UCRL-11818

University of California

Ernest O. Lawrence Radiation Laboratory

DISCUSSION OF
USE OF INDEX OF REFRACTION LIQUIDS FOR THE MEASUREMENT OF THE REFRACTIVE INDEX OF THIN TRANSPARENT FILMS ON SILICON BY
A. E. Lewis, J. E. C. S., 111, 1007-9 (1964)

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Submitted to J. Electrochemical Soc.

UCRL-11818

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

Discussion of
Use of Index of Refraction Liquids for the Measurement of the Refractive Index of Thin Transparent Films on Silicon
by
A. E. Lewis, J.E.C.S., 111, 1007-9 (1964)

Rolf H. Muller

December 1964

Rolf H. Muller

Inorganic Materials Research Division
Lawrence Radiation Laboratory
University of California
Berkeley, California

Discussion of

Use of Index of Refraction Liquids for the Measurement of the Refractive Index of Thin Transparent Films on Silicon

A. E. Lewis, J.E.C.S., 111, 1007-9 (1964)

It is interesting to see that the time-honored immersion method for the determination of refractive indices has found a new application for transparent solid films. One of the limitations of the method described is due to the necessity of a well-observable light interference such as saturated interference colors in the film before immersion. This requires, as stated by the author, A. E. Lewis, equal reflectivities of the air-oxide and oxide-metal interfaces at normal incidence. An extension

of the present technique, using particular angles of incidence[1] and polarized light should alleviate this situation.

As reported earlier,[2] "optimum" angles of incidence $\phi_{||}$ and $\phi_{\perp}$ exist for light polarized parallel and normal to the plane of incidence,[3] respectively, under which the amplitudes of the reflections from the air-film and film-metal interfaces are equal. This results in easily observable interference phenomena, even under conditions where the difference in reflectivity precludes any observation at normal incidence. Typical values of these optimum angles of incidence have been computed for silicon covered by transparent dielectric films of the reported refractive index of the oxide and adjacent values. The results are given in Table I together with those for two other base-metals. The numerical values used for the complex refractive index of the metals $n_2(1-i\kappa_2)$ are also listed in Table I.

In the modification of the immersion technique, suggested here, the reflection coefficient[4] of the film-liquid interface is a much steeper function of the refractive index difference between the two phases than under normal incidence (Fig. 1). Thus, the sensitivity of the method is improved in addition to making observation of the film interference

---

[1] Defined as the angle between incident beam and normal to the surface.

[2] R. H. Muller, J. Opt. Soc. Amer., 54, 419-20 (1964).

R. H. Muller, Lawrence Radiation Laboratory Report UCRL-10963.

[3] Defined as the plane containing incident and reflected beams.

[4] Defined as the ratio of the incident and reflected amplitudes.

easier. The use of polarization normal to the plane of incidence will in general be preferable to that parallel to the plane of incidence because the observations are possible at a lower angle of incidence which is often more convenient. As shown in Fig. 1, for an angle of incidence of 75°, which represents an average of the desirable values listed in Table I, the polarization normal to the plane of incidence also is associated with a somewhat better sensitivity.

It must be borne in mind that the immersion method presupposes a sharp boundary between homogeneous dielectrics. It is therefore strictly valid only for non-absorbing films. Computations for the reflection on absorbing media carried out according to Koenig[5] indicate that even for very slightly absorbing films (absorption index $\varkappa_2 < 0.05$), the minimum in reflectance at the liquid-film interface, which occurs instead of the zero reflectance for a dielectric, gives only an approximate value of the real part of the complex film refractive index (Fig. 2).

---

[5] W. Koenig, Elektromagnetische Lichttheorie, in Handbuch der Physik edited by H. Geiger and K. Scheel (Springer, Berlin, 1928) Vol. 20, page 242.

