AVAILABILITY NOTICE

Qualified requesters may obtain copies from the Defense Documentation Center (TISIR), Cameron Station, Alexandria, Va., 22314. Other requesters may order copies from the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151.

Responsibility for the contents of papers presented at the Symposium and published herein rests solely upon the authors and not upon RADC or IIT.

Physics of Failure in Electronics

Volume 4

Reliability Series

Edited by

M.E. Goldberg
IIT Research Institute

and

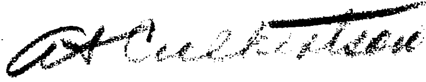
Joseph Vaccaro
Rome Air Development Center
USAF

RADC SERIES IN RELIABILITY

Distribution of this document is unlimited

AIR FORCE, Cato Show Prtg. Co. - 7/22/66 - 1253

These proceedings are approved for publication as a part of the RADC Reliability Series.



A. T. CULBERTSON
Brig. Gen. USAF
Commander

PREFACE

This volume contains the proceedings of the 1965 Symposium on the Physics of Failure in Electronics, held at the Illinois Institute of Technology in Chicago on 16-18 November 1965. This is the fourth of an annual series of symposia jointly sponsored by the Rome Air Development Center and the IIT Research Institute.

The purpose of the meeting was to exchange information on fundamental physical and chemical processes which contribute to degradation, aging, and failure of electronic parts and materials. Emphasis was placed on the application of this information to the problems of reliability control, measurement, prediction, and improvement.

Introductory remarks were made at the opening session by G. T. Jacobi, on behalf of the IIT Research Institute, followed by an opening address given by Brig. Gen. A. T. Culbertson, Commander, Rome Air Development Center, USAF. The symposium luncheon address was delivered by Dr. Thomas P. Cheatham, Jr., Deputy Director of Defense Research and Engineering.

Papers were presented at six half-day sessions as follows: Session I - Interconnections; Session II - Test, Analysis, and Correlation; Session III - Device Physics; Session IV - Surface Effects; Session V - Bulk Effects; Session VI - Minuteman II CQAP Program. Session VI was co-sponsored by the Ballistic Systems Division, USAF. Included in this volume are also a number of standby papers which were not presented at the symposium.

The symposium co-chairmen were:

Morton E. Goldberg
IIT Research Institute

Joseph M. Schramp
Rome Air Development Center, USAF

Session moderators were:

N. M. Parikh
IIT Research Institute

J. Vaccaro
Rome Air Development Center, USAF

W. C. Dunlap
NASA, ERC, Cambridge, Massachusetts

P. Handler
University of Illinois, Urbana, Illinois

A. Tamburrino
Rome Air Development Center, USAF

D. F. Barber
Rome Air Development Center, USAF

Dr. J. S. Burgess, RADC, and Mr. J. D. Meindl, USAEC, scheduled as session moderators, did not attend.

The editors would like to acknowledge the assistance of Mrs. Margaret L. Warner in reading and correcting proofs.

M. E. GOLDBERG

J. VACCARO

TABLE OF CONTENTS

Contents *Page*

Opening Address – Brig. Gen. A. T. Culbertson, USAF xiii

SECTION I – INTERCONNECTIONS

Reliability Phenomena in Aluminum Metalizations on Silicon Dioxide 1
W.M. Berger
R.S. Keen
G.L. Schnable

The Role of Metallography in the Analysis of Failures of Electronic Components 32
William C. Coons

Analysis of Seven Semiconductor Metallurgy Systems Used on Silicon Planar Transistors 46
William H. Gianelle

SECTION II – TEST, ANALYSIS, AND CORRELATION

A Technique for Controllable Acceleration and Prediction of Degradation Mechanisms of Electronic Parts 59
T. Walsh
M. Rocci

Cumulative Degradation Model and its Application to Component Life Estimation 74
Hiroshi Shiomi

The Application of Failure Analysis in Procuring and Screening of Integrated Circuits 95
Jayne Partridge
Eldon C. Hall
L. David Hanley

