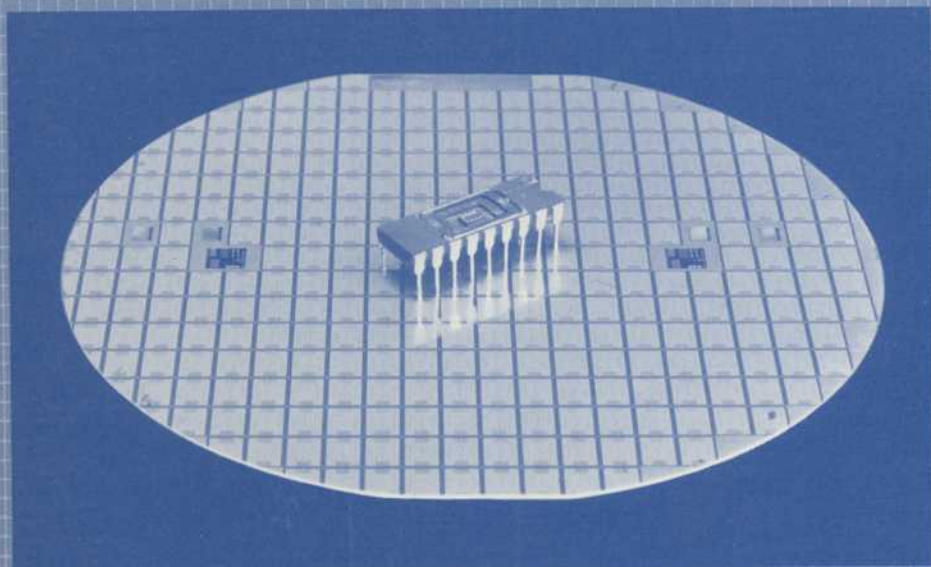


Semiconductor Processing



D. C. Gupta, editor

ASTM STP 850

SEMICONDUCTOR PROCESSING

A symposium
sponsored by ASTM
Committee F-1 on Electronics,
National Bureau of Standards,
Semiconductor Equipment and Materials Institute,
and Stanford University IC Laboratory
San Jose, CA, 7-10 Feb. 1984

ASTM SPECIAL TECHNICAL PUBLICATION 850
D. C. Gupta, Siliconix Inc., editor

ASTM Publication Code Number (PCN)
04-850000-46



1916 Race Street, Philadelphia, PA 19103

Library of Congress Cataloging in Publication Data

Semiconductor processing.

(ASTM special technical publications; 850)

"ASTM publication code number (PCN) 04-850000-46."

Includes bibliographies and index.

1. Semiconductor industry—Congresses. I. Gupta, D. C. (Dinesh C.) II. ASTM Committee F-1 on Electronics. III. Series: ASTM special technical publication; 850.
TK7871.85.S467 1984 621.3815'2 84-18476
ISBN 0-8031-0403-0

Copyright © by AMERICAN SOCIETY FOR TESTING AND MATERIALS 1984
Library of Congress Catalog Card Number: 84-18476

NOTE

The Society is not responsible, as a body,
for the statements and opinions
advanced in this publication.

Printed in Baltimore, MD
October 1984

Foreword

The Third Symposium on Semiconductor Processing was held at San Jose, California on 7-10 February, 1984 under the chairmanship of Dinesh C. Gupta, Siliconix Incorporated. It was sponsored by ASTM Committee F-1 on Electronics and co-sponsored by the National Bureau of Standards, Semiconductor Equipment and Materials Institute and Stanford University Integrated Circuits Laboratory. The Technical Committee was headed by Edward E. Gardner, IBM Corporation and the Arrangements and Publicity Committee by Carl A. Germano, Motorola Incorporated.

The following persons participated in the Advisory Board, and various Committees, namely; the Technical Committee, the Arrangements and Publicity Committee, Registration Committee and the Spouse Committee: Lisa Anderson, SEMI; Kenneth E. Benson, AT&T Bell Laboratories; W.Murray Bullis, Siltec Corporation; Kathleen Bullis; Michael H. Christ, Dynamit Nobel Silicon; Peter Douglas, American Fine Wire Corporation; Terry A. Francis, Air Products Corporation; Barbara Germano; Gilbert A. Gruber, Siliconix, Inc.; Lou Ann Gruber; Vijay Gupta; Heinz Herzer, Wacker-Chemitronic, Philip L. Lively, ASTM; Robert D. Larrabee, National Bureau of Standards; Robert E. Lorenzini, Siltec Corporation; Samuel L. Marshall, Solid State Technology; Jan Meighan, San Jose Convention Bureau; James D. Meindl, Stanford University; Eric Mendel, IBM Corporation; J. Timothy Raab, Rockwell International; Robert I. Scace, National Bureau of Standards; Donald G. Schimmel, AT&T Bell Laboratories; Fritz G. Vieweg-Gutberlet, Wacker-Chemitronic and William R. Wheeler, Tencor Instruments.

