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END-OF-THE-YEAR REPORT

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENTS REPORT

for

Grant or Contract N000014-87-K-0211

R&T Code 413h004

Encapsulation and Packaging of Integrated Circuits

David S. Soane
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Submitted on May 5, 1990

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Part I

a. Papers Submitted to Refereed Journals

1. A few are being written when student Rolf Biernath graduates and will be submitted in the summer of 1990.

b. Papers Published in Refereed Journals

Characterization of Stresses in Polymer Films for Microelectronics Applications, in Polymeric Materials for Electronic Packaging and Interconnection, ACS Symposium Series, 407, 356 (1989) (with R.W. Biernath).

Water Sorption in Epoxy Thin Films, IEEE-CHMT, 12, 373 (1989) (with M.G. McMaster).

c. Books Submitted for Publication

None.

d. Books Published

None

e. Technical Reports Published

1. ONR Technical Reports

A few will be circulated in the summer 1990.

2. Characterization and Curing of Microelectronics Encapsulants, PMSE, 59, 647 (1988) (with R.W. Biernath).
3. Stress and Dielectric Characterization of Thermosets for Microelectronics Interconnection and Encapsulation, Polymers for Microelectronics - Science and Technology, p. 104, 1989 (with R.W. Biernath).
4. Stress in Thin Films for Microelectronics and Other High Technology Applications, Chem. Eng. Progress, 86, 28 (1990).
5. Stress and Dielectric Characterization of Thermosets for Microelectronics Interconnection and Encapsulation, to appear in Symposium Volume on Polymers for Microelectronics, 89, Japan (with R.W. Biernath).

f. Patents Filed - None.

g. Patents Granted - None.

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h. Invited Presentations at Topical or Scientific/Technical Society Conferences ,

1. "Processing and Characteristics of Thin Film Thermosets for Microelectronics Applications," 3rd International Conference on Crosslinked Polymers, Lucerne, Switzerland, May, 1989.
2. "Dynamic Microdielectric Monitoring of Epoxy/Phenolic Cure," 3rd International SAMPE Electronics Conference, Los Angeles, CA, June, 1989.
3. "Stress and Dielectric Characterization of Thermosets for Microelectronics Interconnection and Encapsulation," PME 89, Tokyo, Japan, November, 1989.
4. "Stress, Dielectric, and Nonlinear Optical Characterization of Thermosets for Microelectronics Interconnection and Encapsulation," Hitachi Satellite Conference, Tokyo, Japan, November, 1989.

i. Contributed Presentations at Topical or Scientific/Technical Society Conferences

None.

j. Honors/Awards/Prizes ,

None.

k. Number of Graduate Students Receiving Full or Partial Support on ONR Grant or Contract (Total: 3, Minorities: 1, Asian: 1) ,

1. R.W. Biernath (will graduate in the summer of 1990, then work for 3M)
2. R.K. Yonkoski
3. J.Y. Chee (1st year student)

l. Number of Postdoctoral Fellows Receiving Full or Partial Support on ONR Grant or Contract (Total: 1, Minorities: 1, Asian: 1) *and*

1. J.Y. Zhang (Second harmonic generation study of metal corrosion on polyimide surfaces)

m. Other Funding , *26-4*

The work by J.Y. Zhang is in collaboration with Digital Equipment Corporation. We are receiving a total of \$60K for two years, beginning July 1, 89 ending June 30, 91.

Part II.**a. Principal Investigator**

David S. Soane

b. Current Telephone Number

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c. Cognizant ONR Scientific Officer

Kenneth J. Wynne

d. Brief Description of Project

High-temperature organic thermosetting polymers have found wide use as interlayer dielectrics and chip passivants/encapsulants. However, stress-induced failure is a critical issue where much material design and improvements are needed. Such refinement is being pursued via a firm understanding of factors contributing to stress generation, including epoxy chemistry. We have recently concentrated on the system, epoxy novolac cured by phenol and catalyzed by triphenyl phosphine. The stoichiometry and functionality of epoxy and phenol have been altered, so final thermoset network has different stress states. We have successfully correlated and modeled the network stress behavior.

Two stress measurement devices based on interferometry and bending beam principles have been developed to determine the effects of chemical modification, curing schedule variation, and method of deposition on the thermoelastic stresses in composite structures. Data thus obtained form the foundation for model development to achieve quantitative predictive abilities. Hermeticity and dielectric properties of the modified encapsulants are being measured by a high-frequency ac network analyzer, Eumetrics d.c. conductivity dielectrometer, and a Cahn microbalance. The overall goal of this work is to develop new materials and processing strategies for high density interconnection and packaging of integrated circuits. In a new effort, metal deposited on polyimide is probed by a YAG laser in a high vacuum chamber. This technique allows metal diffusion into the underlying polymer and metal oxidation on the surface to be monitored.

e. Significant Results During Last Year

1. Completion of data collection and correlation of epoxy cure with phenol and triphenyl phosphine.
2. Completion of quantitative thermoplastic and thermosetting film stress model, and use of such model for comparison of experimental data and property prediction.
3. Successful data correlation of DSC and microdielectrometry on curing systems.

