ADVANCES IN CERAMICS • VOLUME 26

CERAMIC SUBSTRATES AND PACKAGES FOR ELECTRONIC APPLICATIONS

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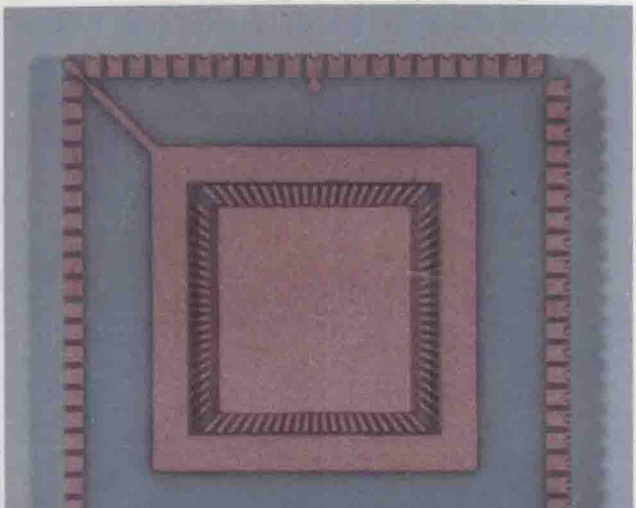

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The American Ceramic Society, Inc.
Westerville, Ohio

Proceedings of the International Symposium on Ceramic Substrates and Packages, sponsored by the Electronics Division of the American Cramic Society and the Ceramic Society of Japan, held in Denver, CO, on October 18–21, 1987.

On the cover: Cu 84 leadless chip carrier. (See pp. 229–238 for description.)

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Foreword

Recently, there has been a significant interest in ceramic substrates and packages for electronics applications. Many research activities in these areas are found in both industry and academia throughout the industrial world. Having recognized this trend, the program committees of the Electronics Divisions of the American Ceramic Society and the Ceramic Society of Japan investigated the feasibility of co-sponsoring a meeting on this topic. The result was the International Symposium on Ceramic Substrates and Packages which took place during the 1987 Fall Meeting of the Electronics Division of the American Ceramic Society. The Symposium was held in Denver, Colorado, on October 18–21, 1987. Proceedings of this symposium are published in this volume of Advances in Ceramics.

The timeliness and contined interest in this symposium was attested to by the total of 67 contributed and invited papers, which were scheduled into a total of 8 sessions during the Fall meeting. Of these papers, 50 were submitted and accepted for publication in this volume. Each of these papers has been reviewed by two reviewers prior to acceptance for publication.

An overview paper by R. R. Tummala provides an excellent introduction to applications in electronic and information industries. Recent advances in covalent ceramics for electronic applications are demonstrated by the fifteen papers in this volume. A significant interest has been shown in the research and development of new low temperature firing ceramic compositions for novel applications. Processing and characterization of ceramics with low dielectric constants provide one of the most fruitful areas in material research. A special section in this volume is devoted to substrates and packages for electronic microwave applications. Innovation and basic research in ceramic processing remain one of the most important topic areas and they are highlighted by several papers in this volume.

It is clear that there is increasing interest with regard to new materials, novel applications, structural and property characterizations, and processing innovations. We hope that this volume will prove useful to current and future practitioners who make and use ceramic substrates and packages.

The success of this volume is a result of many people. The symposium program committee was chaired by Man Yan and other committee members were Roger Cannon, James Keski, Koichi Niwa, Henry O'Bryan, David Wirth, and Wayne Young. We acknowledge the contribution of Mani Nair, John Thomson, and some of the program committee members in serving as session chairs at the symposium. Manuscripts submitted for the proceedings were reviewed by Alan Bleir, John Blum, Robert Bouchard, Relva Buchanan, Daniel Button, Roger Cannon, Rajen Chanchani, David Chang, Ye Chou, Rosairo Gerhardt, John Halloran, Shin-Ichi Hirano, Basavaraj Hiremath, James Humenik, Kimio Inoue, Manfred Kahn, Hung Ling, David Marchant, Mani