In addition, the guidance was provided by the Chairmen and the officers of ASTM Committee F-1 on Electronics and its various subcommittees. The following persons presided the technical and workshop sessions: K.G.Barraclough, Royal Signals & Radar Establishment; K.E.Benson, AT&T Bell Laboratories; W.M.Bullis, Siltec Corporation; P.L.Castro, Hewlett-Packard Laboratories; M.I.Current, Trilogy Systems Corporation; P. Douglas, American Fine Wire Corporation; C. A. Germano, Motorola, Inc.; G.G.Harman, National Bureau of Standards; H. Herzer, Wacker-Chemitronic; P. H. Langer, AT&T Bell Laboratories; R. D. Larrabee, National Bureau of Standards; B. J. Masters, IBM Corporation; J.H.Matlock, SEH America Inc., A. R. Neureuther, University of California, Berkeley; A. Rapa, IBM Corporation; W. R. Schevey, Allied Chemical

Corporation; G.R.Srinivasan, IBM Corporation; B.Stone, Monsanto Company & C.J.Varker, Motorola Incorporated.

We are specially indebted to William Cavanaugh, President of ASTM, for an impressive talk on "The Role of ASTM in the Electronics Industry", Sheldon Weinig, Chairman, Materials Research Corporation and a member of the President's Advisory Council on Private Sector Initiatives who presented a dinner speech on "Competitive IC Market: Will Automation and Technology Improvements Offset the Rising Costs of Manufacturing and Equipment", and to the members of the panel on Cooperative Research; Erich Bloch, Chairman, Semiconductor Research Cooperative and Director, National Science Foundation; Richard Fair, Vice President, Microelectronics Center of North Carolina; Angel Jordan, Provost, Carnegie-Mellon University; James Meindl, Director, Stanford Center for Integrated Systems; and William Oldham, Professor, University of California, Berkeley. The panel was moderated by Dr. Angel G. Jordan.

We are grateful to the members and the guests of ASTM Committee F-1 and SEMI who were called upon from time to time for special assignments during the two-year planning of the Symposium.

Over one hundred and forty persons participated in the review process for the papers published in these proceedings. Without their participation, this publication would not have been possible. And finally, we acknowledge the hard work and efforts of the staff of publication, review and editorial departments of ASTM in bringing out this book.

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

Related ASTM Publications

Silicon Processing, STP 804 (1983), 04-804000-46

Lifetime Factors in Silicon, STP 712 (1980), 04-712000-46

Laser-Induced Damage in Optical Materials: 1982, STP 847 (1984),
04-847000-46

Laser-Induced Damage in Optical Materials: 1981, STP 799 (1983),
04-799000-46

Preface

The papers in this volume were presented at the Third Symposium on Semiconductor Processing held in San Jose, California on 7-10 February 1984. The symposium was sponsored by ASTM Committee F-1 on Electronics, and co-sponsored by National Bureau of Standards, Semiconductor Equipment & Materials Institute and Stanford University Integrated Circuits Laboratory. In addition to the technical presentations, the symposium included well-attended workshops and panel discussions; impressions of these workshops and panel discussions are provided in appendices I-III.

The symposium addressed new problems in semiconductor technology for the mid 80's which arise from the rapid increases in device complexity and performance, emergence of integrated systems on-a-chip, automated factories, and silicon foundries. The realization of acceptable yields and reliability in the face of these demands requires greater manufacturing discipline from starting materials to finished devices. The symposium theme was chosen to be Quality Through Measurement and Control.

The symposium opened with the talks on the role of ASTM in the electronics industry by William T. Cavanaugh, ASTM, and the impact of standards on semiconductor quality and manufacturing efficiency by W. Murray Bullis, Siltec Corporation. These presentations were followed by two keynote papers, one on the process and device modeling for VLSI structures by James D. Plummer, Stanford University and the other on the equipment requirements for the VLSI production by Wilmer R. Bottoms, Varian Associates. Both these papers described techniques and equipments needed to achieve the required functional yields in complex devices on an integrated circuit chip.

The opening general session included a discussion on the Cooperative Research among industry, academia and government. Brief summaries of activities at the Semiconductor Research Cooperative, Microelectronics Center of North Carolina, Stanford Center for Integrated Systems and the University of California at Berkeley were presented. A synopsis of the panel discussion in response to key questions from the audience is presented in appendix I.

