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Wire-Bond Electrical Connections: Testing, Fabrication and Degradation—

A Bibliography 1957–1971

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

More than 245 papers relevant to wire-bond type electrical interconnections used in microelectronic and low-power discrete and hybrid devices are listed together with key words. The bibliographic search concentrated on compiling papers which appeared in the period from 1965 to 1970, inclusive. The selection of papers was generally limited to those that were pertinent to wire-bonds where the wire diameter is less than about 50μm (2 mils) and where the wire is bonded by either thermocompressive or ultrasonic means. Two indexes are provided: (1) an Author Index and (2) a Key Word Index. The latter includes a tabulation of the literature citations.

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Wire-Bond Electrical Connections: Testing, Fabrication and Degradation— A Bibliography 1957-1971

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Wire-Bond Electrical Connections: Testing, Fabrication and Degradation – A Bibliography 1957-1971

Harry A. Schafft

More than 245 papers relevant to wire-bond type electrical interconnections used in microelectronic and low-power discrete and hybrid devices are listed together with key words. The bibliographic search concentrated on compiling papers which appeared in the period from 1965 to 1970, inclusive. The selection of papers was generally limited to those that were pertinent to wire bonds where the wire diameter is less than about 50 μm (2 mils) and where the wire is bonded by either thermocompressive or ultrasonic means. Two indexes are provided: (1) an Author Index and (2) a Key Word Index. The latter includes a tabulation of the literature citations.

Key Words: bibliography; degradation (wire bond); discrete devices; electrical interconnection; fabrication (wire bond); failure (wire bond); hybrid circuits, integrated circuits; microelectronics; reliability; testing (wire bond); wire bond.

1. Introduction

Small-diameter (< 50 μm) wire is the principal means of making electrical connections (1) between the semiconductor die and the terminals leading outside the package of microelectronic and low-power discrete and hybrid devices, and (2) between different dice on a single device header of hybrid circuits. This *electrical interconnection* or *wire-bond*,* as it will be referred to here, is considered to be the wire between two bonded points, the bonds, the bonding surface films, and the underlying material in the immediate vicinity of the bonds. *Failure* of a wire bond is one of the principal failure modes in these devices. As a result, great importance has been attached to the following three subject areas: (1) methods for testing and evaluating wire bonds, (2) optimization of the fabrication processes for making wire bonds, and (3) mechanisms of degradation and failure of wire bonds.

This bibliography is a *compilation* of more than 245 published articles, U. S. government reports, U. S. patents, and conference presentations relevant to wire bonds in these three subject areas of testing, fabrication, and degradation.

The *selection of papers* is generally limited to those that are pertinent to wire bonds that have wire diameters of less than about 50 μm (2 mils) and are bonded by either thermocompressive or ultrasonic means. This is the class of wire bonds that is of most interest in microelectronics. An attempt was made to make the collection of papers on test and evaluation methods complete while the collection of articles in the area of fabrication and degradation is meant to be representative. Some interesting papers could not be included because of restrictions on their distribution. It is quite possible that some papers which should have been included were overlooked. The compiler would appreciate having such omissions called to his attention.

Acknowledgement

The author is pleased to acknowledge the significant contributions made by Elaine C. W. Cohen who assisted in collecting much of the material and performed both expeditiously and cheerfully many of the tedious labors that the compilation of such a bibliography requires. Thanks also go out to Kathryn O. Leedy, Frank R. Kelly, Terry A. Schultz and especially to Ruth E. Joel for assisting in various stages of the preparation of the bibliography; to Kaye E. Dodson for typing the final draft with such dispatch; and to W. Murray Bullis, Frank F. Oettinger, and George J. Rogers for their assistance with various aspects of the format.

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* Certain words or phrases are printed in script to assist in scanning.

2. Bibliography Format, In Brief

The two entries shown on the next page are used to indicate the various elements of the format which are encircled and numbered. The numbers refer to the explanatory notes listed below. A more complete description of the organization and format is given in Appendices A thru D.

Explanatory Notes:

1. *Identification code* for entry. The first two digits give the year of publication; the letter is the initial of the first author's surname; the last digit serves to distinguish entries which have the same first three alphanumerics. Entries are arranged in the bibliography (pp. 21-48) according to these codes.

2. *Author(s)*, editor(s), or organization (if no name(s) are provided). For *Author Index*, see page 4.

3. *First-level key word*† for general subject area. First-level key words are capitalized for identification purposes.

4. *Descriptors*†† to identify the kind(s) of wire bond(s) pertinent to or described under the subject of the first-level key word (in this example, DEGRADATION).

5. *Second-level key word*† to narrow the subject area of the first-level key word above it (in this example Mechanism modifies DEGRADATION). The first letter of a second-level key word is capitalized.

6. *Third-level key word*† to modify the second-level key word at its left (in this example intermetallics modifies Mechanism). All the letters are in lower-case. Some third-level key words include words in parentheses.

7. *Order* of first-level key words for subject area indicates the relative emphasis or importance given the respective areas in the entry. In this example, the main subject is degradation with test and fabrication following in that order.

8. *First-level key word* indicating approach or type of entry. Only one such key word is used per entry and it is listed last.

9. *Reading priority* is suggested by underlining the identification code and the appropriate key word(s) of those entries that are of such relative importance in a particular area that they should be seen first. The codes for these entries are also underlined in Section 4B (pp. 12-20).

10. *Title*

11. *Source.* See Appendix B (p. 49) and Table 1 (p. 50) for sources used. See Table 2 (p. 51) for *abbreviations* used for journals and conferences.

12. *Availability note* refers to an address listed in the Appendix. If the number is in brackets the address is one to which an order may be placed for a copy of the entry; if it is in parentheses the address is that of the first author's place of work at the time of publication.

13. *Availability note.* When the report citation is followed by a number preceded by the letters AD or PB, or by the letter N, the report is available from the National Technical Information Service (NTIS), Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151 by using this NTIS accession number when ordering.

14. In some entries, additional *guidance* is provided in brackets. For example, reference may be made to the pages in the paper that are relevant to the subject.

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† The three levels of *key words* indicating subject area are listed in alphabetical order in Section 4A (pp. 8-11). Page numbers are provided to assist in locating these key words in Section 4B (pp. 12-20) where they are ordered by subject: test, fabrication, and degradation. With each key word in Section 4B is a tabulation of literature citations (using their identification codes). In both *Sections 4A and 4B*, each key word that may require additional definition is followed by an *explanatory phrase in brackets*. An exception is made for the test method key words. Key words for the test methods are listed in alphabetical order in *Table 4* (p. 54) with a brief description for each method. The descriptions are oriented to their function in testing wire bonds.

†† *Descriptors* are listed in Section 4B (pp. 12-20) with a tabulation of literature citations.

1 — 67P1 Parker, C. D.
INTEGRATED SILICON DEVICE TECHNOLOGY
2 — VOLUME XV RELIABILITY — 10
Contract No. AF 33(615)-8306,
May 1967. AD 655082 [see pp. 35-65] — 14
3 — DEGRADATION-bond: TC, US; wire: Al, Au;
film: Al, Au, Au/Mo; substrate: FeNiCo,
Si — 13
Stress: process; thermal
Part: bond
5 — Mechanism: contamination; intermetallics — 6
Failure Rates
7 — TEST
Screening Procedures
FABRICATION-bond: TC, US; wire: Au, Al;
film: Ag, Ag/Cr, Al, Au, Au/Mo;
substrate: Si
Evaluation: metal systems; metallization; wire
Procedure
8 — REVIEW

9 — 68A3 Anderson, J. H., Jr. and W. P. Cox
AGING EFFECTS IN AU-AL AND AL-AL
BONDS USED IN MICROELECTRONICS
Proc. 7th Annual Reliability and
Maintainability Conf., pp. 533-536, — 11
San Francisco, Calif., July 1968.
[7], (21) — 12
DEGRADATION-bond: TC, US; wire: Al, Au; film:
Al — 4
Stress: thermal
Part: wire; bond
Mechanism: anneal, intermetallics
Test: pull; resistance
FABRICATION-bond: TC; wire: Au; film: Al
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Wrench, G. D., 68H3
Wright, L. G., 69U2

Young, J. G., 66C2

4. Key Word Index Introduction

The three levels of key words indicating subject area are listed in alphabetical order in Section 4A with page numbers where they are located in section 4B. In section 4B these key words and descriptors are listed by the three subject areas: test, fabrication, and degradation. By each key word and descriptor is a tabulation of identification codes of entries to which this key word or descriptor was assigned in the bibliography. Key words and descriptors that may require additional definition are followed by explanatory phrases, in brackets. An exception is made for the test method key words. They are listed in alphabetical order in Table 4 with brief descriptions for each method.

To help identify key words of different level: first-level key words are in upper-case, second-level key words have only the first letter capitalized, and third-level key words are in lower-case. Descriptors are also in lower-case and are listed immediately below the associated first-level key words in section 4B.

4A Alphabetical Key Word Listing

KEY WORD - [DESCRIPTIVE PHRASE]	PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)
adjustment - [of apparatus]	16
- [of bonding tool]	17
air blast - [description]	12
[evaluation]	13
anneal - [of wire, responsible for degradation or failure]	19
Apparatus: [bonding machines and accessories]	16
apparatus - [importance of rigidity]	17
- [evaluation of]	16
Application - [information applicable to test method]	12
bond - [affected by stress]	18
bond (adhesion) - [evaluation of]	16
bond monitor - [application]	13
- [correlation]	13
- [description of test method]	12
- [to evaluate fabrication procedures and processes]	17
bond temperature - [test method used to evaluate fabrication procedures and processes]	17
bond (type) - [evaluation of]	16
Bonding Surface - [information pertinent to the surface film(s) or metal substrate of bonding area]	17
care - [of wire]	17
centrifuge - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [to evaluate fabrication procedures and processes]	17
- [to determine degradation or failure]	20
- [to stress wire bond]	19
contamination - [of bonding surface as related to fabrication of wire bond]	17
- [of parts of the wire bond before or after bonding, responsible for degradation or failure]	19
- [of wire as related to fabrication of wire bond]	17
Control - [importance of control of bonding parameters]	17
Correlation - [between test methods]	13
corrosion - [responsible for degradation or failure of wire bond]	19
DEGRADATION - [degradation or failure]	18
description - [of apparatus]	16
Description - [of the test method]	12
design - [of apparatus]	17
- [of bonding tool]	17
device - [affected by stress]	19
electrical - [stress to wire bond]	19
electrical characteristics - [of wire]	17
electrical parameter - [test method to determine degradation or failure]	20
electron microprobe - [test method to determine degradation or failure]	20
electromigration - [responsible for degradation or failure]	20
Evaluation - [of test methods]	13
Evaluation - [as related to fabrication of wire bonds]	16
FABRICATION - [of wire bonds]	13
fabrication - [of wire]	17
Failure Rates - [general reliability data; relative percentage of failure modes]	20
fatigue - [metal fatigue responsible for degradation or failure]	19
film thickness - [of bonding surface]	17
force - [control of in bonding]	17
grain growth - [responsible for degradation or failure]	20
hardening - [of wire and responsible for degradation or failure]	20
interferometer - [test method to evaluate fabrication procedures and processes]	17
intermetallics - [intermetallic compound formation or the Kirkendall effect responsible for degradation or failure]	20
IR monitor - [description of test method]	12
- [evaluation]	13
mechanical - [stress to wire bond]	19
mechanical shock - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	17
- [to stress wire bond]	19

4A Alphabetical Key Word Listing (continued)

KEY WORD - [DESCRIPTIVE PHRASE]	PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)
mechanical shock (radiation induced) - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [application]	13
- [to stress wire bond]	19
Mechanism - [of failure or degradation]	19
mechanical characteristics - [of bonding surface]	17
- [of wire]	17
metal system - [evaluation of, for fabricating wire bonds]	16
- [of bonding surface]	17
metallization - [affected by stress]	19
- [evaluation of, for fabricating wire bonds]	16
metallurgical exam - [description of test method]	12
- [to evaluate fabrication procedures and processes]	17
- [to determine degradation or failure]	20
metal system - [of bonding surface]	15
MIL-STD-883 - [description of test methods]	12
- [evaluation]	13
- [application]	13
MIL-STD-750B - [description of test methods]	12
moisture - [stress to wire bond]	19
noise - [description of test method]	12
- [evaluation]	13
orientation - [of bonding surface]	17
- [with respect to bonding tool]	17
oscillation - [of bonding tool]	17
package - [evaluation of]	16
- [importance of rigidity]	17
Part - [primarily or the wire bond, affected by stress]	19
photoelastic stress analysis - [test method used to evaluate fabrication procedures and processes]	17
power - [control of, in bonding]	17
Precautions - [in the use of a test method]	13
preparation - [of bonding surface for bonding]	17
Procedure - [for making a wire b	16
process - [stress on wire bond]	19
pull - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
- [to stress wire bond]	19
pull (nondestructiv - [description of test method]	12
- [evaluation]	13
- [correlation]	13
- [to evaluate fabrication procedures and processes]	18
radiation - [stress to wire bond]	19
radiotracer - [test method used to evaluate fabrication procedures and processes]	18
resistance - [descripti of test method]	12
- [evaluation]	13
- [correlation]	13
- [precautions]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
Rigidity - [importance of rigidity when fabricating wire bonds]	17
Schedule - [optimization of procedures and processes for making wire bonds]	16
Screening Procedures - [where a series of test methods are used]	13
shear - [description of test method]	12
- [evaluation]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
size - [of wire]	17
spallation - [responsible for degradation or failure]	20

4A Alphabetical Key Word Listing (continued)

KEY WORD - [DESCRIPTIVE PHRASE]	PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)
Stress - [stresses that produce weakened wire bonds as a result of the fabrication process or that result in degradation or failure of already completed wire bonds]	19
substrate - [affected by stress]	19
TC - [effects of process and material variables on making thermocompression wire bonds]	16
- [evaluation of thermocompression bonding]	16
- [failure rates of thermocompression wire bonds]	20
- [procedure for making thermocompression wire bonds]	16
- [schedule for optimizing procedures and processes for making thermocompression wire bonds]	16
- [theory of thermocompression bonding]	17
temperature - [importance of the control of]	17
temperature control - [evaluation of methods used in making thermocompression bonds]	16
temperature cycle - [description of the test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
- [to stress wire bond]	19
terminal - [importance of rigidity]	17
TEST - [test, evaluation, and screening methods for wire bonds]	12
Test - [used to evaluate fabrication procedures and processes]	17
Theory - [of thermocompression and ultrasonic bonding]	15
thermal mismatch - [responsible for degradation or failure]	20
thermal shock - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to stress wire bond]	19
thermal - [stress on wire bond]	19
time - [control of, in bonding]	17
Tool - [bonding tool, as related to the fabrication of wire bonds]	17
tool - [evaluation of]	16
topography - [of bonding surface]	17
- [of wire]	17
Trouble Shooting - [methods for locating and correcting deficiencies in wire bond fabricating procedures]	18
US - [effects of process and material variables on making ultrasonic wire bonds]	16
- [evaluation of ultrasonic bonding]	16
- [failure rates of ultrasonic wire bonds]	20
- [procedure for making ultrasonic wire bonds]	16
- [schedule for optimizing procedures and processes for making ultrasonic wire bonds]	16
- [theory of ultrasonic bonding]	17
US probe - [description of test method]	12
- [to evaluate fabrication procedures and processes]	18
US stress - [description of test method]	12
- [to stress wire bond]	19
Variables - [effects of process and material variables on the quality of wire bonds]	16
vibration (variable frequency) - [description of test method]	12
- [evaluation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
vibration (monitored) - [description of test method]	12
- [evaluation]	13
vibration (fatigue) - [description of test method]	12
- [application]	13
- [to determine degradation or failure]	20
visual inspection - [description of test method]	13
- [evaluation]	13

4A Alphabetical Key Word Listing (continued)

KEY WORD - [DESCRIPTIVE PHRASE]	PAGE NUMBER IN SUBJECT AREA LISTING OF KEY WORDS (Section 4B)
- [correlation]	13
- [application]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
visual inspection (SEM) - [description of test method]	13
- [to evaluate fabrication procedures and processes]	18
- [to determine degradation or failure]	20
wear - [of bonding tool]	17
wire - [affected by stress]	19
wire - [evaluation of, for different wire bonds]	16
Wire - [information pertinent to fabrication of wire bonds]	17
wire bond - [evaluation of]	16
x-ray - [description of test method]	13
- [evaluation]	13
- [to determine degradation of failure]	20