4. Beginning of stress evolution study on latest polyimides.
5. Beginning of second harmonic generation study of metal on polyimides.
6. Formulation of improved planarization ideas for polyimides as interlayer dielectrics.

f. Plans for Next Year

We would like to continue this project, especially along the directions specified above as items 4-6. This will depend on our ability of obtaining renewal of this project.

- g. R.W. Biernath (will graduate in the summer of 1990, then work for 3M)
R.K. Yonkoski
J.Y. Chee (1st year student)
J.Y. Zhang (Second harmonic generation study of metal corrosion on polyimide surfaces)

Project: **Encapsulation and Packaging of Integrated Circuits**

Research Team: **David S. Soane (P.I.)
Rolf W. Blernath
Jo Ann Y. Chee
Roger K. Yonkoski
Jing Y. Zhang
Department of Chemical Engineering
University of California at Berkeley
Berkeley, CA 94720**

Objectives: **Stress in Thin Film Thermosets for
Microelectronics Interlayer Dielectrics
and Encapsulants**

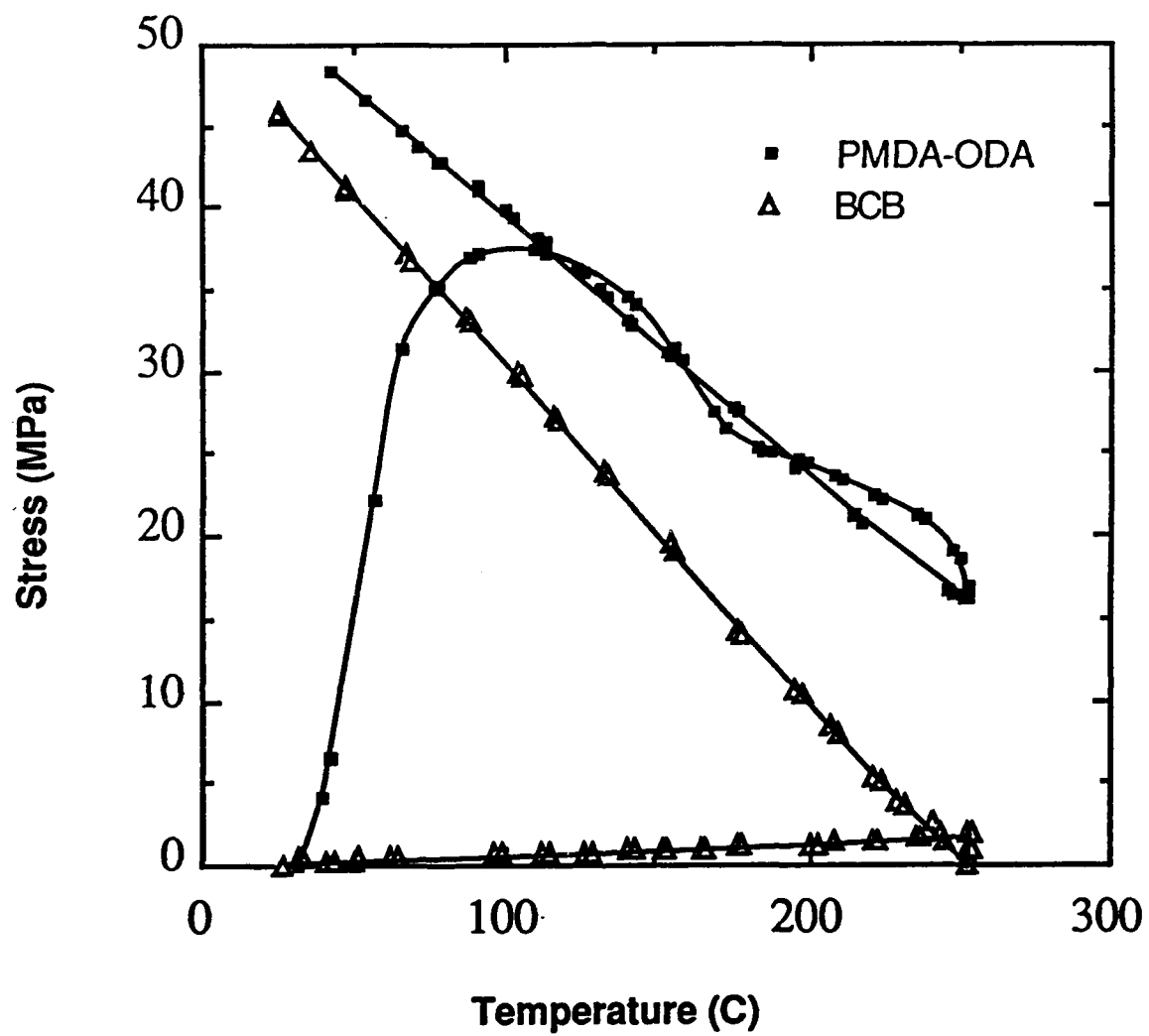
**Moisture Uptake, Interfacial Delamination
and Water Accumulation, Stress Enhancement
of Interface Debonding**