Many other forums including the Fifth International Conference on Neutron Transmutation Doping and the

CHMT chapter of IEEE decided to meet with the Symposium.

The response to the symposium was extremely favorable once again. The involvement of industry, academia and government including the participation of foreign institutions confirmed a continued need for a regular forum to discuss technology topics in the context of measurement and control; a consistent theme which the Symposium established in 1982 evolving the understanding and control of the complex process technologies required for VLSI and other advanced device concepts.

The plans for the next symposium in 1986 in the series of symposia to be held at two-year intervals are underway. The problem areas and standardization needs identified in these symposia will provide the feedback to the research community and voluntary standards system essential for the future growth of the industry.

The cooperation and support of the ASTM staff in the formulation of these proceedings is appreciated. Finally, we are indebted to our industrial, government and university colleagues who contributed to the contents of the Symposium and the Proceedings.

San Jose, California.

Dinesh C. Gupta

Contents

Introduction	1
STANDARDS IN SEMICONDUCTOR INDUSTRY	
The Impact of Standards on Semiconductor Quality and Manufacturing Efficiency—W. MURRAY BULLIS	9
FABRICATION TECHNOLOGY	
Process and Device Modeling for VLSI Structures— JAMES D. PLUMMER	21
Effect of Process Conditions on Autodoping in Silicon Epitaxy— HSUEH-RONG CHANG	38
An Intrinsic Gettering Process to Improve Minority Carrier Lifetimes in MOS and Bipolar Silicon Epitaxial Technology— JOHN O. BORLAND, MAX KUO, JAMES SHIBLEY, BRUCE ROBERTS, ROLAND SCHINDLER, AND TERRY DALRYMPLE	49
Control of Gain Variations in Shallow Junction Ion Implanted Bipolar Transistors Caused by Planar Channelling— DAVID J. BAZLEY	63
Ion Implantation for Deep [$> 100\ \mu\text{m}$] Buried Layers— WOLFGANG R. FAHRNER, DIETER BRÄUNIG, MEINHARD KNOLL, AND JOACHIM R. LASCHINSKI	77
A Study of Strain in Ion Implanted Silicon—MASAYOSHI SASAKI AND KOUICHI SAKAMOTO	96
Dry Etching Using NF_3/Ar and NF_3/He Plasmas—JOHN BARKANIC, ANDREW HOFF, JOSEPH STACH, AND BOGDAN GOLJA	110
Edge-Controlled, Self-Consistent Proximity Effect Corrections— HARRY L. BERKOWITZ, CHARLES F. COOK, JR., JOSEPH H. KWIATKOWSKI, AND WAYNE M. GOODREAU	124

The Effect of Wafer Flatness on Yield by Off-Line Computer Simulation of the Photolithographic Process— LOUIS DENES	143
--	-----

CONTROL OF PARTICULATE CONTAMINATION

Forms of Contamination Affecting Device Processing— ANGELO C. RAPA	163
--	-----

Problems Associated with Submicrometre Contaminant Measurement— ALVIN LIEBERMAN	172
--	-----

Point-of-Use Ultrafiltration of Deionized Rinse Water and Effects on Microelectronics Device Quality— PETER W. GAUDET	184
--	-----

DEFECTS AND GETTERING TECHNIQUES

The Effects of Wafer Thermal History on the 450°C Thermal Donor Formation in Cz-Grown P(100) Silicon— JOHN OGAWA BORLAND	201
--	-----

Interaction Between Point Defects and Oxygen in Silicon— JOSEPH R. MONKOWSKI, DANIEL HECK, THOMAS A. BAGINKSI, DAVID KENNEY, AND RICHARD E. TRESSLER	219
---	-----

Effects of Oxygen on Process-Induced Defects and Gettering in Cz-Silicon— ROBERT B. SWAROOP	230
--	-----

Precipitation Behavior of Deposited Metals in Cz-Silicon— HISAAKI SUGA, YASUSHI SHIMANUKI, KOJI MURAI, AND KAZUYOSHI ENDO	241
--	-----

Evaluation of Gettering Efficiency of Backside Damage by the Use of the "Haze" Test— MARCELLO DOMENICI, GIANCARLO FERRERO, AND PAOLO MALINVERNI	257
---	-----

Extrinsic Gettering Via the Controlled Introduction of Misfit Dislocations— ALI S. M. SALIH, HYEONG J. KIM, ROBERT F. DAVIS, AND GEORGE A. ROZGONYI	272
---	-----

The Effect of Si-SiO₂ Interface on the Excess Point Defect Distribution in Silicon— YUN-SEUNG SHIN AND CHOONG-KI KIM	283
--	-----