Nair, Koichi Niwa, Michael Notis, Henry O'Bryan, Terry Ring, William Robbins, Michael Sacks, Daniel Shanefield, Vishwa Shukla, Harold Stetson, John Thomson, David Wirth, Man Yan, and Wayne Young. Furthermore, we acknowledge the effort of John Blum, Shin-Ichi Hirano, David Johnson, Lionel Levinson, Masanari Mikoda, and William Robbins in coordinating the co-sponsorship of the American Ceramic Society and the Ceramic Society of Japan. We also thank Jan Graham and Bill Douglas in managing the symposium and Su Yan in coordinating the correspondence with the authors and reviews. Their help is sincerely appreciated.

Man F. Yan
Henry M. O'Bryan, Jr.
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Section I
OVERVIEW

Ceramics in Microelectronic Packaging

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A broad review of ceramics in microelectronics for processing, storing, transferring, printing, and displaying information is highlighted. Emphasis is on ceramic packaging, with a review of history, evolution, and state-of-the-art. Recent developments in ceramics that have resulted in potentially improved thermal and electrical properties through the use of SiC, AlN, and glass + ceramics are also discussed, and the scientific understanding necessary to support these developments is mentioned.

Ceramics—defined as inorganic and nonmetallic materials, including glasses—have been an integral part of the information-processing industry. In the form of semiconductor devices interconnected onto packages, ceramics are used for data processing. Ceramics also make it possible to 1) store information, by the use of such magnetic materials as iron and chromium oxides and ferrites; 2) display information, using low-temperature solder glasses sealed to transparent faceplate glasses; 3) print information, using ceramic-metal print heads and corrosion-resistant glasses; and 4) transfer information, by the use of very low-loss glass fibers. The materials currently used for these applications are shown in Table I.

Packaging remains the most important application of ceramics in microelectronics. Ceramic materials in the form of dual-in-line packages, chip carriers, and pin grid arrays are used throughout the industry, in everything from consumer electronics to mainframe computers. Ceramic packages constitute roughly two-thirds of the total packaging market, currently a multibillion-dollar industry. Ceramics possess a combination of electrical, thermal, mechanical, and dimensional properties unmatched by any other group of materials; for example, ceramics have dielectric constants ranging from 4 to 10 000, thermal expansion coefficients matching that of silicon ($30 \times 10^{-7}/°C$) or copper ($170 \times 10^{-7}/°C$), and thermal conductivities that range from matching that of one of the best insulators to exceeding that of aluminum metal (220 $W/m \cdot K$), one of the best thermal conductors known. Recent technological breakthroughs have opened the doors for ceramics as superconductors, which provide no electrical resistance to current flow. Another desirable property of ceramic substrates is their high-temperature stability. Where hermeticity is required, ceramic packages are often the only choice.

On the other hand, ceramic packages suffer from three main drawbacks.

1. They require higher processing temperatures than do plastics, making them more expensive.

Table I. Application of Ceramics in Microelectronics

Information Technology	Application	Ceramic Materials
Processing		
Package	Substrate	Al_2O_3, BeO, SiC, AlN
Device	Dielectric	Si_3N_4, SiO_2
	Mask	Borosilicate glasses
Storage	Disk	Iron oxide, ferrite
	Tape	Chrome oxide
	Head	Ferrites, glass
		Al_2O_3 + TiC substrate
Display	Dielectric	Lead borosilicate glass
	Seal	Lead zinc borosilicate glass
	Face plate	Soda-lime glass
Printing	Ink jet	ZrO_2-containing glass
	Electroerosion	Ceramic-metal composites
Transfer	Optical fiber	SiO_2, B_2O_3–SiO_2

2. Ceramics are brittle, thus prone to catastrophic failure and sensitive to stress corrosion.
3. In very high-performance applications requiring very low dielectric constants and high packaging densities, ceramics cannot compete with thin-film organic packages.