TEST [test, evaluation, and screening methods for wire bonds]

bond

TC [thermocompression]
64D1, 64H2, 65B1, 65C2, 67A1, 67G1, 67H1, 67S4, 68D2, 68F1, 68P1, 68R1, 69A1, 69K4, 69S1, 70A1, 70B1, 70H2, 71B3, 71H2, 71S1

US [ultrasonic]
59J1, 60J1, 61J1, 62J1, 64C2, 64W1, 66R1, 67P2, 67R1, 67R2, 68D2, 68F1, 68R1, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1

wire

Al [aluminum hardened with silicon]
64D1, 66R1, 67R1, 67R2, 68D2, 68R1, 69B5, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1

Al (pure) [pure aluminum]
67R2

Au [gold]
65C2, 67A1, 67G1, 67H1, 68D2, 68L1, 68P1, 69A1, 69B5, 69K4, 69S1, 70A1, 70B1, 70H2, 71B3, 71H2, 71S1

Au/Cu [gold plated copper]
67S4

film [metal or metal film(s) of bonding surface]

Ag [silver]
70B1, 71B3

Al [aluminum]
65C2, 67A1, 67R1, 67R2, 68D2, 68P1, 69B6, 69B7, 69K1, 69K4, 69P1, 70A1, 70B2, 70D2, 71B1, 71B4, 71G1, 71S1

Au [gold]
67A1, 67H1, 67S4, 68D2, 69P1, 69K4, 70A1, 70B1, 70D2, 71B3, 71S1

Au/Cr [gold on chromium]
66R1, 67R1, 67R2

Au/Mo [gold on molybdenum]
67G1

substrate [material underlying bonding surface film(s)]

alumina
66R1, 67R1, 67R2

beryllia
66R1, 67R1

ceramic
67S4

sapphire
66R1, 67R1, 67R2

Si [silicon]
67R1, 67R2

silica (96%)
67R1, 67R2

application

plastic devices
70B1, 70C2, 70H2, 71B3, 71H2

hybrid devices
70S2, 71S1

Description [of the test method]

air blast
68D2

bond monitor
59J1, 60J1, 61J1, 62J1, 64W1, 67P2, 69B6, 69B7, 71B4

centrifuge
63W1, 66L4, 66P1, 68B1, 68D2, 68I1, 69B2, 69O1, 69S4, 70B7, 70D3

IR monitor
67B1, 67S4, 68B1

mechanical shock
63W1, 66P1, 67I1, 68D2, 69B2, 69S4, 70D3, 71N2, 71K1

mechanical shock (radiation-induced)
68F1

metallurgical exam
68B1

MIL-STD-883
68D2, 69O1, 70C2, 71N1

MIL-STD-750B
66P1

noise
65M1

pull
63W1, 65W1, 67H1, 68B1, 68D2, 68P1, 69K1, 69O1, 69S1, 70A1, 70B7, 71N1, 71N2

pull (nondestructive)
65B1, 69S1

resistance
66M1, 68D2, 70B2, 70H2, 71H2, 71N1, 71N2

shear
67A1, 68D2

temperature cycle
66L4, 66P1, 68D2, 69O1, 69S4, 70H2, 71H2

thermal shock
63W1, 68D2, 69B2, 69S4, 70D3

US probe
59R1, 67B4

US stress
69K4, 70B7

vibration (fatigue)
66I1, 68D2, 69S4, 70D3

vibration (monitored)
66L4, 68D2, 70D3

vibration (variable frequency)
63W1, 66I1, 66P1, 68D2, 69S4, 70D3

visual inspection
66P1, 66L4, 68D2, 68R1, 69O1, 71N1

visual inspection (SEM)
69S1, 71N1

x-ray
66L4, 68D2, 68L1, 69S1

Evaluation [of the test method]
air blast
69P1

centrifuge
66L4, 67G1, 68H4, 69O1

IR monitor
67S4

mechanical shock
68F1, 68H4

mechanical shock (radiation-induced)
68F1

MIL-STD 883
70S2

noise
68B1

pull
67R2, 68H4, 70B8, 71B1

pull (nondestructive)
64D1

resistance
67R2, 68B1, 70H2, 71H2

shear
67G1

temperature cycle
66L4, 68H4, 69B1, 70H2, 71H2

thermal shock
65H3, 68H4, 69B1, 69P1, 70B1, 71B3

vibration (monitored)
66L4

vibration (variable frequency)
69S4

visual inspection
64H2, 66L4, 67G1, 68H4, 69K1, 69O1, 69P1, 69S4

x-ray
66L4, 67G1, 68H4

Correlation [between methods for the same type of wire bond]
bond monitor
69B7

centrifuge
65B1

mechanical shock-(radiation-induced)
69P1, 70D2

pull
65B1, 66R1, 67R1, 67R2, 69A1, 69B7, 69K1, 69P1, 70D2, 71G1

pull (nondestructive)
69A1

resistance
66R1, 67R1, 67R2

visual inspection
67B7, 67G1, 69K1, 69P1, 70D2, 71G1

Application [information relevant to a particular test method]
bond monitor
64C2, 70B7, 71K2

mechanical shock
61A2, 69K2

mechanical shock (radiation-induced)
67G2, 70M2

MIL-STD-883
69B8, 69D3, 71N1

pull
67S3, 68A1, 69B5, 69D1, 70A6, 70B8, 71B4

temperature cycle
69K2, 70P2, 70V1

thermal shock
69K2, 70P2

US probe
69D2

vibration (fatigue)
69K2

visual inspection
68H1

Precautions [in the use of a test method]
resistance
65C2, 68E1

Screening Procedures [where a series of tests is used to cull out unsatisfactory wire bonds]
66P1, 67G1, 67P1, 68D2, 69D3, 69L1, 70S2, 71N1, 71S1

FABRICATION
bond
TC [thermocompression]
57A1, 57A2, 58C1, 61A1, 62M1, 63M1, 63P1, 63W1, 64A1, 64D1, 64H1, 64H2, 64J1, 64M1, 65B1, 65C1, 65C5, 65H1, 65H2, 65R1, 65S1, 65S3, 66A1, 66A2, 66B1, 66B3, 66B4, 66B6, 66C1, 66E1, 66G2, 66H1, 66K3, 66L1, 67A2, 67B2, 67C1, 67H1, 67K1, 67P1, 67R4, 67S1, 67S5, 68A2, 68A3, 68B1, 68D1, 68G1, 68H3, 68H5, 68J1, 68K1, 68M1, 68M2, 68M3, 68P1, 68R2, 68T2, 69A2, 69B3, 69G2, 69O2, 69S1, 69S2, 69S5, 69T2, 70A2, 70D4, 71B2, 71M1, 71P1, 71R1

US [ultrasonic]
59A1, 59J1, 59V1, 60J1, 60J2, 60W1, 61D1, 61J1, 62P1, 63W1, 64D2, 65D1, 65J1, 65N1, 66B1, 66B6, 66E1, 66H1, 66L3, 66R1, 67B2, 67H2, 67J1, 67L1, 67P1, 67R1, 67R2, 67S1, 67T1, 68B1, 68D1, 68H3, 68K1, 68M1, 68M2,

FABRICATION

68S1, 68T2, 68U1, 68U2, 68U3, 68U4, 68U5, 69B2, 69B3, 69E5, 69B6, 69K1, 69K3, 69L2, 69O2, 69P1, 69S1, 69S2, 69S5, 69T2, 69U1, 69U2, 70B2, 70B3, 70B5, 70B6, 70B7, 70B8, 70C1, 70D2, 70D4, 70P1, 70W1, 71B1, 71B2, 71B4, 71D1, 71G1, 71H1, 71J1, 71M1, 71P1, 71P2, 71R1

wire

Ag [silver]
57A1, 57A2, 58C1, 61A1, 62M1, 63W1, 64A1, 66A1, 66C1, 66G2

Al [aluminum hardened with silicon]
57A1, 57A2, 58C1, 61A1, 63M1, 63W1, 64A1, 64D1, 64S1, 65B1, 65D1, 65R1, 66A1, 66B4, 66G2, 66R1, 67B2, 67C1, 67K1, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 67V1, 68G1, 68H3, 68K1, 68M2, 68R2, 68T2, 68U1, 69B2, 69B3, 69B5, 69B6, 69K1, 69K3, 69O2, 69P1, 69S1, 69S2, 69U1, 70B2, 70B3, 70C1, 70D2, 70D4, 70P1, 71B1, 71B2, 71G1, 71J1, 71P1, 71P2, 71R1

Al/Mg [aluminum hardened with magnesium]
67V1, 68U1, 69U1, 70P1

Al (pure) [pure aluminum]
67R2, 67V1, 69O2

Au [gold]
57A1, 57A2, 58C1, 61A1, 62M1, 63M1, 63P1, 63W1, 64A1, 64C1, 64H1, 64H2, 64M1, 64S1, 65B1, 65C5, 65D1, 65H1, 65H2, 65R1, 65S1, 66A1, 66B3, 66B4, 66C1, 66G2, 66L1, 66W1, 67B2, 67C1, 67H1, 67K1, 67P1, 67S1, 67S5, 67T1, 68A3, 68H3, 68K1, 68M2, 68M3, 68P1, 68R2, 68S1, 68T2, 68U1, 69A2, 69B3, 69G2, 69P1, 69S1, 69S2, 69S3, 69U1, 70A2, 70A3, 70D4, 71B2, 71P1

Au/Ag [gold with silver added]
66W1

Au/Cu [gold plated copper]
61A1, 66C1

Au/CuBeO [gold plated CuBeO]
71D1

Au/Ga [gold with gallium added]
68S1

Au/Ni [gold covered nickel]
64C1

Au/Pt [gold covered platinum]
64C1

Au/W [gold covered tungsten]
64C1

Cu [copper]
57A1, 57A2, 61A1, 62M1, 63M1

Cu/Ni [gold plated nickel]
66C1

Pb [lead]
57A2

Pl [palladium]
63W1

Pt [platinum]
57A2, 63M1, 65C1

Sn [tin]
57A2

Sn/Cu [tinned copper]
61A1

Ti [titanium]
63M1

Zr [zirconium]
63M1

film

Ag [silver]
63W1, 66G2, 67P1

Ag/Al [silver on aluminum]
63W1, 68T2

Ag/Cr [silver on chromium]
63W1, 64S1, 66G2, 67K1, 67P1, 67S5, 68K1

Ag/Cr-Al [silver on chromium-aluminum alloy]
63W1

Al [aluminum]
62M1, 63M1, 63W1, 64D1, 64H1, 64H2, 64M1, 64S1, 65B1, 65C5, 65H1, 65H2, 65R1, 65R2, 65S1, 66A1, 66B3, 66B4, 66G2, 66H1, 66W1, 67B2, 67C1, 67H1, 67K1, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 68A3, 68G1, 68H3, 68K1, 68M2, 68M3, 68P1, 68R2, 68T2, 69A2, 69B2, 69B5, 69B6, 69K1, 69O2, 69P1, 69S1, 69S2, 69U1, 70A2, 70B2, 70B3, 70C1, 70D2, 70D4, 71B1, 71G1, 71J1, 71P1, 71P2

Al/Cr [aluminum on chromium]
63P1, 66H1, 67B2, 67R2

Au [gold]
63W1, 64D1, 64S1, 64B1, 65C5, 65R1, 66A1, 66B4, 66G2, 66H1, 67B2, 67H1, 67K1, 67P1, 67S1, 68H3, 68K1, 68R2, 69A3, 69B2, 69B3, 69K3, 69O2, 69P1, 69S1, 69U1, 70D2, 70D4, 71G1, 71J1, 71P1

Au/Ag [gold on silver]
65C5

Au/Ag/Cr [gold on silver on chromium]
69S3

Au/Ag/Cr-Al [gold on silver on chromium-aluminum alloy]
63W1

Au/Al [gold on aluminum]
63M1

$AuAl_2$ [gold-aluminum compound]
68T2

Au/Co [gold on cobalt]
65C5

Au/Cr [gold on chromium]
63P1, 63M1, 65C5, 66H1, 66R1, 67B2, 67L1, 67R1, 68M2, 69S2

FABRICATION

Au/Cu [gold plated copper]
71D1

Au/Cu/Ti [gold on copper on titanium]
68M2

Au/Cr/Al [gold on chromium on aluminum]
68K1

Au/Mo [gold on molybdenum]
65C6, 66G2, 67C1, 67P1, 67S1, 67S5, 68M2, 69S2, 69S3

Au/Mo/Al [gold on molybdenum on aluminum]
67S5, 70A2

Au/Mo/Mn [gold on molybdenum on manganese]
69B3

Au/Mo/Pt [gold on molybdenum on platinum]
67C1, 67K1, 68K1

Au/Ni [gold on nickel]
65C5, 68M2

Au/NiCr [gold on nichrome]
65S1

Au/Pl [gold in palladium]
63W1

Au/Pt/Ti [gold on platinum on titanium]
67S5, 68M2

Au/Pt/Ti/Pt [gold on platinum on titanium on platinum]
69S3

Au/Ti/Al [gold on titanium on aluminum]
69S3, 70A2

Bi [bismuth]
62M1

Cr [chromium]
68H3, 68T2

Cr/Al [chromium on aluminum]
64S1, 67S5, 69S3

Cu/NiCr [copper or nichrome]
65S1

Ga [gallium]
62M1

In [indium]
62M1

Ni [nickel]
66A1

NiCr [nichrome]
63M1

Pl [palladium]
64S1

Pt [platinum]
64H2, 64S1

Pt/Ti [platinum on titanium]
68M2

Sb [antimony]
62M1

Ta [tantalum]
63M1

Ti [titanium]
63M1

thick film
Ag [silver]
69B3

Ag/Pd [silver-palladium composition]
69B3

Au [gold]
69B3

Au/Pd [gold-palladium composition]
69B3

Au/Pd/Pt [gold-palladium-platinum composition]
69B3

Au/Pt [gold-platinum composition]
69B3

Pd/Ag [palladium-silver composition]
69B3

substrate
Al [aluminum]
66B4

alumina
65R2, 65S1, 66C1, 66R1, 67L1, 67R1, 67R2, 68H3

beryllia
66R1, 67L1, 67R1

BN [boron nitride]
65R2

ceramic
63P1, 66H1

epoxy
71D1

Fe/Ni/Co [iron-nickel-cobalt alloy]
65B1, 66B4, 69K3, 71G1, 71J1

Ge [germanium]
57A1, 57A2, 57C1, 61A1, 62M1, 65D1

glass
63P1, 65D1, 65H1, 65H2, 65R2, 66C1, 66H1, 67L1, 68H3

sapphire
66R1, 67L1, 67R2

Si [silicon]
57A1, 57A2, 57C1, 61A1, 62M1, 63M1, 64A1, 64H2, 65C1, 65C5, 65D1, 65R2, 65S1, 66A1, 66B4, 67L1, 67P1, 67R2, 68H3, 68T2

silica (96%)
67L1, 67R1, 67R2

application
hybrid devices
67L1, 67R1, 68H3, 68M3, 69T2

Theory [of bonding]
TC [thermocompression]
57A2, 61A1, 63M1, 64A1, 66A1, 66B4, 66B6, 67B2, 68B1, 69S1

FABRICATION

US [ultrasonic]
59A1, 59J1, 59W1, 60J1, 60J2, 60W1, 61J1, 62P1, 65D1, 65J1, 65N1, 65P1, 66B6, 67B2, 67J1, 68B1, 68U2, 68U3, 68U4, 69P1, 69S1, 69U1, 70B3, 70B8, 71P2

Evaluation [of]
TC [thermocompression bonding]
63P1, 63W1, 66B1, 66C1, 66E1, 67B2, 67S1, 68H3, 68K1, 68M1, 69C1, 69S1, 69T2, 70D4, 71B2

US [ultrasonic bonding]
60J2, 61J1, 62P1, 63W1, 66B1, 66E1, 66R1, 67B2, 67L1, 67R1, 67S1, 68H3, 68K1, 68M1, 69C1, 69S1, 69T2, 70D4, 71B2, 71P2

wire bond [wire bonds, in general, and versus other bonding methods]
67L1, 69B2, 69B3, 69C1, 69S5, 70D4, 70M1, 71B2, 71M1

apparatus (US) [ultrasonic bonding equipment]
61D1

bond (adhesion)
57A2, 63M1, 63P1

bond (ball)
64M1, 65B1, 65R1, 66B4, 66E1, 66G2, 66L1, 67B2, 67C1, 67K1, 68M3, 68R2, 69B6, 69C1

bond (stitch)
65D1, 65R1, 66E1, 66L1, 67B2, 68M3, 68R2, 69C1

bond (wedge)
65B1, 65R1, 66B4, 66E1, 66G2, 66L1, 67B2, 67C1, 67K1, 68R2, 69C1

bond (general)
66C2

metal system [of the wire bond, i.e. wire-metallization-substrate, for]

