

**QUICK
REFERENCE
MANUAL**



**FOR
SILICON
INTEGRATED
CIRCUIT
TECHNOLOGY**



K.F. WENDT LIBRARY
UW COLLEGE OF ENGR.
215 N. RANDALL AVENUE
MADISON, WI 53706

QUICK REFERENCE MANUAL FOR SILICON INTEGRATED CIRCUIT TECHNOLOGY

QUICK REFERENCE MANUAL FOR SILICON INTEGRATED CIRCUIT TECHNOLOGY

W. E. BEADLE
J. C. C. TSAI
R. D. PLUMMER

Editors

TK
74874

A Wiley-Interscience Publication
JOHN WILEY & SONS
New York • Chichester • Brisbane • Toronto • Singapore



Copyright © 1985 by Bell Telephone Laboratories, Incorporated

Published by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Sections 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional service. If legal advice or other expert assistance is required, the services of a competent professional person should be sought. *From a Declaration of Principles jointly adopted by a Committee of the American Bar Association and a Committee of Publishers.*

Library of Congress Cataloging in Publication Data:

Main entry under title:

Quick reference manual for silicon integrated circuit technology.

"A Wiley-Interscience publication."

Includes index.

1. Integrated circuits—Handbooks, manuals, etc.
 2. Silicon—Handbooks, manuals, etc. I. Beadle, W. E. II. Tsai, J. C. C. III. Plummer, R. D.
- TK7874.Q38 1984 621.381'73 84-25667
ISBN 0-471-81588-8

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Engin
TK
7874
Q38
1985

CONTRIBUTORS

Editors	Physical Constants	1
Editors	Physical Properties	2
L. J. Turgeon	Basic Expressions	3
S. P. Weeks	Measurements	4
D. G. Schimmel	Chemical Recipes	5
J. C. C. Tsai	Diffusion	6
J. C. C. Tsai	Ion Implantation	7
H. R. Maxwell, Jr.	Process Data	8
D. Koehler and W. E. Beadle	IC Structures and Wafer Properties	9
Editors	Conductivity of Diffused Layers	10
Editors	Properties of p-n Junctions	11
W. C. Ballamy	Metal-Semiconductor Junctions	12
R. D. Plummer	Surface Properties	13
C. A. Goodwin and W. G. Meyer	MOS	14
W. H. Becker	Reliability	15

CONTENTS

	PAGE
1. PHYSICAL CONSTANTS	1-1
2. PHYSICAL PROPERTIES	2-1
3. BASIC EXPRESSIONS	3-1
4. MEASUREMENTS	4-1
5. CHEMICAL RECIPES	5-1
6. DIFFUSION	6-1
7. ION IMPLANTATION	7-1
8. PROCESS DATA	8-1
9. IC STRUCTURES AND WAFER PROPERTIES	9-1
10. CONDUCTIVITY OF DIFFUSED LAYERS	10-1
11. PROPERTIES OF p-n JUNCTIONS	11-1
12. METAL-SEMICONDUCTOR JUNCTIONS	12-1
13. SURFACE PROPERTIES	13-1
14. MOS	14-1
15. RELIABILITY	15-1
INDEX	IND-1

QUICK REFERENCE MANUAL FOR SILICON INTEGRATED CIRCUIT TECHNOLOGY

2. PHYSICAL PROPERTIES

	Page
List of Symbols	2-2
2.1 Equilibrium Semiconductor Electron and Hole Carrier Concentrations	2-3
2.2 Energy Gap, E_g , and Density-Of-States Effective Mass $\langle m \rangle$	2-9
2.3 Carrier Concentration with Impurity Levels	2-12
2.4 Debye Length	2-15
2.5 Resistivity and Mobility Versus Impurity Concentration for Silicon	2-20
Introduction	2-20
Resistivity Versus Impurity Concentration Curves	2-20
Boron-Doped Silicon	2-20
Phosphorus-Doped Silicon	2-28
High-Concentration Considerations	2-28
Mobility Versus Concentration	2-40
Resistivity Versus Concentration for Deep-Level Impurities	2-41
2.6 Resistivity and Mobility Versus Temperature for Germanium and Silicon	2-41
2.7 Drift Velocity	2-54
2.8 Thermal Expansion Coefficient	2-54
2.9 Optical Properties	2-54
2.10 Thermal Properties	2-54
References	2-72