Nonetheless, ceramics are expected to be the stable building blocks on which high-performance thin-film wiring can be developed, with the use of polymeric materials for high-performance applications.

Ceramic packages are offered in a variety of materials and in such forms as dual-in-line packages (DIP), chip carriers, flat-packs, and pin grid arrays capable of supporting from one to as many as one hundred or more chips per package.

Early Ceramic Packaging

The initial TO (transistor outline) package was developed with as many as 14 leads, until the need for many more leads in the 1960s led to the development of rectangular ceramic packages, known as dual-in-line, or planar, packages, with up to 64 leads on 2 opposite sides.

Solid Logic Technology (SLT)

At about the same time IBM introduced, for its own use, a ceramic package[1] called SLT (Solid Logic Technology) that measured 12 by 12 mm and was made of 96% alumina on which conductors and resistor pastes were screened and fired at ≈800°C. Sixteen connector pins of copper were swaged into the holes in the substrate, and the entire assembly was immersed in a solder bath to coat the conductors and pins, forming electrical contacts between pins and conductor lines. Semiconductor chips were soldered into place and the cap sealed to the module with epoxy, as shown in Fig. 1.

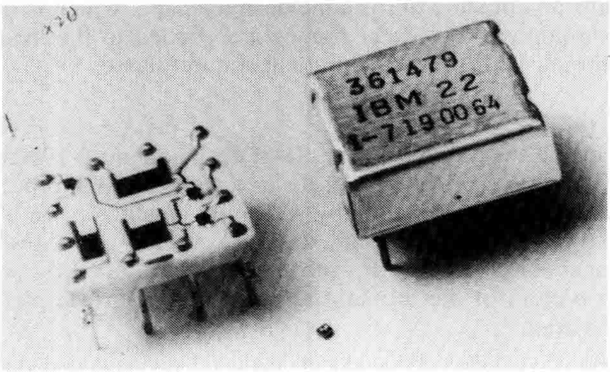

Fig. 1. SLT package.

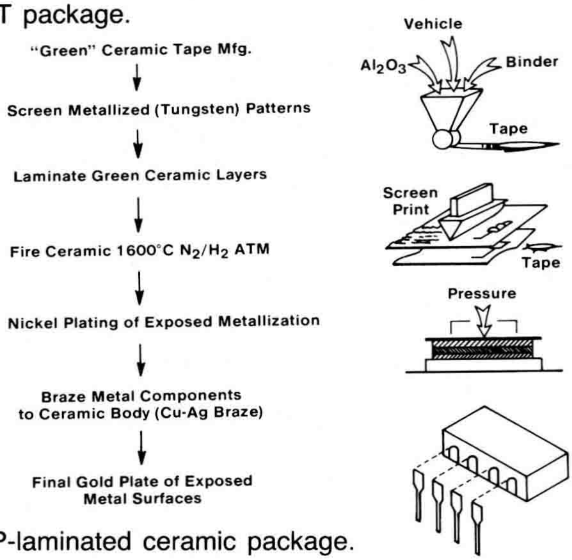

Fig. 2. DIP-laminated ceramic package.

Ceramic Dual-In-Line (DIP) Packages

The availability of DIP and the ease with which it can be automatically inserted into the holes of printed circuit board and soldered into place made it an industry standard. Ceramic DIPs were fabricated using either ceramic green sheets or dry-pressing processes (Fig. 2.). In either process, the maximum number of leads fabricated for DIP has been 64.

The tape process involves forming a slurry of well-dispersed alumina and glass in a suitable organic vehicle and doctor-blading to form tape, which is metalized with a tungsten-metal paste. The desired number of layers is laminated and sintered in a controlled atmosphere between 1500° and 1600°C. Exposed metalizations are nickel- and gold-plated and then brazed with a Cusil* alloy.

Pressed ceramic, as the name implies, involves molding a mixture of

*Cusil, GTE Products Corp. Wesgo Div., Belmont, CA.