(TC) [thermocompression bonds]
63W1, 64S1, 65C5, 65R2, 66G2, 67K1, 67P1, 67S5, 68M2, 68T2, 70A2

(US) [ultrasonic bonds]
61J1, 67P1, 67R2, 68M2, 68T2

(general) [bond type not specified]
66W1, 69S3

metallization
65C5, 66H1, 67C1, 67P1, 68T2, 69B3, 69S2

package
67G1

temperature control [for thermocompression bonding]
66L1, 67K1, 68H3, 71B2

tool
(TC) [to make thermocompression bonds]
63W1, 64M1, 65B1, 66B4, 68H3

(US) [to make ultrasonic bonds]
63W1

wire

(TC) [for thermocompression wire bonds]
65B1, 65R1, 65R2, 66G2, 67P1, 68H3, 68R2, 71R1

(US) [for ultrasonic wire bonds]
63W1, 67P1, 68U1, 69U1, 70C1, 70P1, 71R1

(ribbon)
65B5, 69B6

(general)
66W1

Procedure [for making a wire bond]
TC [thermocompression]
57A1, 57C1, 60J2, 61A1, 62M1, 64H2, 64M1, 65C1, 65R1, 65S1, 66A2, 66L1, 67A2, 67B2, 67H1, 67K1, 67P1, 68A2, 68B1, 68H5, 68K1, 68R2, 69G2, 69S1, 71B2

US [ultrasonic]
60J1, 60J1, 65N1, 67B2, 67P1, 67R2, 67T1, 68B1, 68K1, 69K2, 69K3, 69S1

Schedule [optimization of procedures and processes for making wire bonds]
TC [thermocompression]
57A1, 63M1, 63P1, 64A1, 64H2, 65B1, 66A1, 66C1, 67B2, 67H1, 68B1, 68K1

US [ultrasonic]
59A1, 59W1, 60J1, 60W1, 61J1, 63W1, 65J1, 66R1, 67J1, 67L1, 67R1, 67R2, 68K1, 68U1, 68U4, 69P1, 69U1, 70B8, 70D2

Variables [effects of process and material variables on quality of wire bond]
TC [thermocompression bond]
57A1, 57C1, 59A1, 61A1, 63M1, 63P1, 64A1, 64H2, 65H1, 65H2, 66A1, 66B1, 66C1, 66L1, 67B2, 67H1, 67K1, 68P1, 69B3

US [ultrasonic bond]
59W1, 60J1, 60J2, 60W1, 61J1, 63W1, 65D1, 65J1, 65N1, 66B1, 67J1, 67R1, 69B3, 69P1, 70D2, 71J1

Apparatus [of bonding machines and accessories]
adjustment (TC) [of thermocompression bonding apparatus]
67H1, 63W1

adjustment (US) [of ultrasonic bonding apparatus]
64D2, 68U5, 69B6, 69P1, 69U1, 70B3, 70D2, 71B4, 71H1

description (TC) [of thermocompression bonding apparatus]
68D1, 68H3

description (US) [of ultrasonic bonding apparatus]
60J1, 62P1, 63W1, 67B2, 67L1, 67R2, 68D1, 69U1

FABRICATION

design (TC) [of thermocompression bonding apparatus]
63M1, 63W1, 64J1, 64M1, 65S3, 66A2, 66K3, 67A2, 67R4, 68H5

design (US) [of ultrasonic bonding apparatus]
59A1, 59W1, 60J2, 60W1, 63W1, 65D1, 65J1, 65N1, 67H2, 67J1, 67S1, 68B1, 68U5, 69L2, 69U1, 69U2, 70B2, 70B3, 70B6, 70D2, 70W1, 71B4, 71J1

Control [importance of control of]
force (TC) [applied in making thermocompression bond]
68P1

force (US) [applied in making ultrasonic bond]
68U4, 70C1

power (US) [used in making ultrasonic bond]
68U4, 70C1

temperature (TC) [in making thermocompression bond]
64H2, 65H1, 65H2, 65S1, 66C1, 66L1, 68B1, 68H3, 68J1, 68M3, 68P1

temperature (US) [in making ultrasonic bond]
68B1

time (US) [for making ultrasonic bond]
68U4, 70C1

Tool [bonding]
adjustment (US) [for ultrasonic bonding]
69U1, 70B2, 70B3, 71H1, 70D2

design (TC) [for thermocompression bonding]
63W1, 64H2, 65B1, 65S3, 66B4, 66C1, 67B2, 67R3, 67S1, 68B1, 68H3, 69G1, 71B2

design (US) [for ultrasonic bonding]
59W1, 60W1, 63W1, 65D1, 67R1, 67R3, 67S1, 67T1, 68U1, 69G1, 69P1, 70B2, 70B7, 70D2, 71B1, 71D1, 71G1, 71J1

oscillation (US) [of the ultrasonic bonding tool]
69B6, 70B2, 70B3, 70D2, 70W1, 71B1, 71D1, 71H1

wear (TC) [of the thermocompression bonding tool]
68H3

wear (US) [of the ultrasonic bonding tool]
67R1, 71J1

Rigidity [importance of in]
apparatus
67R2, 68U5, 69P1, 69U1, 70B2, 70B3, 70B7, 70B8, 70D2, 71B1, 71B4, 71J1

terminal [device]
68U5, 69P1, 70D2, 71B2

package
69U1, 70D2, 71J1

Wire
care
64C1, 67B2, 68S1, 70A3

contamination
65K1, 70A3, 70B3

electrical characteristics
66R1, 67R1, 69O2, 70A7

fabrication
69O2, 70S1

mechanical characteristics
63W1, 64C1, 65K1, 66L3, 67R2, 67V1, 68G1, 68S1, 68U1, 69D2, 69O2, 69U1, 70A3, 70A4, 70B3, 70B5, 71B4, 71R1

size
66C1, 66K2, 68B2, 70A3, 70A4, 70A5

topography [of the surface]
65K1, 69O2

Bonding Surface [of film(s) or metal substrate]
contamination
59W1, 60W1, 64H2, 65B1, 66B4, 66C1, 69A3, 69H1, 69P1, 70D2, 71G1

film thickness
64H1, 65C5, 65H1, 65H2, 66B3, 66G2, 66R1, 67L1, 67R1, 67R2, 68A3, 69A2, 69A3, 69K1, 69K3, 70D2, 71G1, 71P1

mechanical characteristics
59W1, 60W1, 69A3, 69P1, 71H3

metal system
67C1, 68T2, 71G1

orientation [with respect to the bonding tool]
68S1

preparation
59W1, 60W1, 63P1, 64H1, 65H1, 65H2, 65R2, 66H1, 67C1, 67L1, 67R2, 68T2, 69A3, 69B3, 70A2, 70B3, 71G1

topography
59W1, 60W1, 63P1, 64H2, 65D1, 66R1, 67L[illegible], 67R1, 67R2, 69A3, 69P1, 70D2, 70P1, 71J[illegible], 71P2

Test [used to evaluate fabrication procedures and processes]
bond monitor
59A1, 59W1, 61J1, 65J1, 65P1, 67J1

bond temperature
61J1

centrifuge
63W1, 64M1, 65B1, 65R1, 67K1, 68R2, 69B2

interferometer
70B2, 70W1

mechanical shock
63W1, 64M1, 65R1, 68R2, 69B2

metallurgical exam
59W1, 60J1, 60J2, 60W1, 61J1, 65H2, 65J1, 66C2, 67J1

photoelastic stress analysis
61J1

pull
57C1, 59W1, 60W1, 61A1, 63M1, 63P1, 63W1, 64H2, 65B1, 65C5, 65H1, 65H2, 65J1, 65S1, 66B4, 66C1, 66G2, 66R1, 66W1, 67H1, 67K1, 67L1, 67R2, 68B1, 68U1, 69B3, 69O2, 69P1, 69S1, 69U1, 70B3, 70B7, 70B8, 70C1, 70D2, 71D1, 71G1

pull (nondestructive)
65B1, 66B4

radiotracer
61J1, 69H1

resistance
63M1, 63P1, 66G2, 66R1, 67R2, 70C1

shear
61D1 64A1, 66A1

temperature cycle
63P1, 69B2

thermal shock
63P1, 63W1, 64M1, 66C1, 67R2

US probe
69D2

vibration (variable frequency)
63W1, 64M1, 65R1, 68R2

visual inspection
57A1, 60J1, 61A1, 63M1, 63P1, 67L1, 67R2, 68U1, 69P1, 69U1, 70C1, 70D2, 71G1

visual inspection (SEM)
69C2, 70B7, 70B8

Trouble Shooting [methods for locating and correcting deficiencies in fabricating procedures]
69U1, 71H1

DEGRADATION [degradation or failure]
bond
TC [thermocompression]
61G1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G2, 66L2, 67A1, 67A3, 67B3, 67C1, 67G1, 67K1, 67K2, 67P1, 67S1, 67S5, 68A3, 68F1, 68G1, 68G2, 68H2, 68M1, 68M2, 68P1, 68R2, 69A2, 69B3, 69B4, 69K4, 69L1, 69O1, 69O2, 69S1, 69T1, 70A1, 70A2, 70B1, 70D1, 70H2, 70R1, 70S2, 70V1, 71B3, 71H2, 71P1, 71R1, 71S1

US [ultrasonic]
59W1, 60W1, 66K1, 66L3, 66R1, 67A3, 67C3, 67F1, 67L1, 67R1, 67R2, 67S1, 68A3, 68F1, 68M1, 68U1, 69B5, 69K3, 69K4, 69L1, 69O1, 69O2, 69P1, 69U1, 70A1, 70B2, 70B8, 70C1, 70P1, 70V1, 71B1, 71B4, 71G1, 71G2, 71P1, 71R1

wire
Al [aluminum hardened with silicon or so implied]
64S1, 64U1, 65C5, 65R1, 66B4, 66K1, 66R1, 67A3, 67C1, 67L1, 67P1, 67R1, 67R2, 67S1, 67S2, 67S5, 68F1, 68G1, 68G2, 68M1, 68R2, 68U1, 69B4, 69B5, 69K3, 69K4, 69L1, 69O1, 69O2, 69P1, 69S3, 69U1, 70A1, 70B2, 70C1, 70P2, 70V1, 71B1, 71B4, 71G2, 71P1, 71R1

Al (pure) [pure aluminum]
67R2, 70P2

Al/Mg [aluminum hardened with magnesium]
69P1, 70P1

Au [gold]
61G1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G2, 66L2, 67A1, 67B3, 67C1, 67C3, 67G1, 67K1, 67K2, 67P1, 67S1, 67S5, 67A3, 68F1, 68G1, 68H2, 68L1, 68M1, 68M2, 68P1, 68R2, 69A2, 69B3, 69B4, 69K4, 69L1, 69O1, 69S1, 69S3, 69T1, 70A1, 70A2, 70B1, 70D1, 70H2, 70P2, 70R1, 70V1, 71B3, 71G1, 71H2, 71P1, 71S1

film
Ag [silver]
69T1

Ag/Cr [silver or chromium]
67S5

Al [aluminum]
64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B5, 66B7, 66G2, 66K1, 67A1, 67B3, 67C1, 67C3, 67K1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 67A3, 68G1, 68G2, 68H2, 68M2, 68P1, 68R2, 68U1, 69A2, 69B4, 69B5, 69K4, 69L1, 69O1, 69O2, 69S1, 69S3, 69T1, 70A1, 70A2, 70B2, 70C1, 70D1, 70R1, 70V1, 71B1, 71B4, 71P1, 71S1

Au [gold]
64S1, 64U1, 65C5, 65R1, 65S2, 67A1, 67P1, 67S1, 68H2, 68M2, 68R2, 69K3, 69K4, 69L1, 69O1, 69O2, 69S3, 69T1, 70A1, 70B1, 71B3, 71P1, 71S1

Au/Cr [gold on chromium]
66R1, 67L1, 67R1, 67R2

Au/Mo [gold on molybdenum]
65C5, 67C1, 67G1, 67P1, 67S1, 67S5, 69B4

Au/Mo/Al [gold on molybdenum on aluminum]
67S5, 70A2

Au/Mo/Pt [gold on molybdenum on platinum]
67C1

Au/Pt/Ti [gold on platinum on titanium]
67S5

Au/Ti/Al [gold on titanium on aluminum]
70A2

Cr/Al [chromium on aluminum]
67S5

Ni [nickel]
69T1

thick film
Ag/Pd [silver-palladium composition]
69B3

DEGRADATION

Au [gold]
69B3, 71G2

substrate
alumina
65R2, 66R1, 67L1, 67R2

beryllia
66R1, 67L1

BN [boron nitride]
65R2

FeNiCo [iron-nickel-cobalt alloy]
64S1, 66B4, 66K1, 67P1, 69K3

glass
65H1, 65H2, 65R2

sapphire
66R1, 67L1, 67R2

Si [silicon]
61G1, 64S1, 65R2, 65S2, 67L1, 67P1, 67R2, 69U1

silica (95%)
67R2, 67L1

application
plastic device
68L1, 69T1, 70B1, 70B4, 70H1, 70H2, 71B3, 71H2

hybrid devices
67L1, 70S2, 71L1, 71S1

Stress [that produces a weakened wire bond as a result of the fabrication process or that results in degradation or failure of an already completed wire bond]
electrical
67B3

mechanical
70W2

moisture
66B7, 69T1, 70B4, 70H2, 71H2, 71L1

process
59W1, 60W1, 61G1, 64P1, 64U1, 65R2, 65S2, 66B2, 66B5, 66G1, 66K1, 66L3, 67A3, 67C2, 67G1 67P1, 67L1, 67R1, 67R2, 67S1, 67S5, 68H2, 68L1, 68M2, 68P1, 68U1, 69L1, 69U1, 70B4, 70B8, 70C1, 71B1, 71B4, 71G1

radiation
66L2, 66O1

test (centrifuge)
64P1, 64U1, 65S2, 67G1, 67S1, 71S1

test (mechanical shock)
65U1, 71S1

test (mechanical shock (radiation-induced))
68F1

test (mechanical shock)
71S1

test (pull)
70A1, 70B8

test (temperature cycle)
66K1, 70B4, 70H1, 70H2, 71H2, 71L1, 71P1, 71S1

test (thermal shock)
64U1, 67G1, 67R2, 69T1, 70B1, 70B4, 70H1, 71B3, 71S1

test (US stress)
69K4

thermal
61B1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 66R1, 65R2, 65S2, 66B3, 66B4, 66B5, 66G2, 66K1, 66R1, 67A1, 67B3, 67C1, 67C3, 67G1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S2, 67S5, 67A3, 68G1, 68G2, 68P1, 68R1, 68T1, 69A2, 69B3, 69B4, 69B5, 69K3, 69L1, 69O1, 69O2, 69P1, 69S1, 69S3, 69T1, 70A1, 70A2, 70B2, 70C1, 70P1, 70P2, 70R1, 70V1, 71G2, 71P1, 71R1

Part [part affected, primarily of the wire bond]
bond
59W1, 60W1, 61B1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G1, 66G2, 66K1, 66L2, 66O1, 67A1, 67A3, 67B3, 67C1, 67C2, 67C3, 67G1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 68A3, 68F1, 68H2, 68M2 68P1, 68T1, 69A2, 69B4, 69K3, 69K4, 69S1, 69S3, 69T1, 70A2, 70B1, 70B8, 70D1, 70R1, 70H2, 71B3, 71B4, 71G2, 71H2, 71P1, 71S1

metallization
64U1, 65S2, 66B7, 66R1, 67G1, 67L1, 67R1, 67R2, 68M2, 69A2, 70B4, 70H2, 71H2, 71L1

substrate
61G1, 65S2, 67G1, 68M2, 68U1, 69U1, 70C1

wire
64P1, 64U1, 65H1, 65H2, 65K1, 65S2, 66B2, 66B4, 66G1, 66G2, 66K1, 66L3, 67A3, 67G1, 67L1, 67R2, 67S1, 67S5, 67A3, 68G1, 68G2, 68H2, 68L1, 69B5, 69K4, 69O2, 69P1, 69T1, 70A1, 70B1, 70B2, 70B4, 70C1, 70H2, 70V1, 70W2, 71B1, 71B3, 71B4, 71G1, 71G2, 71H2, 71L1, 71P1, 71R1, 71S1

device [the device of which the wire bond is a part]
67S2, 69P1, 70P1

Mechanism
anneal [wire anneal]
66K1, 67S5, 68A3, 69P1, 69B5, 69L1, 69O1, 69O2, 69P1, 70A1, 70B2, 70C1, 71B4, 71R1

contamination [on or in the parts of the wire bond before or after bonding]
65S2, 66G1, 66K1, 67C2, 67G1, 67P1, 67S2, 68H2, 68M2, 69L1, 69P1, 70D1, 70P1, 71L1

corrosion
65S2, 66B7, 67C1, 69T1, 70B4, 70H2, 71H2, 71L1

fatigue [metal fatigue]
59W1, 60W1, 65K1, 68C1, 68G2, 70L4, 70V1, 70W2, 71L1, 71P1, 71R1