LIST OF SYMBOLS

Symbol	Definition
a	Absorption coefficient
C_T	Total phosphorus concentration
E_c	Energy at conduction band edge
E_f	Fermi energy
E_g	Energy gap
E_i	Intrinsic Fermi energy
E_v	Energy at valence band edge
h	Planck's constant
k	Boltzmann's constant
K_{th}	Thermal conductivity
L	Effective (extrinsic) Debye length
m	Electron rest mass
m_l	Light hole mass
m_h	Heavy hole mass
$m^{(N)}$	"Effective density-of-states" mass
$m^{(N)}_{lc}$	Effective density-of-states mass for conduction-band electrons
$m^{(N)}_{lv}$	Effective density-of-states mass for valence-band holes
m_1	Transverse electron-effective-mass in the conduction band
m_{11}	Longitudinal electron-effective-mass in the conduction band
$\langle m \rangle$	Average density-of-states mass
n	Equilibrium concentration of electrons
n_a	Un-ionized acceptor density
n_d	Un-ionized donor density
n_i	Intrinsic Fermi level
n_n	Electron concentration in n-type material
n_p	Electron concentration in p-type material
N	Impurity concentration
N_a	Acceptor doping density
N_d	Donor doping density
N_c	Effective density-of-states at the conduction band edge
N_v	Effective density-of-states at the valence band edge
p	Equilibrium concentration of holes
p_n	Hole concentration in n-type material
p_p	Hole concentration in p-type material
q	Electronic charge
T	Absolute temperature
V_D	Drift velocity
E_a	Acceptor energy level measured relative to the valence band edge
E_d	Donor energy level measured relative to the conduction band edge
ϵ_λ	Spectral emissivity
ρ	Resistivity
μ	Carrier mobility
μ_n	Electron mobility
μ_p	Hole mobility
ν	Number of valleys in momentum space
λ	Wavelength

2-60
PHYSICAL PROPERTIES

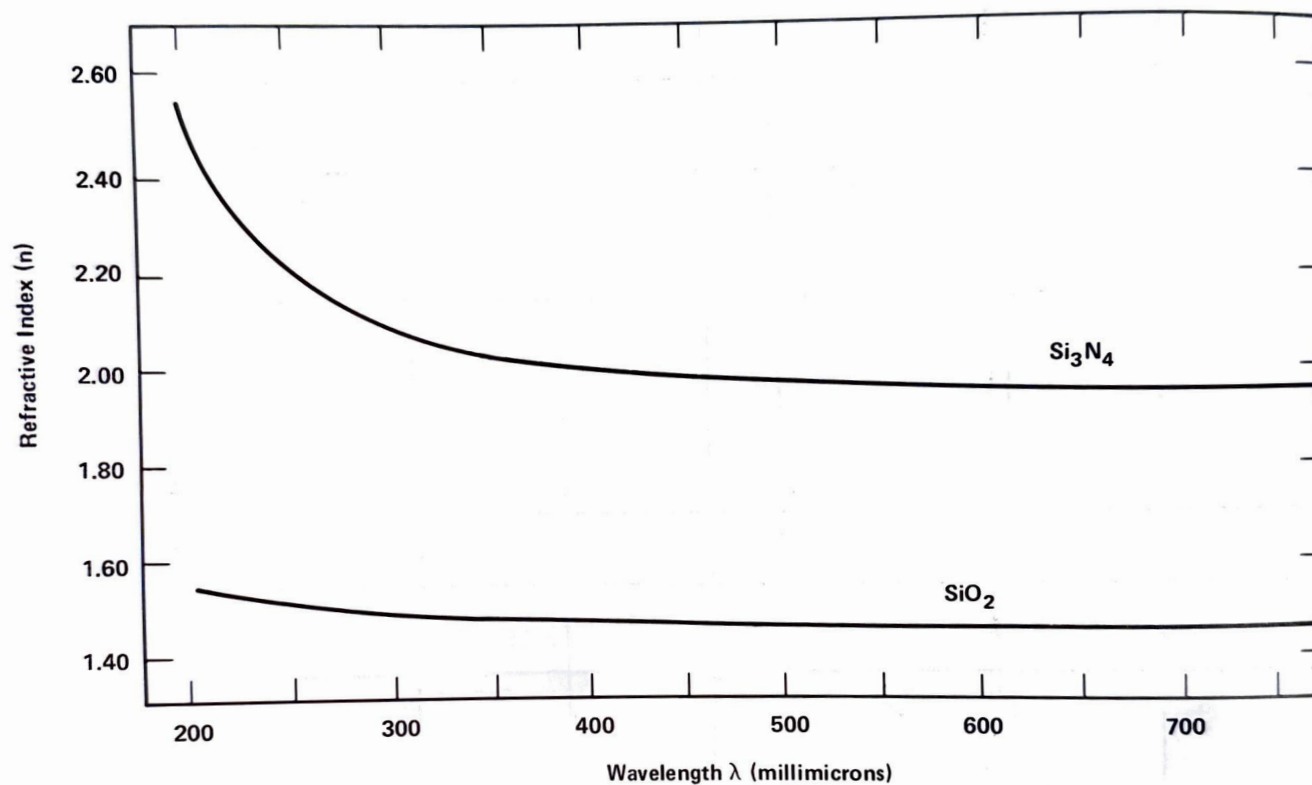


Figure 2-39 — Refractive Index Versus Wavelength for SiO₂ and Si₃N₄^[36]
(Reprinted with permission from Pergamon Press, Ltd.)