Dielectric Property Evolution During Cure

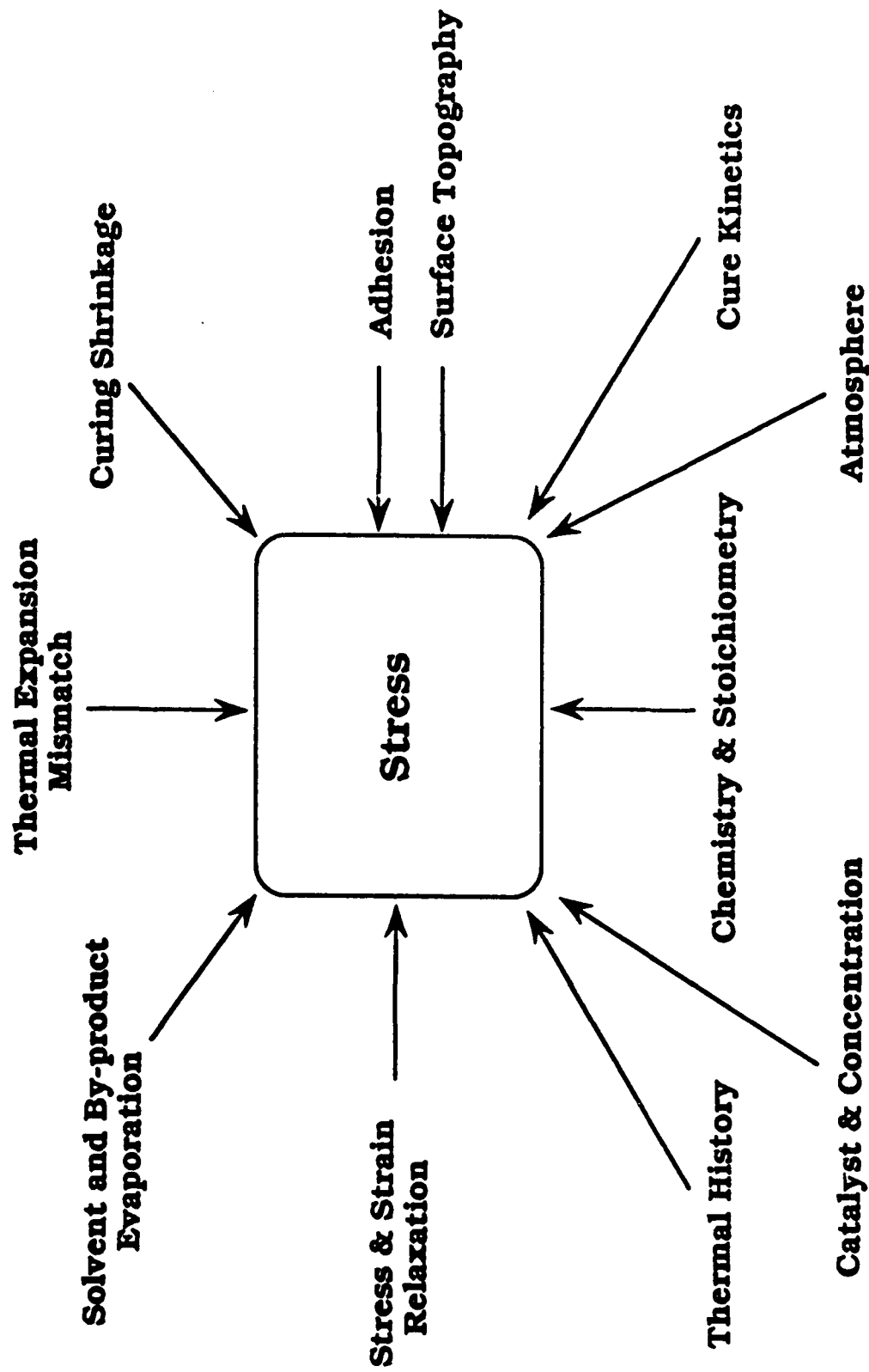
**Production of Stress-Free Microstructures for
VSLI**

Planarization of Substrate Topography

**Metal Adhesion and Oxidation on Polyimide
Thin Films**



Sources of Stress and Material / Processing Variables



Explanatory Notes

Viewgraph One gives the program title, research team composition, and current emphases for our work. This project seeks to establish quantitatively the various factors contributing to microelectronics reliability. Of particular interest is the role of stress in high temperature polymeric dielectrics and the influence of curing chemistry and processing. We focus on epoxies and polyimides. Experimental systems have been constructed to monitor stress evolution in thin films cast from such materials. We also correlate stress generation with interfacial accumulation of moisture and film delamination. Both stress and moisture uptake are critical considerations for current and future generations of microelectronics interconnection and encapsulation. Viewgraph Two shows stress traces of Kapton as compared with BCB (Benzocyclobutene) under identical processing conditions. The stress profiles are distinctly different due to the chain-like nature of polyamic acid and the monomeric state of BCB in the casting solution. Viewgraph Three summarizes all the factors studied in this project contributing to stress in thin films. A list of primary conclusions is also given.