DEGRADATION

electromigration
67B3

grain growth
66G2, 66K1, 68P1, 69O2, 70A1, 71R1

hardening [of the wire]
59W1, 60W1, 66L3

intermetallics [intermetallic compounds and the Kirkendall effect]
61B1, 64P1, 64S1, 64U1, 65C3, 65C4, 65C5, 65H1, 65H2, 65R1, 65R2, 65S2, 66B2, 66B3, 66B4, 66B5, 66G1, 66G2, 66W1, 67A1, 67A3, 67B2, 67B3, 67C1, 67C3, 67C4, 67K1, 67K2, 67L1, 67P1, 67R1, 67R2, 67S1, 67S5, 68A3, 68H2, 68M2, 68P1, 68R2, 68T1, 69A2, 69B4, 69K3, 69L1, 69O1, 69S1, 69S3, 70A2, 70P2, 70R1, 71L1, 71P1

spallation [separation of a material or interface caused by stress-wave interactions]
66O1, 68F1

thermal mismatch
65S2, 68H2, 69T1, 70B1, 70B4, 70H2, 71B3, 71H2

Test [used to determine degradation or failure]

centrifuge
65C5, 65S2, 66G1, 67G1

electron microprobe
67C2

electrical parameter
67S2, 69P1

metallurgical exam
59W1, 60W1, 65C3, 65C4, 65H1, 65H2, 66B3, 66B5, 69K3, 70P2

pull
59W1, 60W1, 64S1, 65C4, 65C5, 65H1, 65H2, 66B4, 66G2, 66K1, 66R1, 67C3, 67R1, 67R2, 67S5, 67A3, 67L1, 68P1, 69B3, 69B5, 69L1, 69O1, 69O2, 69P1, 70A2, 70B2, 70C1, 70P2, 70R1, 70V1, 71B4, 71G1, 71R1

resistance
65H2, 65S2, 66B3, 66B5, 66G2, 66R1, 67C3, 67K2, 67L1, 67R1, 67R2, 67A3, 69K3, 70A2, 70B4, 70C1, 70R1, 71G2, 71L1

shear
67A1, 67G1, 69L1

temperature cycle
65C5, 66G1

vibration (fatigue)
65C5

vibration (variable frequency)
66G1

visual inspection
65C3, 70C1

visual inspection (SEM)
67A3, 67G1, 68P1, 69S1, 70A1, 70B8, 70D1, 70V1

x-ray
68L1, 70B4

Failure Rates [general reliability data; relative percentages of failure modes]

TC [thermocompression wire bonds]
64U1, 66B2, 67G1, 67P1, 67S1, 68H2, 68M1, 68R2, 69B4, 69K4, 69L1, 69O1, 70S2, 70V1

US [ultrasonic wire bonds]
67P1, 67S1, 68M1, 69K4, 69L1, 69O1, 70V1

general
68E2, 70B4, 70H1

5. Bibliography

57A1 Anderson, O. L., H. Christensen, and P. Andreatch
TECHNIQUE FOR CONNECTING ELECTRICAL LEADS TO SEMICONDUCTORS
J. Appl. Phys., vol. 28, p. 923, Aug. 1957.
FABRICATION-bond: TC; wire: Ag, Al, Au, Cu; substrate: Ge, Si
Procedure
Schedule
Variables
Test: visual inspection
DESCRIPTIVE

57A2 Anderson, O. L.
ADHESION OF SOLIDS: PRINCIPLES AND APPLICATIONS
Bell Lab. Rec., vol. 35, pp. 441-445, Nov. 1957.
FABRICATION-bond: TC; wire: Ag, Al, Au, Cu, Pb, Pt, Sn; substrate: Ge, Si
Theory: TC
Evaluation: bond (adhesion)
DESCRIPTIVE

58C1 Christensen, H.
ELECTRICAL CONTACT WITH THERMO-COMPRESSION BONDS
Bell Lab. Rec., vol. 36, pp. 127-130, April 1958.
FABRICATION-bond: TC; wire: Ag, Al, Au; substrate: Ge, Si
Procedure
Variables
Test: pull
DESCRIPTIVE

59A1 Antonevich, J. N.
ULTRASONIC WELDING EQUIPMENT
IRE Intern. Conv. Record, vol. 7, pt. 6, pp. 204-212, 1959.
FABRICATION-bond: US
Theory: US
Schedule
Variables
Apparatus: design
Test: bond monitor; pull
DESCRIPTIVE

59J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
FUNDAMENTALS OF ULTRASONIC WELDING-PHASE I
Final Rpt. (Dec. 1, 1957 to Dec. 1, 1958), Contract No. NOas 58-108c, May 1959. AD 235508 [summarized in 61J1].
FABRICATION-bond: US
Theory: US
TEST-bond: US
Description: bond monitor
EXPERIMENTAL

59R1 Renaut, P.
APPARATUS FOR THE DETERMINATION OF THE EXISTENCE OR NON-EXISTENCE AND THE QUALITY OF A BONDING BETWEEN TWO PARTS OR MEMBERS
U.S. Patent 2,903,886; Sept. 15, 1959.
TEST
Description: ultrasonic probe
PATENT

59W1 Weare, N. E., J. N. Antonevich, R. E. Monroe, and D. C. Martin
RESEARCH AND DEVELOPMENT OF PROCEDURES FOR JOINING OF SIMILAR AND DISSIMILAR HEAT-RESISTING ALLOYS BY ULTRASONIC WELDING
Rpt. (July 1957 to June 1958), Contract No. AF 33(616)-5342, Feb. 1959. AD 208323 [summarized in 60W1].
FABRICATION-bond: US
Theory
Schedule
Variables
Apparatus: design
Tool: design
Bonding Surface: contamination; mechanical characteristics; preparation; topography
Test: bond monitor; metallurgical exam; pull
DEGRADATION-bond: US
Stress: process
Part: bond
Mechanism: fatigue; hardening
Test: metallurgical exam; pull
EXPERIMENTAL

60J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
FUNDAMENTALS OF ULTRASONIC WELDING-PHASE II
Final Rpt. (Dec. 1, 1958 to Feb. 1, 1960), Contract No. NOas 59-6070-c, Dec. 1960. AD 257514.
FABRICATION-bond: US
Theory
Procedure
Schedule
Variables
Apparatus: description
Test: metallurgical exam; visual inspection
TEST-bond: US
Description: bond monitor
EXPERIMENTAL

60J2 Jones, J. B., W. C. Elmore and C. F. De Prisco
METHOD AND APPARATUS EMPLOYING VIBRATORY ENERGY FOR BONDING METALS
U.S. Patent 2,946,119; July 26, 1960.
FABRICATION-bond: US
Theory
Evaluation: US
Procedure
Variables
Apparatus: design
Test: metallurgical exam
PATENT

60W1 Weare, N. E., J. N. Antonevich, and R. E. Monroe
FUNDAMENTAL STUDIES OF ULTRASONIC WELDING
Welding J., vol. 39 (supplement), pp. 331S-341S, Aug. 1960. [summary of 59W1]
FABRICATION-bond: US
Theory: US
Schedule
Variables
Apparatus: design
Tool: design
Bonding Surface: contamination; mechanical characteristics; preparation; topography
Test: metallurgical exam, pull
DEGRADATION-bond: US
Stress: process
Part: bond
Mechaniam: hardening; fatigue
Test: metallurgical exam, pull
EXPERIMENTAL

61A1 Anderson, O. L. and H. Christensen
THERMO-COMPRESSION BONDING OF METAL TO SEMICONDUCTORS, AND THE LIKE
U.S. Patent 3,006,067; Oct. 31, 1961.
FABRICATION-bond: TC; wire: Ag, Al, Au, Au/Cu, Cu, Sn/Cu; substrate: Ge, Si
Theory
Procedure
Variables
Test: pull; visual inspection
PATENT

61A2 Ayre, R. S.
TRANSIENT RESPONSE TO STEP AND PULSE FUNCTIONS
Shock and Vibration Handbook, Volume 1 Basic Theory and Measurements
C. M. Harris and C. E. Crede, Eds., McGraw-Hill Book Co., Inc., New York, 1961, pp. 8-1 to 8-54.
TEST
Application: mechanical shock
THEORETICAL

61B1 Bernstein, L.
GOLD ALLOYING TO GERMANIUM, SILICON AND ALUMINUM-SILICON EUTECTIC SURFACES PART 2
Semicond. Prod., vol. 4, pp. 35-39, Aug. 1961
DEGRADATION
Stress: therm
Part: bond
Mechanism: intermetallics
EXPERIMENTAL

61D1 De Prisco, C. F.
METHOD AND APPARATUS FOR BONDING METALS
U.S. Patent 3,002,270; Oct. 3, 1961.
FABRICATION-bond: US
Evaluation: apparatus
Apparatus: adjustment
Test: shear
PATENT

61G1 Goetzberger, A.
INVESTIGATION OF CRYSTAL IMPERFECTIONS BY MEANS OF AVALANCHE BREAKDOWN PATTERNS OF VERY THIN DIFFUSED JUNCTIONS IN SILICON
International Conf. on Semiconductor Physics, Prague, 1960, Academic Press, New York, 1961, pp. 808-811.
DEGRADATION-bond: TC; wire: Au; substrate: Si
Stress: process
Part: substrate
EXPERIMENTAL

61J1 Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft
PHENOMENOLOGICAL CONSIDERATIONS IN ULTRASONIC WELDING
Welding J., vol. 40 (supplement), pp. 289S-305S July 1961. [summary of 59J1]
FABRICATION-bond: US
Theory
Evaluation: US; metal system
Schedule
Variables
Test: bond monitor; bond temperature; metallurgical exam; photoelastic stress analysis; radiotracer
TEST-bond: US
Description: bond monitor
EXPERIMENTAL

62J1 Jones, J. B.
VIBRATORY WELDING PROCESS AND APPARATUS
U.S. Patent 3,056,192; Oct. 2, 1962.
TEST-bond: US
Description: bond monitor
PATENT

62M1 Matsuura, E., K. Matsui, and R. R. Hasiguti
TECHNIQUE FOR OHMIC CONNECTING LEADS TO SILICON
J. Appl. Phys., vol. 33, pp. 1610-1611, April 1962.
FABRICATION-bond: TC; wire: Ag, Au, Cu; film: Al, Bi, Ga, In, Sb; substrate: Ge, Si
Procedure
DESCRIPTIVE

62P1 Peterson, J. M., H. L. McKaig, and C. F. De Prisco
ULTRASONIC WELDING IN ELECTRONIC DEVICES
IRE Intern. Conv. Record, vol. 10, pt. 6, pp. 3-12, 1962.
FABRICATION-bond: US
Theory
Evaluation: US
Apparatus: description
DESCRIPTIVE

63L1 Longo, T. A. and B. Selikson
ALUMINUM WIRE BONDING OF SILICON TRANSISTORS
Semicond. Prod., vol. 6, pp. 27-31, Nov. 1963.
DEGRADATION-bond: TC; wire: Al, Au, Ag; film: Al, Au; substrate: Si, FeNiCo
Stress: process; thermal
Part: bond
Mechanism: intermetallics
ANALYTIC

63M1 McKinnon, M. C. and R. F. Hoeckelman
MECHANICAL AND ELECTRICAL PROPERTIES OF THERMOCOMPRESSION BONDS
IEEE Intern. Conv. Record, vol. 11, pt. 6, pp. 93-[illegible]3, March 1963.
FABRICATION-bond: TC, wire: Al, Au, Cu, Pt, Ti, Zr; film: Al, Au/Al, Au/Cr, NiCr, Ta, Ti; substrate: Si
Theory
Evaluation: bond (adhesion)
Schedule
Variables
Apparatus: design
Test: pull; resistance; visual inspection
EXPERIMENTAL

63P1 Phillips, L. S.
THERMOCOMPRESSION BONDING TO THIN FILM MICROCIRCUITS
Brit. Commun. Electron., vol. 10, pp. 456-458, June 1963.
FABRICATION-bond: TC; wire: Au; film: Al/Cr, Au/Cr; substrate: ceramic, glass
Evaluation: TC; bond (adherence)
Schedule
Variables
Bonding Surface: preparation; topography
Test: pull; resistance; temperature cycle; thermal shock; visual inspection
DESCRIPTIVE

63W1 Weiler, P. M., Ed.
PRODUCTION ENGINEERING MEASURE 2N914 AND 2N995
Final Rpt. (May 1, 1962-Oct. 31, 1963), Contact No. DA-36-039-SC-86726, Oct. 1963. AD 429 920
FABRICATION-bond: TC, US; wire: Ag, Al, Au, Pl; film: Ag, Ag/Al; Ag/Cr, Ag/Cr-Al, Al, Au, Au/Ag/Cr-Al, Au/Pl
Evaluation: TC; US; metal system (TC); tool (TC,US); wire (US)
Schedule: US
Variables: US
Apparatus: adjustment (TC); description (US); design (TC, US)
Tool: design (TC, US)
Wire: mechanical characteristics
Test: centrifuge, mechanical shock, pull, thermal shock, vibration (variable frequency)
TEST
Description: centrifuge; mechanical shock; pull; thermal shock; vibration (variable frequency)
DESCRIPTIVE

64A1 Ar le, W. K.
FR. TION TECHNIQUE FOR OPTIMUM THERMOCOMPRESSION BONDS
IEEE Trnas. Component Parts, vol. CP-10, pp. 25-29, Dec. 1964
FABRICATION-bond: TC; wire: Ag, Al, Au; substrate: Si
Theory
Schedule
Variables
Test: shear
EXPERIMENTAL

64C1 Cohn, A.
GOLD BONDING WIRES
Semicond. Prod. Solid State Technol., vol. 7, pp. 18-20, July 1964.
FABRICATION-wire: Au, Au/Ni, Au/Pt, Au/W
Wire: care; mechanical characteristics
DESCRIPTIVE

64C2 Clunie, J. M. and N. H. Rock
THE LASER FEEDBACK INTERFEROMETER
J. Sci. Instruments, vol. 41, pp. 489-492, Aug. 1964.
TEST-bond: US
Application: bond monitor
EXPERIMENTAL

64D1 Davidson, K. W.
RELIABILITY IMPROVEMENT PROCESS EVALUATION
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 1, sect. 14, pp. 14.1-14.34, June 1964. AD 645221
FABRICATION-bond: TC; wire: Al; film: Al, Au
Evaluation: bond (stitch)
TEST-bond: TC; wire: Al
Evaluation: pull (nondestructive)
DESCRIPTIVE

64D2 De Prisco, C. F. and W. M. Barfield
METHOD AND MEANS FOR OPERATING A GENERATING MEANS COUPLED THROUGH A TRANSDUCER TO A VIBRATORY ENERGY WORK PERFORMING DEVICE
U.S. Patent 3,158,928; Dec. 1, 1964.
FABRICATION-bond: US
Apparatus: adjustment
PATENT

64H1 Hill, P.
UNIFORM METAL EVAPORATION
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 2, sect. 27, pp. 27.1-27.10, June 1964. AD 645222
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness; preparation
EXPERIMENTAL

64H2 Howell, J. R. and J. W. Slemmons
EVALUATION OF THERMOCOMPRESSION BONDING PROCESSES
Presented to 9th Welded Electric Packaging Association Symposium, Santa Monica, California, Feb. 27, 1964; Autonetics Report No. T4-240/3110, March 1964. (13)
FABRICATION-bond: TC; wire: Au; film: Al, Pt; substrate: Si
Procedure
Schedule
Variables
Control: temperature
Tool: design
Bonding Surface: contamination; topography
Test: pull
TEST-bond: TC
Evaluation: visual inspection
REVIEW