MATERIAL AND PROCESS CHARACTERIZATION

Fracture Tracing in Semiconductor Wafers—LAWRENCE D. DYER	297
A Preferential Etch for Silicon Crystals—K. H. YANG	309
Oxygen Determination in Silicon Using Fourier Transform Infrared Spectroscopy—L. W. SHIVE AND B. K. SCHULTE	320
A Study of the Spatial Distribution of the Oxygen Content in Silicon Wafers Using an Infrared Transmission Microscope—KRISHNASWAMY KRISHNAN AND DONALD KUEHL	325
Influence of Electrically Active Impurities on IR Measurements of Interstitial Oxygen in Silicon—S. P. WEEKS	335
The Effects of Instrumental Artifacts on the Quantitative Determination of Oxygen in Silicon by FTIR—ASLAN BAGHDADI	343
Simultaneous Determination of the Boron and Phosphorus Content in Silicate Glasses by FTIR Spectroscopy—KRISHNASWAMY KRISHNAN	358
A Method to Determine the Initial Phosphorus and Boron Concentrations in Float-Zoned Polysilicon Rods—HERNG-DER CHIOU	364
The Effects of RF Electromagnetic Radiation on Spreading Resistance Measurements—ROBERT G. MAZUR	375
Dopant Profiling in Silicon—MAREK PAWLIK	390
Comparison of Depth Profiling of ^{10}B in Silicon Using Spreading Resistance Profiling, Secondary Ion Mass Spectrometry, and Neutron Depth Profiling—JAMES R. EHRSTEIN, R. GREGORY DOWNING, BRIAN R. STALLARD, DAVID S. SIMONS, AND RONALD F. FLEMING	409

INTERCONNECTION TECHNOLOGY: WIRE AND TAPE BONDING

The Ball Bond Shear Test: Its Methodology and Application—HARRY K. CHARLES, JR., GUY V. CLATTERBAUGH, AND JOEL A. WEINER	429
---	-----

The Annealing and Low Temperature Aging Characteristics of Fine Diameter Wire Produced from Dilute Aluminum Alloys— DAVID F. HEBERT	458
Capacitive Microphone Tuning of Ultrasonic/Thermosonic Bonders— WILLIAM L. LOOFBOURROW	472
A Comparative Study of the Mechanical Properties of Bonding Wire— S. P. HANNULA, J. WANAGEL, AND C. Y. LI	485
New Applications of Tape Bonding for High Lead Count Devices— JAMES F. MARSHALL AND ROBERT P. SHEPPARD	500
Bumped Tape Processing and Application— FRANK A. LINDBERG	512
 NEUTRON TRANSMUTATION DOPING TECHNIQUES AND FACILITIES	
Production and Development of Neutron Transmutation Doped Silicon— HEINZ HERZER	533
Production of Detector-Grade Silicon by Neutron Transmutation Doping— WILFRIED VON AMMON AND J. KEMMER	546
Neutron Transmutation Doping in Hydrogenated Amorphous Silicon— H. HAMANAKA, K. KURIYAMA, M. YAHAGI, K. IWAMURA, C. KIM, F. SHIRAISHI, K. TSUJI, AND S. MINOMURA	558
Effects of Hydrogen on Defects in Neutron Irradiated Silicon— YONGCHANG DU, YUFENG ZHANG, AND XIANGTI MENG	566
Neutron Transmutation Doping of Semi-Insulating Czochralski-Grown GaAs— ANDREW T. HUNTER, MARY H. YOUNG, HARVEY V. WINSTON, OGDEN J. MARSH, AND RON R. HART	575
Ion Channeling Study of Damage in Neutron Transmutation Doped Semiconductors: Application to GaAs— M. YAHAGI, M. SATOH, K. KURIYAMA, K. IWAMURA, C. KIM, AND F. SHIRAISHI	587
A New Silicon Irradiation Facility in the PLUTO MTR at Harwell— J. BAXTER AND N. W. CRICK	595

Equalization of Axial Neutron Flux Density for the Transmutation Doping of Silicon in a Heavy Water Reactor— KIRSTEN ANDRESEN, KAJ HEYDORN, AND ERIK NONBØL	605
Potential for Large-Diameter NTD Silicon Production in the Advanced Test Reactor—J. STEPHEN HERRING AND ROBERT E. KORENKE	615
Advanced Test Reactor NTD Silicon Production Hardware— MARK J. SCHELL	628

APPENDIXES

Appendix I—Panel Discussions Cooperative Research Programs	647
Appendix II—Workshop Sessions Control of Contaminants Interconnection Technology	654 655
Appendix III—Panel Discussions Material and Process Induced Defects Ion Implantation Advanced Lithographic Technology	657 660 662
Index	665

ISBN 0-8031-0403-0