Life Predictions of Diffused Germanium Transistors by Means of Power Stress 140
W.C. Gibson

TABLE OF CONTENTS (CONT)

Contents *Page*

Failure Mechanisms of Electronic Components 156
H.F. Church
B.C. Roberts

Accelerated Aging and Failure Mechanism Analysis of Thin Tantalum Film R-C Networks 179
A. McKelvey
G. Schnable
M. Sharp
M. Walker

SECTION III – DEVICE PHYSICS

A Transient Component in the Breakdown Voltage of Silicon P-N Junction Rectifiers 211
H.C. Gorton

Elimination of Forward–Biased Second Breakdown by Resistive Ballasting of Silicon Power Transistors 227
Daniel Stolnitz

Failure of Large–Area Epitaxial–Diffused Silicon Devices 242
T.L. Chu
P.J. Kannam

A Limitation to the Step Stress Testing Concept for Integrated Circuits 258
W. Shurtleff
W. Workman

Thermophysics of Silicon Power Transistors 279
David A. Peterman

SECTION IV – SURFACE EFFECTS

Accumulation and Decay of Mobile Surface Charges on Insulating Layers and Relationship to Reliability of Silicon Devices 291
W. Schroen

TABLE OF CONTENTS (CONT)

Contents *Page*

Mechanisms of Channel Current Formation in Silicon P-N Junctions 315
D.J. Fitzgerald
A.S. Grove

Effect of Ambient on Breakdown of Silicon P-N Junctions 333
John F. Carroll

Surface Leakage of Dielectrics 345
L. Fedotowsky
P. Ho
K. Lehovec

A Simple Technique for the Direct Observation of Temperature Distribution in Microelectronic Structures 354
Donald W. Howarth

SECTION V – BULK EFFECTS

The Role of Microdefects in Silicon Starting Materials as Quality Reducing Factors in Semiconductor Devices 367
J.W. Faust, Jr.
H.F. John
R. Stickler

Structural Defects and Junction Characteristics in Silicon Transistors 379
E.D. Jungbluth
P. Wang

The Effect of Phosphorus Diffusion in Thermal Oxides on the Elevated Temperature Stability of MOS Structures 390
H.G. Carlson
G.A. Brown
C.R. Fuller
J. Osborne

Radiochemical Study on Lateral Ion Migration in Insulating Substrates for Thin Film Microcircuits 408
S.S. Choi

Contents | *Page*

SECTION VI – MINUTEMAN II CQAP PROGRAM

Opening Remarks – Minuteman II, Physics of Failure Program 423
J.F. Wiesner, Capt., USAF

Failure Mechanisms Associated with Thermocompression Bonds in Integrated Circuits 428
G.V. Browning
L.E. Colteryahn
D.G. Cummings

Failure Mechanisms Associated with Thermally Induced Mechanical Stress in Minuteman Devices 447
C.G. Jennings

Properties of Plastic Materials and How They Relate to Device Failure Mechanisms 464
S.M. Lee
J.J. Licari
A. Valles

Investigation of Surface Failure Mechanisms in Semiconductor Devices by Envelope Ambient Studies 493
G.V. Brandewie
P.H. Eisenberg
R.A. Meyer

Imperfections and Impurities in Silicon Associated with Device Surface Failure Mechanisms 522
J.E. Forrester
R.E. Harris
J.E. Meinhard
R.L. Nolder

Design and Process Contribution to Inherent Failure Mechanisms of Microminiature Electronic Components for Minuteman II 561
A.J. Borofsky
D.C. Fleming

Contents | *Page*

SECTION VII – PAPERS NOT PRESENTED AT SYMPOSIUM

Selective Chromate Conversion of Integrated Circuit Interconnecting Aluminization 597
D.A. Abdo

Hot Spot Mesoplasma Formation in Silicon Planar Transistors 609
E.B. Hakim

Failure Mechanisms Associated with Die–To–Header Bonds of Planar Transistors 620
J.D. Guttenplan
F.H. Stuckenberg