64J1 Johnson, W. G.
LEAD BONDING MACHINE
U.S. Patent 3,125,906; March 24, 1964.
FABRICATION-bond: TC
Apparatus: design
PATENT

64M1 Myers, D. K.
SMALL BALL BONDING
Proc. Conf. on Reliability of Semiconductor Devices and Integrated Circuits, vol. 2, sect. 28, pp. 28.1-28.6, June 1964. AD 645222
FABRICATION-bond: TC; wire: Au; film: Al
Evaluation: bond (ball); tool
Procedure
Apparatus: design
Test: centrifuge; mechanical shock; thermal shock; vibration (variable frequency)
DESCRIPTIVE

64P1 Partridge, J., L. D. Hanley and E. C. Hall
PROGRESS REPORT ON ATTAINABLE RELIABILITY OF INTEGRATED CIRCUITS FOR SYSTEMS APPLICATION
Symp. on Microelectronics and Large Systems, Washington, D. C., cosponsored by ONR and UNIVAC, Nov. 1964. (12)
DEGRADATION-bond: TC; wire: Au; film: al
Stress: process; test (centrifuge)
Part: wire; bond
Mechanism: intermetallics
DESCRIPTIVE

64S1 Selikson, B., and T. A. Longo
A STUDY OF PURPLE PLAGUE AND ITS ROLE IN INTEGRATED CIRCUITS
Proc. IEEE, vol. 52, pp. 1638-1641, Dec. 1964.
DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au; substrate: FeNiCo, Si
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: pull
FABRICATION-wire: Al, Au; film: Ag/Cr, Al, Au, Cr/Al, Pl, Pt
Evaluation: metal system
DESCRIPTIVE

64U1 Univac
FINAL REPORT FOR INTEGRATED CIRCUIT STUDY
Contract No. NObsr 89341, Aug. 1964. AD 605432
DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au
Stress: process; test (centrifuge, mechanical shock, thermal shock); thermal
Part: wire; bond; metallization
Mechanism: intermetallics
Failure Rates
EXPERIMENTAL

64W1 Worlton, D. C. and R. A. Walker
METHOD AND DEVICE FOR CONTROLLING ULTRASONIC WELDING APPARATUS
U.S. Patent 3,153,850; Oct. 27, 1964.
TEST-bond: US
Description: bond monitor
PATENT

65B1 Baker, D. and I. E. Bryan
AN IMPROVED FORM OF THERMOCOMPRESSION BOND
Brit. J. Appl. Phys., vol. 16, pp. 865-871, June 1965. [similar to 66B4]
FABRICATION-bond: TC; wire: Al, Au; film: Al, Au; substrate: FeNiCo
Evaluation: bond (ball, wedge); tool; wire
Schedule: TC
Tool: design
Bonding Surface: contamination
Test: centrifuge, pull, pull (nondestructive)
TEST-bond: TC
Description: pull (nondestructive)
Correlation: centrifuge; pull
DESCRIPTIVE

65C1 Cohen, J.
PLATINUM-SILICON THERMO-COMPRESSION BONDS
Solid State Electron., vol. 8, p. 79, Jan. 1965.
FABRICATION-bond: TC; wire: Pt; substrate: Si
Procedure
DESCRIPTIVE

65C2 Cummings, D. G.
IDENTIFICATION OF THERMAL COMPRESSION BOND FAILURES
IEEE WESCON Convention Record, vol. 9, Session 16B.1, pp. 1-3, July 1965. [2]
TEST-bond: TC; wire: Au; film: Al
Precaution: resistance
DESCRIPTIVE

65C3 Colteryahn, L. E. and D. D. Shaffer
CHARACTERIZATION OF FAILURE MODES IN GOLD-ALUMINUM THERMOCOMPRESSION BONDS
IEEE WESCON Convention Record, vol. 9, Session 16B.2, pp. 1-8, July 1965. [2]
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; visual inspection
DESCRIPTIVE

65C4 Colteryahn, L. E. and J. F. Kersey
FAILURE MECHANISMS AND KINETICS OF INTERMETALLIC FORMATION
IEEE WESCON Convention Record, vol. 9, Session 16B.3, pp. 1-10, July 1965. [2]
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; pull
EXPERIMENTAL

65C5 Cunningham, J. A.
EXPANDED CONTACTS AND INTERCONNEXIONS TO MONOLITHIC SILICON INTEGRATED CIRCUITS
Solid State Electron, vol. 8, pp. 735-745, April 1965.
FABRICATION-bond: TC; wire: Au; film: Al, Au, Au/Ag, Au/Co, Au/Cr, Au/Mo, Au/Ni; substrate: Si
Evaluation: metal system; metallization
Bonding Surface: film thickness
Test: pull
DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au, Au/Mo
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: centrifuge; pull; temperature cycle; vibration (fatigue)
ANALYTIC

65D1 Daniels, H. P. C.
ULTRASONIC WELDING
Ultrasonics, vol. 3, pp. 190-196, Oct.-Dec. 1965
FABRICATION-bond: US; wire: Al, Au; substrate: Ge, glass, Si
Theory
Variables
Apparatus: design
Tool: design
Bonding Surface; topography
REVIEW

65H1 Howell, J. R.
INFLUENCE OF BONDING VARIABLES ON AU/AL TC BOND FAILURE
Proc. Second Physics of Failure Colloquim (CQAP), pp. 71-79, June 4, 1965, presented on March 29, 1965 at North American Aviation, Inc., Autonetics, Anaheim, California 92803, [similar to 65H2] (13)
FABRICATION-bond: TC; wire: Au; film: Al; substrate: glass
Variables
Control: temperature
Bonding Surface: film thickness; preparation
Test: pull
DEGRADATION-bond: TC; wire: Au; film: Al; substrate: glass

65H1 (cont.)

Stress: thermal
Part: wire; bond
Mechanism: intermetallics
Test: metallurgical exam; pull
EXPERIMENTAL

65H2 Howell, J. R. and J. W. Kanz
TIME-TEMPERATURE EFFECTS ON GOLD-ALUMINUM THERMOCOMPRESSION BONDS
IEEE WESCON Convention Record, vol. 9, Session 16B.4, pp. 1-19, July 1965. [2]
FABRICATION-bond: TC; wire: Au, film: Al; substrate: glass
Variables
Control: temperature
Bonding Surface: film thickness; preparation
Test: pull; metallurgical exam
DEGRADATION-bond: TC; wire: Au; film: Al; substrate: glass
Stress: thermal
Part: wire; bond
Mechanism: intermetallics
Test: metallurgical exam; pull; resistance
EXPERIMENTAL

65H3 Hakim, E. B. and B. Reich
U.S. ARMY ADVANCEMENT IN TRANSISTOR RELIABILITY THROUGH MANUFACTURING PROCESS IMPROVEMENTS
IEEE Trans. Reliability, vol. R-14, pp. 94-99, Oct. 1965. [see p. 98]
TEST
Evaluation: thermal shock
DESCRIPTIVE

65J1 Jones, J. B., G. W. Fable, A. L. Jamieson, E. F. Nippes, N. E. Promisel, F. N. Rhines, and R. K. Sager
ULTRASONIC WELDING
Welding Handbook, A. L. Phillips, Ed., American Welding Society, New York, 1965, Chapt. 49, pp. 1-48. [8]
FABRICATION-bond: US
Theory
Procedure
Schedule
Variables
Apparatus: design
Test: bond monitor; metallurgical exam; pull
REVIEW

65K1 Kramer, I. R.
EFFECT OF SURFACES ON MECHANICAL BEHAVIOR OF METALS
Proc. 3rd Symp. on Fundamental Phenomena in the Materials Sciences, Boston, Mass.; vol. 3, pp. 171-193, Jan. 1965.
FABRICATION
Wire: contamination; mechanical characteristics; topography
DEGRADATION
Part: wire
Mechanism: fatigue
ANALYTIC

65M1 Maki, C. E., F. W. Hagert, H. J. Avil, L. Kirvida, M. N. Asmus, W. T. Sackett, Jr., C. R. Seashore
DETECTION OF ELECTRICAL FAULTS BY R. F. TECHNIQUES
Mater. Eval., vol. 23, pp. 285-291, June 1965.
TEST
Description: noise
EXPERIMENTAL

65N1 Neppiras, E. A.
ULTRASONIC WELDING OF METALS
Ultrasonics, vol. 3. pp. 128-135, July-Sept. 1965.
FABRICATION-bond: US
Theory
Procedure
Variables
Apparatus: design
DESCRIPTIVE

65R1 Ruggiero, E. M.
ALUMINUM BONDING IS KEY TO 40-WATT MICROCIRCUITS
Electronics, vol. 38, pp. 98-104, Aug. 23, 1965.
FABRICATION-bond: TC; wire: Al, Au; film: Al, Au
Evaluation: bond (ball, stitch, wedge); wire
Procedure
Test: centrifuge; mechanical shock; vibration (variable frequency)
DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au
Stress: thermal
Part: bond
Mechanism: intermetallics
DESCRIPTIVE

65R2 Ruggiero, E. M.
GOLD-ALUMINUM ADHESION AND REACTION ON SEMICONDUCTOR SURFACES
Proc. IEEE Annual Microelectronics Symp., pp. 6B-1 to 6B-4, May 1965. [2] (14)
DEGRADATION-bond: TC; wire: Au; film: Al; substrate: alumina, BN, glass, Si
Stress: process; thermal
Part: bond
Mechanism: intermetallics

65R2 (cont.)

FABRICATION-film: Al; substrate: alumina, BN, glass, Si
Evaluation: metal system; wire
Bonding Surface: preparation
ANALYTIC

65S1 Slemmons, J. W. and J. R. Howell
BETTER BONDING METHODS INPROVE HYBRID CIRCUITS
Electronics, vol. 38, pp. 86-92, March 22, 1965.
FABRICATION-bond: TC; wire: Au; film: Al, Au/NiCr, Cu/NiCr; substrate: alumina, Si
Procedure
Control: temperature
Test: pull
DESCRIPTIVE

65S2 Soltau, R.
FAILURE MODES AND MECHANISMS IN MICRO-ELECTRONIC DEVICES
Seminar on Reliability in Space Vehicles, Los Angeles, Calif., April 2, 1965. (15)
DEGRADATION-bond: TC; wire: Au; film: Al, Au; substrate: Si
Stress: process; test (centrifuge); thermal
Part: wire; bond; metallization; substrate
Mechanism: contamination; corrosion; intermetallics; thermal mismatch
Test: centrifuge; resistance
DESCRIPTIVE

65S3 Szasz, P. R.
BIND-BEAK WIRE BONDING INSTRUMENT FOR THERMOCOMPRESSIVELY SECURING LEADS TO SEMICONDUCTOR DEVICES
U.S. Patent 3,216,640; Nov. 9, 1965.
FABRICATION-bond: TC
Apparatus: design
Tool: design
PATENT

65W1 Wasson, R. D.
THERMOCOMPRESSION BOND TESTER
Proc. IEEE, vol. 53, pp. 1736-1737, Nov. 1965.
TEST
Description: pull
DESCRIPTIVE

66A1 Antle, W. K.
DETERMINING THERMOCOMPRESSION BONDING PARAMETERS BY A FRICTION TECHNIQUE
Trans. Met. Soc. AIME, vol. 236, pp. 392-396, March 1966. [similar to 64A1]
FABRICATION-bond: TC; wire: Ag, Al, Au; film: Al, Au, Ni; substrate: Si
Theory
Schedule
Variables
Test: shear
EXPERIMENTAL

66A2 Angelucci, T. L. and F. W. Kulicke, Jr.
NAIL HEAD BONDING APPARATUS FOR THERMO-COMPRESSIVELY SECURING LEAD WIRE TO SEMI-CONDUCTOR DEVICES
U.S. Patent 3,250,452; May 10, 1966.
FABRICATION-bond: TC
Procedure
Apparatus: design
PATENT

66B1 Bagrowski, J., S. G. Konsowski, Jr., and G. D. Spencer
INTERCONNECTION OF MONOLITHIC INTEGRATED CIRCUITS THROUGH THE USE OF ADVANCED MATERIALS AND TECHNIQUES
IEEE Trans. Pts. Materials Packaging, vol. PMP-2, pp. 90-98, Dec. 1966.
FABRICATION-bond: TC, US
Evaluation: TC, US
Variables: TC, US
DESCRIPTIVE

66B2 Browning, G. V.
FAILURE MECHANISMS IN MICROCIRCUITS
Proc. Second Int. Symp. on Microelectronics, pp. 485-516, Munich, Germany, Oct. 1966. (13)
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: process
Part: wire; bond
Mechanism: intermetallics
Failure Rates
DESCRIPTIVE

66B3 Blech, I. A. and H. Sello
SOME NEW ASPECTS OF GOLD-ALUMINUM BONDS
J. Electrochem. Soc., vol. 113, pp. 1052-1054, Oct. 1966.
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; resistance
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
ANALYTIC

66B4 Baker, D. and R. Jones
NEW DEVELOPMENTS IN THERMOCOMPRESSION BONDING
Microelectronics and Reliability, vol. 5, pp. 229-234, Aug. 1966. [similar to 65B1]
FABRICATION-bond: TC; wire: Al, Au; film: Al, Au; substrate: Al, FeNiCo, Si
Theory
Evaluation: bond (ball, wedge); tool
Tool: design
Bonding Surface: contamination
Test: pull, pull (nondestructive)
DEGRADATION-bond: TC; wire: Al; film: Au; substrate: FeNiCo
Stress: thermal
Part: wire; bond
Mechanism: intermetallics
Test: pull
TEST-bond: TC; wire: Al
Description: pull (nondestructive)
DESCRIPTIVE

66B5 Browning, G. V., L. E. Colteryahn and D. G. Cummings
FAILURE MECHANISMS ASSOCIATED WITH THERMOCOMPRESSION BONDS IN INTEGRATED CIRCUITS
Physics of Failure in Electronics, vol. 4, RADC Series in Reliability, M. E. Goldberg and J. Vaccaro, Eds., 1966, pp. 428-446. AD 637529
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: process; thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; resistance
DESCRIPTIVE

66B6 Bikerman, J. J.
SOLID TO SOLID ADHESION
Symposium on Fundamental Phenomena in the Materials Sciences, 2nd, Boston, 1964. Surface phenomena. L. J. Bonis and H. H. Hausner, Ed. "Fundamental Phenomena in the Materials Sciences, vol. 2", Plenum Press, New York, 1966, pp. 165-174.
FABRICATION-bond: TC, US
Theory
DESCRIPTIVE

66B7 Brandewie, G. V., P. H. Eisenberg, and R. A. Meyer
INVESTIGATION OF SURFACE FAILURE MECHANISMS IN SEMICONDUCTOR DEVICE BY ENVELOPE AMBIENT STUDIES
Physics of Failure in Electronics, vol. 4, M. E. Goldberg and J. Vaccaro, Eds., RADC Series in Reliability, 1966, pp. 493-521. AD 637529. [see pp. 510-516]
DEGRADATION-film: Al
Stress: moisture
Part: metallization
Mechanism: corrosion
EXPERIMENTAL

66C1 Conti, R. J.
THERMOCOMPRESSION JOINING TECHNIQUES FOR ELECTRONIC DEVICES AND INTERCONNECTS
Metals Eng. Quart., vol. 6, pp. 29-35, Feb. 1966.
FABRICATION-bond: TC; wire: Ag, Au, Au/Cu, Cu/Ni; substrate: alumina, glass
Evaluation: TC
Schedule
Variables
Control: temperature
Tool: design
Wire: size
Bonding Surface: contamination
Test: pull; thermal shock
DESCRIPTIVE

66C2 Clews, K. J. and J. G. Young
METALLURGICAL EVALUATION OF MICROCIRCUIT INTERCONNEXIONS MADE BY THE PARALLEL-GAP PROCESS
Microelectronics and Reliability, vol. 5, pp. 207-208, Aug. 1966.
FABRICATION
Evaluation: bond
Test: metallurgical exam
DESCRIPTIVE

66E1 Eimbinder, J.
LINEAR INTEGRATED CIRCUITS
EEE, vol. 14, pp. 76-86, Nov. 1966.
FABRICATION-bond: TC, US
Evaluation: TC; US; bond (ball, stitch, wedge)
DESCRIPTIVE