R. H. Muller, Lawrence Radiation Laboratory Report UCRL 11813.

Table I

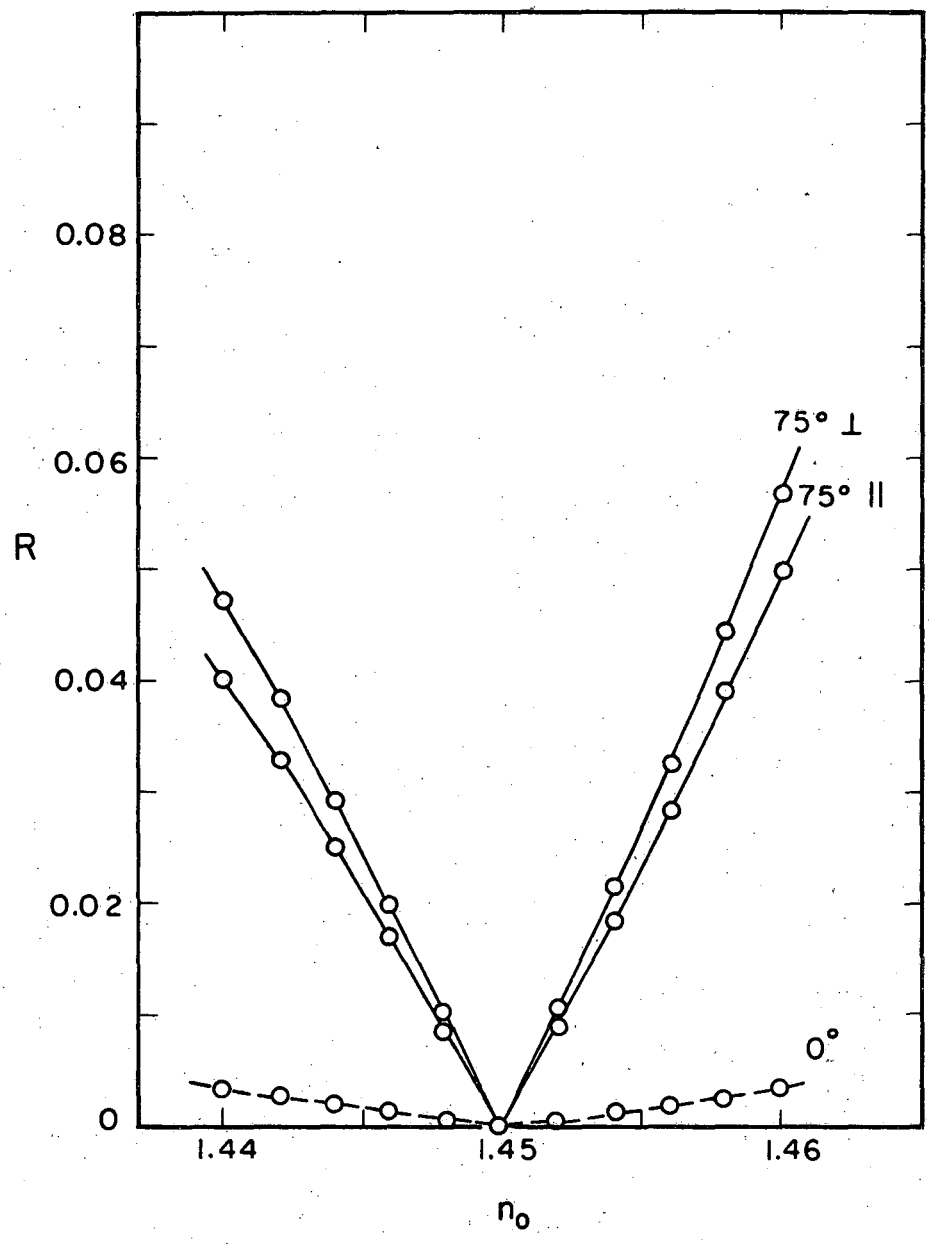
Optimum Angles of Incidence ϕ for Light Interference in Transparent Dielectric Films on Metal Surfaces

Film refractive index n_1			1.30		1.45		1.60	
Angle of incidence			$\phi_{\parallel}$	$\phi_{\perp}$	$\phi_{\parallel}$	$\phi_{\perp}$	$\phi_{\parallel}$	$\phi_{\perp}$
Metal	Optical Constants							
	n_2	$\varkappa_2$						
Si	4.05	0.01	76°	68°	76°	63°	76°	57°
Ni	1.75	1.95	84°	71°	84°	65°	84°	59°
W	3.46	0.94	82°	70°	82°	63°	82°	57°

