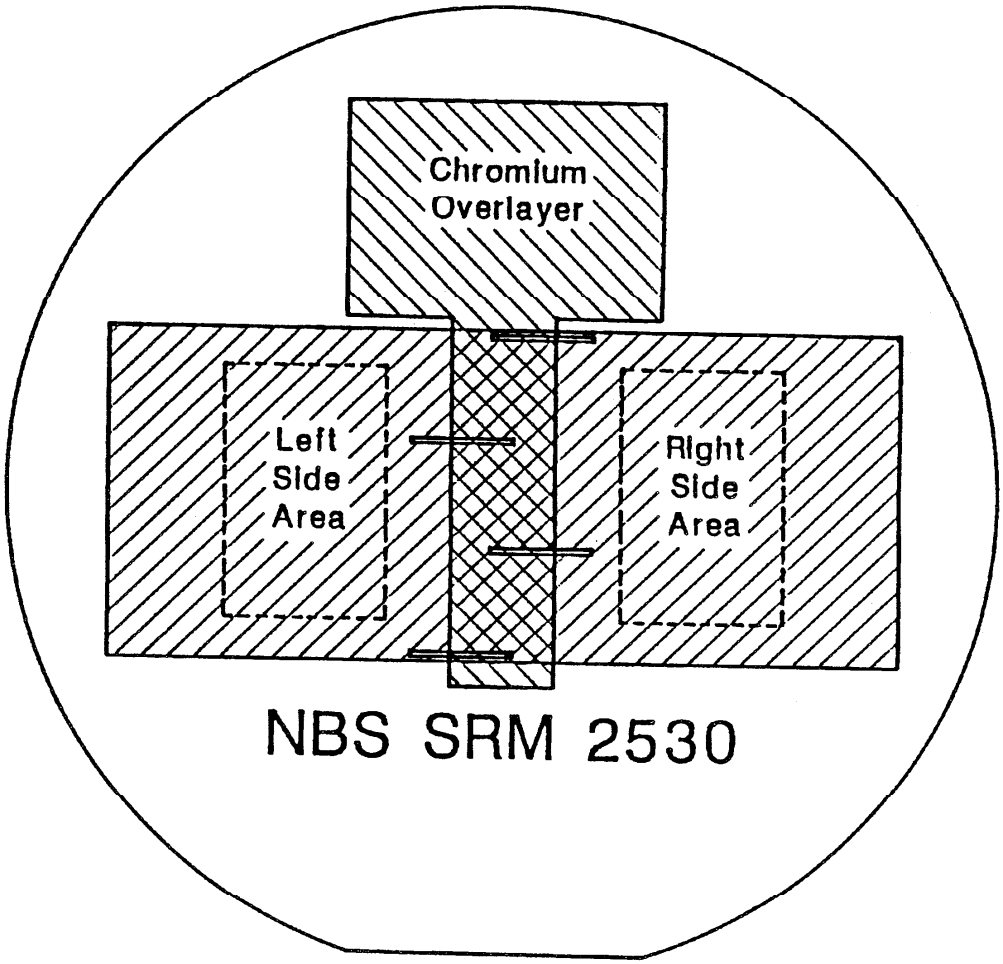
Chromium
Overlayer
Left
Side
Area
Right
Side
Area
NBS SRM 2530

Figure 1