66G1 Go, H. T., N. J. McAfee and H. C. Jones
MICROELECTRONICS RELIABILITY FROM A SYSTEM MANUFACTURER'S POINT OF VIEW
Second Int. Symp. on Microelectronics; Munich, Germany, Oct. 1966. (16)
DEGRADATION
Stress: process
Part: wire; bond
Mechanism: contamination; intermetallics
Test: centrifuge; thermal cycle; vibration (variable frequency)
DESCRIPTIVE

66G2 Gianelle, W. H.
ANALYSIS OF SEVEN SEMICONDUCTOR METALLURGY SYSTEMS USED ON SILICON PLANAR TRANSISTORS
Physics of Failure in Electronics, vol. 4, M. E. Goldberg and J. Vaccaro, Eds., RADC Series in Reliability, 1966, pp. 46-57. AD 637529
FABRICATION-bond: TC; wire: Ag, Al, Au; film: Ag, Ag/Cr, Al, Au, Au/Mo
Evaluation: bond (ball, wedge); metal system; wire
Bonding Surface: film thickness
Test: pull; resistance
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: wire; bond
Mechanism: grain growth; intermetallics
Test: pull; resistance
ANALYTIC

66H1 Hammond, V. J.
THIN-FILM PREPARATION IN RELATION TO MICROBONDING
Microelectronics and Reliability, vol. 5, pp. 213-217, Aug. 1966.
FABRICATION-bond: TC, US; film: Al, Al/Cr, Au, Au/Cr; substrate: ceramic, glass
Evaluation: metallization
Bonding Surface: preparation
DESCRIPTIVE

66I1 IEC
BASIC ENVIROMENTAL TESTING PROCEDURES FOR ELECTRONIC COMPONENTS AND ELECTRONIC EQUIPMENT PART 2: TESTS—TEST F: VIBRATION
IEC Recommendation, publication 68-2-6 (1966) and supplements 68-2-6A, 68-2-6B and 68-2-6C; 1966-1969. [3]
TEST
Description: vibration (variable frequency, fatigue
STANDARD

66K1 Khorouzan, M. and L. Thomas
CONTAMINATION OF ALUMINUM BONDS IN INTEGRATED CIRCUITS
Trans. Met. Soc. AIME, vol. 236, pp. 397-405, March 1966.
DEGRADATION-bond: US; wire: Al; film: Al; substrate: FeNiCo
Stress: process; test (thermal cycle); thermal
Part: wire; bond
Mechanism: anneal; contamination; grain growth
Test: pull
ANALYTIC

66K2 Koedam, M.
DETERMINATION OF SMALL DIMENSIONS BY DIFFRACTION OF A LASER BEAM
Philips Tech. Rev., vol. 27, pp. 208-212, Nov. 2, 1966.
FABRICATION
Wire: size
DESCRIPTIVE

66K3 Köllner, H.
METHOD AND DEVICE FOR BONDING A CONTACT WIRE TO A SEMICONDUCTOR MEMBER
U.S. Patent 3,289,452; Dec. 6, 1966.
FABRICATION-bond: TC
Apparatus: design
PATENT

66L1 Larson, R. B.
MICROJOINING PROCESSES FOR ELECTRONIC PACKAGING PART 3
Assembly Engineering, vol. 9, pp. 30-33, Nov. 1966. (17)
FABRICATION-bond: TC; wire: Au
Evaluation: bond (ball, stitch, wedge); temperature control
Procedure
Variables
Control: temperature
DESCRIPTIVE

66L2 Landis, D.
CATASTROPHIC FAILURES IN SEMICONDUCTOR DEVICES EXPOSED TO PULSED RADIATION
IEEE Trans. Nucl. Sci., vol. NS-13, pp. 591-600, June 1966.
DEGRADATION-bond: TC; wire: Au
Stress: radiation
Part: bond
ANALYTIC

66L3 Langenecker, B.
EFFECTS OF ULTRASOUND ON DEFORMATION CHARACTERISTICS OF METALS
IEEE Trans. Sonics Ultrason., vol. SU-13, pp. 1-8, March 1966.
FABRICATION-bond: US
Wire: mechanical characteristics
DEGRADATION-bond: US
Stress: process
Part: wire
Mechanism: hardening
REVIEW

66L4 Lombardi, J., L. McDonough, H. Padden
HIGH RELIABILITY SCREENING OF SEMICONDUCTOR AND INTEGRATED CIRCUIT DEVICES
Final Rpt., Contract NAS 5-9639, Sept. 196.. N67-16772
TEST
Description: centrifuge; temperature cycle; vibration (monitored, variable frequency); visual inspection; x-ray
Evaluation: centrifuge; temperature cycle; vibration (monitored, variable frequency); visual inspection; x-ray
DESCRIPTIVE

66M1 Mann, R. M.
BAD WELD DETECTOR USES INTEGRATED CIRCUITS
EDN, vol. 11, pp. 108-112, July 1966.
TEST
Description: resistance
DESCRIPTIVE

66O1 Oswald, K. B., Jr.
FRACTURE OF SILICON AND GERMANIUM INDUCED BY PULSED ELECTRON IRRADIATION
IEEE Trans. Nucl. Sci., vol. NS-13, pp. 63-69, Dec. 1966.
DEGRADATION
Stress: radiation
Part: substrate
Mechanism: spallation
EXPERIMENTAL

66P1 Partridge, J., E. C. Hall, and L. D. Hanley
THE APPLICATION OF FAILURE ANALYSIS IN PROCURING AND SCREENING OF INTEGRATED CIRCUITS
Physics of Failure in Electronics, vol. 4, M. E. Goldberg and J. Vaccaro, Eds., RADC Series in Reliability, 1966, pp. 95-139. AD 637529
TEST
Description: centrifuge; vibration (variable frequency); mechanical shock; Mil-Std-750; temperature cycle; visual inspection
Screening Procedures
DESCRIPTIVE

66R1 Riben, A. R., and S. L. Sherman
MICROBONDS FOR HYBRID MICROCIRCUITS PROGRESS REPORT
Rpt. 8 (Nov. 1, 1965-Jan. 31, 1966), Contract No. DA 36-039 AMC-03742 (E), May 20, 1966. AD 633723 [summarized in 67L1]
FABRICATION-bond: US; wire: Al, film: Au/Cr; substrate: alumina, beryllia, sapphire
Evaluation: US
Schedule
Wire: mechanical characteristics
Bonding Surface: film thickness; topography
Test: pull; resistance
DEGRADATION-bond: US; wire: Al; film: Au/Cr; substrate; alumina, beryllia, sapphire
Stress: thermal
Part: metallization
Test: pull, resistance
TEST-bond: US; wire: Al; film: Au/Cr; substrate: alumina, beryllia, sapphire
Correlation: pull; resistance
EXPERIMENTAL

66W1 Wagner, R.
SEMICONDUCTOR DEVICES WITH SILVER-GOLD LEAD WIRES ATTACHED TO ALUMINUM CONTACTS
U.S. Patent 3,271,635, Sept. 6, 1966.
FABRICATION: wire: Au, Au/Ag; film: Al
Evaluation: metal system; wire
Test: pull
DEGRADATION
Mechanism: intermetallics
PATENT

67A1 Arleth, J. M. and R. D. Demenus
NEW TEST FOR THERMOCOMPRESSION MICROBONDS
Electron. Prod., vol. 9, pp. 92, 94, May 1967.
TEST-bond: TC; wire: Au; film: Al, Au
Description: shear
DEGRADATION-bond: TC; wire: Au; film: Al, Au
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: shear
DESCRIPTIVE

67A2 Avedissian, M. K.
THERMOCOMPRESSION BONDING APPARATUS
U.S. Patent 3,313,464, April 11, 1967.
FABRICATION-bond: TC
Procedure
Apparatus: design
PATENT

67A3 Anstead, R. J.
FAILURE ANALYSIS USING A SCANNING ELECTRON MICROSCOPE
Proc. 6th Annual Reliability Physics Symposium, Los Angeles, Calif. pp. 127-137, Nov. 1967. [2]
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al
Stress: process
Part: wire; bond
Mechanism: intermetallics
Test: visual inspection (SEM)
DESCRIPTIVE

67B1 Bobo, S. N.
MICROELECTRIC WELDING – AN APPROACH TO IMPROVED RELIABILITY
Proc. SAE Electronic Packaging Conf. New York, N. Y., pp. 6-12, Feb. 1967.
TEST
Description: IR Monitor
DESCRIPTIVE

67B2 Beadles, R. L.
INTEGRATED SILICON DEVICE TECHNOLOGY VOLUME XIV
Rpt. (Jan. 1966-March 1967), Contract AF 33 (615)-3305, May 1967. AD 654630. [see pp. 23-48]
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Al/Cr, Au, Au/Cr
Theory: TC, US
Evaluation: US, TC; bond (ball, stitch, wedge)
Procedure: TC, US
Schedule: TC
Variables: TC
Apparatus: description (US)
Tool: design (TC)
Wire: care
DEGRADATION
Mechanism: intermetallics
REVIEW

67B3 Blech, I. A., and H. Sello
THE FAILURE OF THIN ALUMINUM CURRENT-CARRYING STRIPS ON OXIDIZED SILICON
Physics of Failure in Electronics, vol. 5, T. S. Shilliday and J. Vaccaro, Eds., RADC Series in Reliability, 1967, pp. 496-505. AD 655397
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: electrical; thermal
Part: bond
Mechanism: electromigration; intermetallics
DESCRIPTIVE

67B4 Bayer, R. G. and T. S. Burke
APPLICATION OF THE ULTRASONIC RESONANCE TECHNIQUE TO INSPECTION OF MINIATURE SOLDERED AND WELDED JUNCTIONS
Mater. Eval., vol. 25, pp. 20-24, Jan. 1967.
TEST
Description: US probe
DESCRIPTIVE

67C1 Cunningham, J. A. and J. G. Hayser
SEMICONDUCTOR RELIABILITY: FOCUS ON THE CONTACTS
EE, vol. 26, pp. 74-79, Jan. 1967.
FABRICATION-bond: TC; wire: Al, Au; film: Al, Au/Mo, Au/Mo/Pt
Evaluation: metallization; bond (ball, wedge)
Bonding Surface: metal system; preparation
DEGRADATION-bond: TC; wire: Al, Au; film: Al, Au/Mo, Au/Mo/Pt
Stress: thermal
Part: bond
Mechanism: corrosion; intermetallics
DESCRIPTIVE

67C2 Cline, J. E. and S. Schwartz
ELECTRON MICROPROBE TECHNIQUES FOR FAILURE ANALYSIS OF SILICON PLANAR DEVICES
Proc. 6th Annual Reliability Physics Symposium, Los Angeles, Calif. pp. 193-200, Nov. 1967. [2]
DEGRADATION
Stress: process
Part: bond
Mechanism: contamination
Test: electron microprobe
DESCRIPTIVE

67C3 Chen, G. K. C.
ON THE PHYSICS OF PURPLE PLAGUE FORMATION, AND THE OBSERVATION OF PURPLE PLAGUE IN ULTRASONICALLY JOINED GOLD-ALUMINUM BOND
IEEE Trans. Pts. Material Packaging, vol. PMP-3, pp. 149-153, Dec. 1967.
DEGRADATION-bond: US; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: pull; resistance
TEST-bond: US; wire: Au; film: Al
Correlation: pull, resistance
ANALYTIC

67C4 Cunningham, J. A.
THE PLAGUES IN SEMICONDUCTOR CONTACTS
EE, vol. 26, p. 39, April 1967.
DEGRADATION
Mechanism: intermetallics
REVIEW

67G1 Gill, W. L. and W. Workman
RELIABILITY SCREENING PROCEDURES FOR INTEGRATED CIRCUITS
Physics of Failure in Electronics, vol. 5, RADC Series in Reliability, T. S. Shilliday and J. Vaccaro, Eds., 1967, pp. 101-141. AD 655397
DEGRADATION-bond: TC; wire: Au; film: Au/Mo
Stress: process; test (centrifuge, thermal shock); thermal
Part: wire; bond; metallization; substrate
Mechanism: contamination
Test: centrifuge; shear; visual inspection
Failure Rates
TEST-bond: TC; wire: Au; film: Au/Mo

67G1 (cont.)

Evaluation: centrifuge; shear; visual inspection; x-ray
Screening Procedures
FABRICATION
Evaluation: package
DESCRIPTIVE

67G2 Graham, R. A. and R. E. Hutchison
THERMOELASTIC STRESS PULSES RESULTING FROM PULSED ELECTRON BEAMS
Appl. Phys. Lett., vol. 11, pp. 69-72, July 15, 1967.
TEST
Application: mechanical shock (radiation-induced)
ANALYTIC

67H1 Higbie, T. E.
THERMOCOMPRESSION BONDING OF GOLD WIRE FOR MICROELECTRONIC CIRCUITS
Report No. NAFI-TR-1108, Oct. 1967. AD 671879
FABRICATION-bond: TC; wire: Au; film: Al, Au
Procedure
Schedule
Variables
Apparatus: adjustment
Test: pull
TEST-bond: TC; wire: Au; film: Au
Description: pull
DESCRIPTIVE

67H2 Haigler, E. D.
ULTRASONIC SCISSORS BONDING INSTRUMENT
U S. Patent 3,314,582; April 18, 1967.
FABRICATION-bond: US
Apparatus: design
PATENT

67I1 IEC
BASIC ENVIROMENTAL TESTING PROCEDURES FOR ELECTRONIC COMPONENTS AND ELECTRONIC EQUIPMENT PART 2: TESTS — TEST EA: SHOCK
IEC Recommendation, publication 68-2-27 and supplement 68-2-27A; 1967-1968. [3]
TEST
Description: mechanical shock
STANDARD

67J1 Jones, J. B.
ULTRASONIC WELDING
Proc. CIRP Int. Conf. on Mfg. Technol., sponsored by ASTME, pp. 1387-1409, Sept. 1967. (18)
FABRICATION-bond: US
Theory
Schedule
Variables
Apparatus: design
Test: bond monitor, metallurgical exam
REVIEW

67K1 Koshinz, E. F.
THERMOCOMPRESSION BONDING — AN OVERVIEW
Proc. 1967 Welding Congress, pp. 86-94, Stuttgart, Germany, 1967. [In German] (19)
FABRICATION-bond: TC; wire: Al, Au; film: Ag/Cr, Al, Au, Au/Mo/Pt
Evaluation: bond (ball, wedge); metal system; temperature control
Procedure
Variables
Test: centrifuge; pull
DEGRADATION-bond: TC; wire: Au; film: Al
Mechanism: intermetallics
REVIEW

67K2 Keen, R. S., L. R. Loewenstern and G. L. Schnable
MECHANISMS OF CONTACT FAILURES IN SEMICONDUCTOR DEVICES
Proc. 6th Annual Reliability Physics Symp. Los Angeles, Calif., pp. 216-233, Nov. 1967. [2]
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: resistance
REVIEW

67L1 Lane, W. V.
MATERIALS FOR CONDUCTIVE ELEMENTS PART II — CONNECTIONS TO THIN FILMS
IEEE Intern. Conv. Record, vol. 15, pt. 7, pp. 129-145, 1967. [summary of 66R1, 67R2]
FABRICATION-bond: US; wire: Al; film: Al, Au/Cr, substrate: alumina, beryllia, glass, sapphire, Si; silica (96%); application: hybrid devices
Evaluation: US; wire bond
Schedule
Apparatus: description
Bonding Surface: film thickness; preparation; topography
Test: pull; visual inspection
DEGRADATION: bond: US; wire: Al; film: Al, Au/Cr; substrate: alumina, beryllia, glass, sapphire, Si; silica (96%); application: hybrid devices
Stress: process; thermal
Part: bond; metallization; wire
Mechanism: intermetallics
Test: pull; resistance
EXPERIMENTAL

67P1 Parker, C. D.
INTEGRATED SILICON DEVICE TECHNOLOGY VOLUME XV RELIABILITY
Rpt. (March 1966-March 1967), Contract No. AF 33(615)-8306, May 1967. AD 655082 [see pp. 35-65]
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au, Au/Mo; substrate: FeNiCo, Si
Stress: process; thermal
Part: bond
Mechanism: contamination; intermetallics
Failure Rates
TEST
Screening Procedures
FABRICATION-bond: TC, US; wire: Al, Au; film: Ag, Ag/Cr, Al, Au, Au/Mo; substrate: Si
Evaluation: metal system metallization, wire
Procedure
REVIEW