Figure Captions

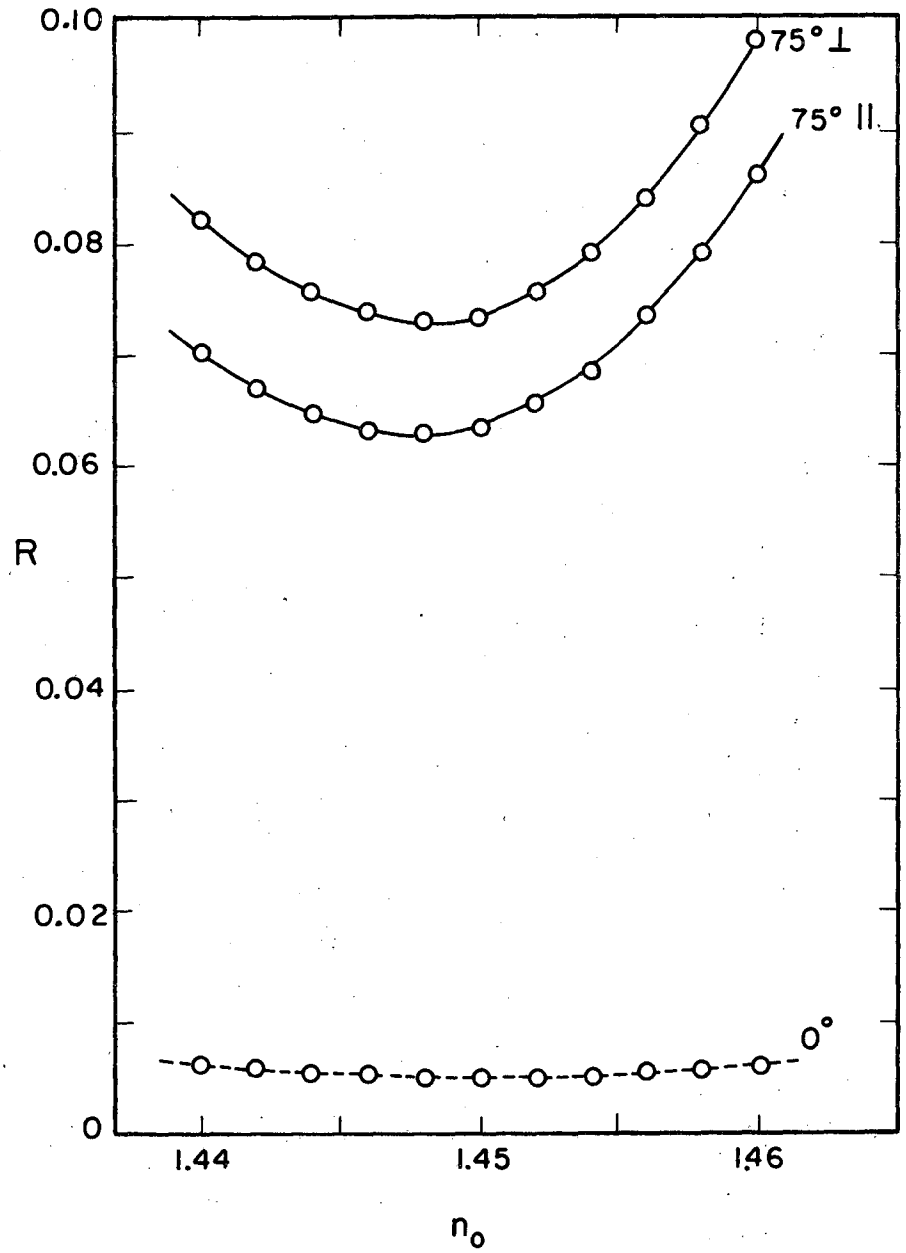
Figure 1. Reflection coefficients R for a dielectric medium ($n_1 = 1.45$) in contact with another dielectric of variable refractive index n_0. Angles of incidence 75° and 0°, polarization parallel ($||$) and normal ($\perp$) to the plane of incidence.

Figure 2. Reflection coefficients of a slightly absorbing medium ($n_1 = 1.45$, $\chi_1 = 0.01$) in contact with a dielectric of variable refractive index n_0. Angle of incidence 75° and 0°, polarization parallel and normal to the plane of incidence.



MUB-4666

Fig. 1.



MUB-4667

Fig. 2.

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.