67P2 Pruden, D. H. and D. Schoenthaler
METHODS OF BONDING ELECTRICAL CONDUCTORS TO ELECTRICAL COMPONENTS
U.S. Patent 3,302,277; Feb. 7, 1967.
TEST-bond: US
Description: bond monitor
PATENT

67R1 Riben, A. R. and S. L. Sherman
MICROBONDS FOR HYBRID MICROCIRCUITS
Physics of Failure in Electronics, vol. 5, RADC Series in Reliability, T. S. Shilliday and J. Vaccaro, Eds., 1967, pp. 534-556. AD 655397. [Summary of 66R1, 67R2]
FABRICATION-bond: US; wire: Al; film: Al, Au/Cr; substrate: alumina, beryllia, silica (96%); application: hybrids
Evaluation: US
Schedule
Variables
Tool: design; wear
Wire: mechanical characteristics
Bonding Surface: film thickness; topography
DEGRADATION-bond: US; wire: Al; film: Al, Au/Cr
Stress: process; thermal
Part: bond; metallization
Mechanism: intermetallics
Test: pull; resistance
TEST-bond: US; wire: Al; film: Al, Au/Cr; substrate: alumina, beryllia, sapphire; silica (96%)
Correlation: pull; resistance
EXPERIMENTAL

67R2 Riben, A. R. and S. L. Sherman
MICROBONDS FOR HYBRID MICROCIRCUITS
Final Rpt. (Feb. 1, 1964-April 30, 1966) Contract Number DA 36-039 AMC-03742(E), Jan. 1967. AD 647464
FABRICATION-bond: US; wire: Al (pure), Al; film: Al, Au/Cr; substrate: alumina, sapphire, Si, silica (96%)
Evaluation: metal system
Procedure
Schedule
Apparatus: description
Rigidity: apparatus
Wire: mechanical characteristics
Bonding Surface: film thickness; preparation; topography
Test: pull; resistance; thermal shock; visual inspection
DEGRADATION-bond: US; wire: Al, Al (pure); film: Al, Au/Cr; substrate: alumina, sapphire, Si, silica (96%)
Stress: process; test (thermal shock); thermal
Part: wire; bond; metallization
Mechanism: intermetallics
Test: pull; resistance
TEST-bond: US; wire: Al, Al (pure); film: Al, Au/Cr; substrate: alumina, sapphire, Si, silica (96%)
Evaluation: pull; resistance
Correlation: pull; resistance
EXPERIMENTAL

67R3 Reber, R. L.
STEPPED BONDING WEDGE
U.S. Patent 3,347,442; Oct. 17, 1967.
FABRICATION
Tool: design
PATENT

67R4 Rasimenoks, P., T. L. Angelucci, and F. W. Kulicke, Jr.
THERMOCOMPRESSION WIRE BONDING APPARATUS WITH SCISSORS CUT-OFF
Patent 3,307,763; March 7, 1967.
FABRICATION-bond: TC
Apparatus: design
PATENT

67S1 Schnable, G. L. and R. S. Keen
METALLIZATION AND BONDS — A REVIEW OF FAILURE MECHANISMS
Proc. 6th Annual Reliability Physics Symp., Los Angeles, Calif. pp. 170-192, Nov. 1967. [2]
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au, Au/Mo
Stress: process; thermal; test (centrifuge)
Part: wire; bond
Mechanism: intermetallics
Failure Rates
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au, Au/Mo
Evaluation: TC; US
Apparatus: design (US)
Tool: design (TC, US)
REVIEW

67S2 Scarbrough, R. J. D. and J. Auchterlonie
THE ISOLATION OF A FAILURE MODE IN SILICON PLANAR TRANSISTORS CAUSED BY ORGANIC RESIDUES ASSOCIATED WITH ALUMINUM WIRE
Microelectronics and Reliability, vol. 6, pp. 319-321, Nov. 1967.
DEGRADATION-wire: Al
Stress: thermal
Part: device
Mechanism: contamination
Test: electrical parameter
ANALYTIC

67S3 Schile, R. D., and G. A. Rosica
SIMPLE TESTER FOR THE RAPID DETERMINATION OF THE TENSILE STRENGTH OF FINE FILAMENTS
Rev. Sci. Instr., vol. 38, pp. 1103-1104, Aug. 1967.
TEST
Application: pull
DESCRIPTIVE

67S4 Schumacher, D. H.
MEASURING MICROBOND INTEGRITY WITH AN INFRARED MICRORADIOMETER
Soc. for Nondestructive Testing, Inc., Fall Conf. ; Cleveland, Ohio, Oct. 1967 (20)
TEST-bond: TC; wire: Au/Cu, film: Au; substrate: ceramic
Description: IR Monitor
Evaluation: IR Monitor
ANALYTIC

67S5 Selikson, B.
FAILURE MECHANISM INTEGRATED CIRCUIT INTERCONNECT SYSTEMS
Proc. 6th Annual Reliability Physics Symposium, Los Angeles, Calif. pp. 201-208, Nov. 1967. [2]
DEGRADATION-bond: TC; wire: Al, Au; film: Ag/Cr; Al, Au/Mo, Au/Mo/Al, Au/Pt/Ti, Cr/Al
Stress: process; thermal
Part: wire: bond
Mechanism: anneal, intermetallics
Test: pull
FABRICATION-bond: TC; wire: Al, Au; film: Ag/Cr, Al, Au/Mo, Au/Mo/Al, Au/Pt/Ti, Cr/Al
Evaluation: metal system
REVIEW

67T1 Tiffany, P.
VIBRATORY WELDING TIP AND METHOD OF WELDING
U.S. Patent 3,357,090; Dec. 12, 1967.
FABRICATION-bond: US; wire: Au
Procedure
Tool: design
PATENT

67V1 van Lancker, M.
METALLURGY OF ALLUMINUM ALLOYS
John Wiley and Sons, Inc., New York 1967.
FABRICATION-wire: Al, Al (pure), Al/Mg
Wire: mechanical characteristics
REVIEW

68A1 Adams, A. H. and J. H. Anderson, Jr.
MEANS FOR GRIPPING FINE WIRES DURING MECHANICAL TESTS
Rev. Sci. Instr., vol. 39, p. 1768, Nov. 1968.
TEST
Application: pull
DESCRIPTIVE

68A2 Avedissian, M. K. and J. S. Manowczak
SEQUENTIAL WIRE AND ARTICLE BONDING METHODS
U.S. Patent 3,397,451; Aug. 20, 1968.
FABRICATION-bond: TC
Procedure
PATENT

68A3 Anderson, J. H., Jr. and W. P. Cox
AGING EFFECTS IN AU-AL AND AL-AL BONDS USED IN MICROELECTRONICS
Proc. 7th Annual Reliability and Maintainability Conf., pp. 533-536, San Francisco, Calif., July 1968. [7], (21)
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al
Stress: thermal
Part: wire; bond
Mechanism: anneal, intermetallics
Test: pull; resistance
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
EXPERIMENTAL

68B1 Berry, R. W., P. M. Hall, and M. T. Harris
THIN FILM TECHNOLOGY
Van Nostrand Reinhold Co., Princeton, New Jersey, 1968, pp. 604-632.
FABRICATION-bond: TC, US
Theory: TC, US
Procedure: TC, US
Schedule: TC
Apparatus: design (US)
Control: temperature (TC, US)
Tool: design (TC)
Wire: size (TC)

68B1 (cont.)

Test: pull
TEST
Description: centrifuge; IR monitor; metallurgical exam; pull
Evaluation: noise; resistance
REVIEW

68D1 Dummer, G. W. A, and J. M. Robertson, Eds.
ELECTRONIC CONNECTION TECHNIQUES AND EQUIPMENT 1968-1969
Pergamon Press, New York, 1968.
FABRICATION-bond: TC, US
Apparatus: description
DESCRIPTIVE

68D2 Department of Defense
TEST METHODS AND PROCEDURES FOR MICROELECTRONICS
Military Standard 883, May 1, 1968; Notice 1, May 20, 1968; Notice 2, Nov. 20, 1969. [1]
TEST-bond: TC, US
Description: air blast; centrifuge; mechanical shock, Mil-Std-883; pull; resistance, shear; temperature cycle; thermal shock; vibration (fatigue, monitored, variable frequency); visual inspection; x-ray
Screening Procedures
STANDARD

68E1 Electronic Design
TEST YOUR IC IQ
Electronic Design, vol. 15, p. 84, July 18, 1968.
TEST
Precaution: resistance
DESCRIPTIVE

68E2 Electronic Design
TEST YOUR IC IQ
Electronic Design, vol. 2, p. 108, Jan. 18, 1968.
DEGRADATION
Failure Rates
REVIEW

68F1 Floyd, H. L., Jr.
A TECHNIQUE FOR DETERMINING TRANSISTOR SPALL THRESHOLDS
Sandia Corp. Rpt. No. SC-M-68-186A, April 1968. [22]
TEST-bond: US, TC
Description: mechanical shock (radiation-induced)
Evaluation: mechanical shock; mechanical shock (radiation-induced)
DEGRADATION-bond: TC, US; wire: Al, Au
Stress: test (mechanical shock (radiation-induced))
Part: bond
Mechanism: spallation
THEORETICAL

68G1 Gaffney, J.
INTERNAL LEAD FATIGUE THROUGH THERMAL EXPANSION IN SEMICONDUCTOR DEVICES
IEEE Trans. Electron Devices, vol. ED-15, p. 617, Aug. 1968.
DEGRADATION-bond: TC; wire: Al, Au; film: Al
Stress: thermal
Part: wire
Mechanism: fatigue
FABRICATION-bond: TC; wire: Al; film: Al
Wire: mechanical characteristics
DESCRIPTIVE

68G2 Gaffney, J., D. Bottaro and C. D. Root
INTERNAL LEAD FATIGUE IN SEMICONDUCTOR DEVICES THROUGH THERMAL EXPANSION
Presentation abstracts 7th Annual Reliability Physics Symp., Washington, D. C., p. 28, Dec. 1968. [2]
DEGRADATION-bond: TC; wire: Al; film: Al
Stress: thermal
Part: wire
Mechanism: fatigue
EXPERIMENTAL

68H1 Harris, D. H.
MEASURING THE ACCURACY OF HUMAN INSPECTION
Mater. Res. Std., vol. 8, pp. 8-12, Dec. 1968.
TEST
Application: visual inspection
DESCRIPTIVE

68H2 Holmes, P. J., and I. C. Jennings
FAILURE ANALYSIS OF PLANAR TRANSISTORS USED IN THE UK3 SATELLITE PROGRAMME
Microelectronics and Reliability, vol. 7, pp. 37-44, Feb. 1968.
DEGRADATION-bond: TC; wire: Au; film: Al, Au
Stress: process
Part: wire; bond
Mechanism: contamination; intermetallics; thermal mismatch
Failure Rates
DESCRIPTIVE

68H3 Hill, W. H., and G. D. Hrench
RECENT ADVANCES IN PULSE-HEATED WIRE BONDING FOR HYBRID MICROELECTRONICS
Proc. NEPCON, June 1968. Also Hughes Welding Note — Bulletin 109. [4] (23)
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au, Cr; substrate: alumina, glass, Si; application: hybrid devices
Evaluation: TC; US; temperature control; tool (TC); wire (TC)
Apparatus: description (TC)
Control: temperature (TC)
Tool: design (TC); wear (TC)
DESCRIPTIVE

68H4 Howard, R. E.
HOW TO USE IC RELIABILITY SCREENING TECHNIQUES
Eval. Eng., vol. 7, pp. 22-26, Nov.-Dec. 1968.
TEST
Evaluation: centrifuge; mechanical shock, pull; temperature cycle; thermal shock; visual inspection; x-ray
DESCRIPTIVE

68H5 Helda, R. W. and W. E. LaPoint
METHOD OF BONDING FILAMENTARY MATERIAL
U.S. Patent 3,400,448; Sept. 10, 1968.
FABRICATION-bond: TC
Procedure
Apparatus: design
PATENT

68I1 IEC
BASIC ENVIROMENTAL TESTING PROCEDURES FOR ELECTRONIC COMPONENTS AND ELECTRONIC EQUIPMENT PART 2: TESTS — TEST GA: ACCELERATION, STEADY STATE
IEC RECOMMENDATION, PUBLICATION 68-2-7, 1968. [3]
TEST
Description: centrifuge
STANDARD

68J1 Johnson, C. A.
HOT GAS THERMO-COMPRESSION BONDING
U.S. Patent 3,409,977; Nov. 12, 1968.
FABRICATION-bond: TC
Control: temperature
PATENT

68K1 Koshinz, E. F.
SEMICONDUCTOR: WIRE BONDING AND FACE BONDING CONSIDERATIONS AND COMPARISONS
Proc. SAE Microelectronic Packaging Conf., Palo Alto, Calif., pp. 94-100, Nov. 1968. (19)
FABRICATION-bond: TC, US; wire: Al, Au; film: Ag/Cr, Al, Au, Au/Cr/Al, Au/Mo/Pt
Evaluation: TC, US
Procedure: TC, US
Variables: TC, US
REVIEW

68L1 Lawhorne, S., and J. N. Ramsey
SIMPLIFIED X-RAY EXAMINATION OF SOLID STATE DEVICES
Solid State Technol., vol. 11, pp. 37-39, Nov. 1968.
TEST-wire: Au
Description: x-ray
DEGRADATION-wire: Au; application: plastic devices
Stress: process
Part: wire
Test: x-ray
DESCRIPTIVE

68M1 McCormick, J. E.
ON THE RELIABILITY OF MICROCONNECTIONS
Electron. Packag. Prod., vol. 8, pp. 187-189, June 1968.
DEGRADATION-bond: TC, US; wire: Al, Au
Failure Rates
FABRICATION-bond: TC, US
Evaluation: TC; US
DESCRIPTIVE

68M2 Muncheryan, H. M.
HOW TO USE FAILURE ANALYSIS TO IMPROVE SEMICONDUCTOR RELIABILITY
EE, vol. 27, pp. 49-54, May 1968.
DEGRADATION-bond: TC, wire: Au; film: Al, Au
Stress: process
Part: bond; metallization; substrate
Mechanism: contamination; intermetallics
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au/Cr, Au/Cu/Ti, Au/Mo, Au/Ni, Au/Pt/Ti, Pt/Ti
Evaluation: metal system
DESCRIPTIVE

68M3 McHale, P. and H. Fenster
INCREASED YIELDS IN HYBRID THICK FILM CIRCUITS BY INDIRECT ACTIVE DEVICE ATTACHMENT
IEEE Microelectronics Symp., St. Louis, Missouri, pp. D7-1 to D7-6, June 1968. [2] (24)
FABRICATION-bond: TC; wire: Au; film: Al; application: hybrid devices
Evaluation: bond (ball, stitch)
Control: temperature
DESCRIPTIVE

68P1 Poston, M. H.
TIME-TEMPERATURE EFFECTS ON WIRE BONDS
IEEE Microelectronics Symp., St. Louis, Missouri, pp. 1-21, June 1968. [?], (25)
FABRICATION-bond: TC; wire: Au; film: Al
Variables
Control: force; temperature
DEGRADATION: TC; wire: Au; film: Al
Stress: process; thermal
Part: bond
Mechanism: anneal; grain growth; intermetallics
Test: pull; visual inspection
TEST-bond: TC; wire: Au; film: Al
Description: pull
DESCRIPTIVE

68R1 Rodrigues de Miranda, W. R.
VISUAL INSPECTION OF IC'S BOOSTS RELIABILITY AT LITTLE COST
Electronics, vol. 41, pp. 104-108, Aug. 19, 1968.
TEST-bond: TC, US; wire: Al, Au
Description: visual inspection
DESCRIPTIVE

68R2 Ruggiero, E. M.
ALUMINUM BONDING FOR HIGH-POWER IC'S
Microelectronic Packaging, George Sideris, Ed., McGraw-Hill, New York, 1968, chapt. 7.3, pp. 240-248.
FABRICATION-bond: TC; wire: Al, Au; film: Al, Au
Evaluation: bond (ball, stitch, wedge), wire
Procedure
Test: centrifuge, mechanical shock, vibration (variable frequency)
DEGRADATION: bond: TC; wire: Al, Au; film: Al, Au
Stress: thermal
Mechanism: intermetallics
Failure Rates
DESCRIPTIVE

68S1 Shockley, W. L. and R. W. Weedfall
ULTRASONIC BONDING
Microelectronic Packaging, George Sideris, Ed., McGraw-Hill, New York, 1968, chapt. 7.2, pp. 232-240. [see p. 239]
FABRICATION-bond: US; wire: Au, Au/Ga
Wire: care; mechanical characteristics
Bonding Surface: orientation
DESCRIPTIVE

68T1 Takei, W. J. and M. H. Francombe
MEASUREMENT OF DIFFUSION-INDUCED STRAINS AT METAL BOND INTERFACES
Solid State Electron., vol. 11, pp. 205-208, Feb. 1968.
DEGRADATION
Stress: thermal
Part: bond
Mechanism: intermetallics
EXPERIMENTAL

68T2 Tanaka, S. and K. Chiba
SEMICONDUCTOR DEVICE UTILIZING AN $AUAL_2$ LAYER AS A DIFFUSION BARRIER THAT PREVENTS 'PURPLE PLAGUE'
U.S. Patent 3,401,316; Sept. 10, 1968.
FABRICATION-bond: TC, US; wire: Au, Al; film: Ag/Al, $AuAl_2$, Al, Cr; substrate: Si
Evaluation: metal system; metallization
Bonding Surface: metal system, preparation
PATENT

68U1 Uthe, P. M.
THE WIRE
Uthe Technology, Inc. Technical Newsletter, vol. 1, Sept. 1968. [summarized in 69U1] (5)
FABRICATION-bond: US; wire: Al, Al/Mg, Au
Evaluation: wire
Schedule
Tool: design
Wire: mechanical characteristics
Test: pull; visual inspection
DEGRADATION-bond: US; wire: Al; film: Al
Stress: process
Part: substrate
DESCRIPTIVE

68U2 Uthe, P. M.
THE SOLID STATE WELD
Uthe Technology, Inc. Technical Newsletter, vol. 1, May 1968. [summarized in 69U1] (5)
FABRICATION-bond: US
Theory
DESCRIPTIVE

68U3 Uthe, P. M.
THE FRICTION OF NON-LUBRICATED METALS
Uthe Technology, Inc. Technical Newsletter, vol. 1, June 1968. [summarized in 69U1] (5)
FABRICATION-bond: US
Theory
DESCRIPTIVE

68U4 Uthe, P. M.
WELDING
Uthe Technology, Inc. Technical Newsletter, vol. 1, July 1968. [summarized in 69U1] (5)
FABRICATION-bond: US

68U4 (cont.)

Theory
Schedule
Control: force; power; time
DESCRIPTIVE

68U5 Uthe. P. M.
A SIMPLE WIRE BONDER
Uthe Technology, Inc. Technical Newsletter, vol. 1, Aug. 1968. [summarized in 69U1] (5)
FABRICATION-bond: US
Apparatus: adjustment; design
Rigidity: apparatus; terminal
DESCRIPTIVE

69A1 Ang, C. Y., P. H. Eisenberg and H. C. Mattraw
PHYSICS OF CONTROL OF ELECTRONIC DEVICES
Proc. 1969 Annual Symp. on Reliability, Chicago, Ill., pp. 73-85, Jan. 1969. [see pp. 76, 62] (13)
TEST-bond: TC; wire: Au
Correlation: pull; pull (nondestructive)
DESCRIPTIVE

69A2 Anderson, J. H., Jr. and W. P. Cox
FAILURE MODES IN GOLD-ALUMINUM THERMOCOMPRESSION BONDS
IEEE Trans. Reliability, vol. R-18, pp. 206-207, Nov. 1969.
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond; metallization
Mechanism: intermetallics
FABRICATION-bond: TC; wire: Au; film: Al
Bonding Surface: film thickness
EXPERIMENTAL

69A3 Antler, M.
WHAT DO GOLD PLATING SPECS REALLY MEAN?
Products Finishing, vol. 34, pp. 56-66, Oct. 1969.
FABRICATION-film: Au
Bonding Surface: contamination; film thickness; mechanical characteristics; preparation; topography
DESCRIPTIVE

69B1 Bell, J. L.
UPGRADING OF MICROELECTRONIC TEST PROCEDURES FOR MILITARY HI-REL ACHIEVEMENT
Trans. 23rd Annual Technical Conf., pp. 767-770, Los Angeles, Calif., sponsored by American Society for Quality Control, Ann Arbor, Mich., May 1969.
TEST
Evaluation: temperature cycle; thermal shock
DESCRIPTIVE

69B2 Binelli, W. D., and R. H. Soltau
DEVELOPMENT OF QUALIFICATION TEST PROGRAM FOR MICROELECTRONIC DEVICES,
Final Rpt. (Nov. 1, 1968 to July 3, 1969), Contract No. NAS1-8714, Sept. 1969. N70-11544
TEST
Description: centrifuge, mechanical shock; thermal shock
FABRICATION-bond: US; wire: Al; film: Al, Au
Evaluation: wire bond
Test: centrifuge; mechanical shock; thermal shock
DESCRIPTIVE

69B3 Budd, J. B.
DIE AND WIRE BONDING CAPABILITIES OF REPRESENTATIVE THICK-FILM CONDUCTORS
Solid-State Technol. vol. 12, pp. 59-63, June 1969.
FABRICATION-bond: TC, US; wire: Al, Au; film: Au/Mo/Mn; thick film: Ag, Ag/Pd, Au, Au/Pd, Au/Pd/Pt, Au/Pt, Pd/Ag
Evaluation: wire bond; metallization
Variables
Bonding Surface: preparation
Test: pull
DEGRADATION-bond: TC; wire: Au; thick film: Ag/Pd, Au
Stress: thermal
Test: pull
ANALYTIC

69B4 Browning, G. V.
MONOLITHIC INTEGRATED CIRCUIT FAILURE MECHANISMS
Nat. Electron. Conf. Seminar, *Designing with Monolithic Integrated Circuits*, Nat. Electron, Conf., Chicago, Ill., pp. 1-22, Dec. 1969. (26)
DEGRADATION-bond: TC, wire: Al, Au; film: Al, Au/Mo
Stress: thermal
Part: bond
Mechanism: intermetallics
Failure Rates
REVIEW

69B5 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 488, Quarterly Rpt. (Jan. 1 to March 31, 1969), July 1969. [see pp. 21-25] [30] (29)

69B5 (cont.)

TEST-wire: Al, Au
Application: pull
FABRICATION-bond: US; wire: Al; film: Al
Evaluation: wire (ribbon)
DEGRADATION-bond: US; wire: Al; film: Al
Stress: thermal
Part: wire
Mechanism: anneal
Test: pull
DESCRIPTIVE

69B6 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 495, Quarterly Rpt. (April 1-June 30, 1969), Sept. 1969. [see pp. 24-31] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Evaluation: bond (ball); wire (ribbon)
Apparatus: adjustment
Tool: oscillation
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
DESCRIPTIVE

69B7 Bellin, J. L. S., A. E. Brown, A. S. Hamamoto, and G. C. Knollman
PIEZOELECTRIC MONITOR OF MICROELECTRONIC WIRE BONDS
Lockheed Rpt. LMSC B-62-69-9, June 1969. (21)
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
Correlation: bond monitor, pull, visual inspection
EXPERIMENTAL

69B8 Brinton, J.
MIL STD 883 — A REAL TEST CASE
Electronics, vol. 42, pp. 131-136, Aug. 18, 1969.
TEST
Application: Mil-Std-883
DESCRIPTIVE

69C1 Circuits Manufacturing
A PACKAGING TECHNIQUE IS NOT A BONDING METHOD . . . WIRE-LEADS, FLIP-CHIPS, ULTRASONICS, WHAT'S IT ALL ABOUT?
Circuits Mfg., vol. 9, pp. 8-16, Dec. 1969.
FABRICATION
Evaluation: TC; US; wire bond; bond (ball, stitch, wedge)
DESCRIPTIVE

69C2 Cline, J. E., J. M. Morris, and S. Schwartz
SCANNING ELECTRON MIRROR MICROSCOPY AND SCANNING ELECTRON MICROSCOPY OF INTEGRATED CIRCUITS
IEEE Trans. Electron Devices, vol. ED-16, pp. 371-375, April 1969.
FABRICATION
Test: visual inspection (SEM)
DESCRIPTIVE

69D1 Dudderar, T. D.
THE EFFECT OF GRIP STRESSES ON THE OCCURRENCE OF FAILURE IN TENSION TESTS OF WIRE
Mater. Res. Std., vol. 9, pp. 26-30, Oct. 1969.
TEST
Application: pull
THEORETICAL

69D2 Demer, L. J. and L. H. Fentnor
LAMB WAVE TECHNIQUES IN NONDESTRUCTIVE TESTING
Int. J. Nondestructive Testing, vol. 1, pp. 251-283, Oct. 1969.
TEST
Application: US probe
FABRICATION
Wire: mechanical characteristic
Test: US probe
ANALYTIC

69D3 Department of Defense
MILITARY SPECIFICATION MICROCIRCUITS GENERAL SPECIFICATION FOR —
Mil-M-38510, Nov. 20, 1969. [1]
TEST
Application: Mil-Std-883
Screening Procedures
STANDARD

69G1 Gurland, J.
MICROSTRUCTURAL ASPECTS OF THE STRENGTH AND HARDNESS OF CEMENTED TUNGSTEN CARBIDE
Contract No. SD-86, Dec. 1969. AD 699187
FABRICATION
Tool: design
DESCRIPTIVE

69G2 Grable, R. C. and H. E. Patzer
WIRE BONDING APPARATUS FOR MICROELECTRONIC COMPONENTS
U.S. Patent 3,430,835; March 4, 1969.
FABRICATION-bond: TC; wire: Au
Procedure
PATENT

69H1 Heinen, K. G. and G. B. Larrabee
THE DETERMINATION OF RESIDUAL PHOTORESIST ON SILICON USING RADIOTRACER IODINE-131
Solid State Technol., vol. 12, pp. 44-47, April 1969.
FABRICATION
Bonding Surface: contamination
Test: radiotracer
DESCRIPTIVE

69K1 Kashiwabara, M., S. Nakayama and M. Suzuki
SETTING AND EVALUATION OF ULTRASONIC BONDING FOR AL WIRE
Rev. Elec. Commun. Lab., vol. 17, pp. 1014-1021, Sept. 1969.
TEST-bond: US; wire: Al; film: Al
Description: pull
Evaluation: visual inspection
Correlation: pull; visual inspection
FABRICATION-bond: US; wire: Al; film: Al
Procedure
Bonding Surface: film thickness
ANALYSIS

69K2 Krieg, R. D. and W. B. Murfin
STRUCTURAL CONSIDERATIONS IN ELECTRONIC MICROCIRCUIT LEAD WIRES
March 1969. PB 183544.
TEST
Application: mechanical shock; temperature cycle; thermal shock; vibration
THEORETICAL

69K3 Kashiwabara, M. and S. Hattori
FORMATION OF AL-AU INTERMETALLIC COMPOUNDS AND RESISTANCE INCREASE FOR ULTRASONIC AL WIRE BONDING
Rev. Elec. Commun. Lab., vol. 17, pp. 1001-1013, Sept. 1969.
DEGRADATION-bond: US; wire: Al; film: Au; substrate: FeNiCo
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: metallurgical exam; resistance
FABRICATION: bond: US; wire: Al; film: Au; substrate: FeNiCo
Procedure
Bonding Surface-film thickness
EXPERIMENTAL

69K4 Knollman, G. C., A. S. Hamamoto, and J. L. S. Bellin
REPORTS ON ULTRASONIC SCREENING OF TRANSISTORS AND INTEGRATED CIRCUITS
Lockheed Rpt. LMSC B-62-69-8, June 1969. (21)
TEST-bond: TC, US; wire: Al, Au; film: Al, Au
Description: US stress
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au
Stress: test (US stress)
Part: bond, wire
Failure Rates
EXPERIMENTAL

69L1 Lauffenburger, H. A. and T. R. Myers
SUMMARY AND INTERPRETATION OF RELIABILITY DATA ON VARIOUS MICROCIRCUIT BONDING TECHNIQUES
Proc. Holm Seminar on Electrical Contact Phenomena, pp. 61-68, Nov. 1969. [6]
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au
Stress: process; thermal
Mechanism: anneal; contamination; intermetallics
Test: pull; shear
Failure Rates
TEST
Screening Procedures
REVIEW

69L2 Laub, J. L. and M. N. Mansour
WIRE CLAMP
U.S. Patent 3,430,834; March 4, 1969.
FABRICATION-bond: US
Apparatus: design
PATENT

6901 O'Connell, E. P.
AN INTRODUCTION TO MIL-STD-883 TEST METHODS AND PROCEDURES FOR MICROELECTRONICS
Proc. 8th Reliability and Maintainability Conf., Denver, Colorado, pp. 530-542, July 1969. [10] (27)
TEST
Description: centrifuge; Mil-Std-883; pull; temperature cycle; visual inspection
Evaluation: centrifuge; visual inspection
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au
Stress: thermal
Mechanism: anneal, intermetallics
Test: pull
Failure Rates
REVIEW

6902 Ono, K., M. Nishihata and S. Kobayashi
FINE ALUMINUM TRANSISTOR LEAD WIRES
Rev. Elec. Commun. Lab., vol. 17, pp. 974-988, Sept. 1969.
FABRICATION-bond: TC, US; wire: Al, Al (pure); film: Al, Au

6902 (cont.)

Wire: electrical characteristics; fabrication; mechanical characteristics; topography
Test: pull
DEGRADATION-bond: TC, US; wire: Al; film: Al, Au
Stress: thermal
Part: wire
Mechanism: anneal; grain growth
Test: pull
EXPERIMENTAL

69P1 Plough, C., D. Davis, and H. Lawler
HIGH RELIABILITY ALUMINUM WIRE BONDING
Proc. Electronic Components Conf., Washington, D. C., pp. 157-165, April-May 1969. [2] (28)
FABRICATION-bond: US; wire: Al, Au; film: Al, Au
Theory
Schedule
Variables
Apparatus: adjustment
Tool: design
Rigidity: apparatus; terminal
Bonding Surface: contamination; mechanical characteristics; topography
Test: pull, visual inspection
TEST-bond: US; wire: Al; film: Al, Au
Evaluation: air blast; thermal shock; visual inspection
Correlation: mechanical shock (radiation-induced); pull; visual inspection
DEGRADATION-bond: US; wire: Al, Al/Mg
Stress: thermal
Part: wire; device
Mechanism: anneal, contamination
Test: electrical parameters; pull
DESCRIPTIVE

69R1 Ruth, S. B.
TORTURE TESTS IMPROVE EQUIPMENT RELIABILITY
The Electronic Engineer, vol. 28, pp. 80-87, June 1969.
TEST
Description: centrifuge; mechanical shock; thermal shock; vibration
DESCRIPTIVE

69S1 Slemmons, J. W.
THE MICROWORLD OF JOINING TECHNOLOGY
American Welding Society 50th Annual Meeting and Welding Exposition; Philadelphia, Pa., April-May, 1969. [8] (13)
FABRICATION-bond: TC, US; wire: Al, Au, film: Al, Au
Theory: TC, US
Evaluation: US
Procedure: TC, US
Test: pull
TEST-bond: TC; wire: Au
Description: pull; pull (nondestructive); visual inspection (SEM); x-ray
DEGRADATION: bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: visual inspection (SEM)
REVIEW

69S2 Schnable, G. L. and R. S. Keen
ALUMINUM METALLIZATION ADVANTAGES AND LIMITATIONS FOR INTEGRATED CIRCUIT APPLICATIONS
Proc. IEEE, vol. 57, pp. 1570-1580, Sept. 1969.
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au/Cr, Au/Mo
Evaluation: metallization
REVIEW

69S3 Selikson, B.
VOID FORMATION FAILURE MECHANISMS IN INTEGRATED CIRCUITS
Proc. IEEE, vol. 57, pp. 1594-1598, Sept. 1969.
DEGRADATION-wire: Al, Au; film: Al, Au
Stress: thermal
Part: bond
Mechanism: intermetallics
FABRICATION-wire: Au; film: Au/Ag/Cr, Au/Mo, Au/Ti/Al, Au/Pt/Ti/Pt, Cr/Al
Evaluation: metal system
REVIEW

69S4 Shurtleff, W. O.
RELIABILITY HANDBOOK FOR SILICON MONOLITHIC MICROCIRCUITS VOLUME 2 — FAILURE MECHANISMS OF MONOLITHIC MICROCIRCUITS
Contract NAS 8-20639, April 1969. N69-23226. [see pp. 2-IV-2 to 2-IV-6]
TEST
Description: centrifuge; mechanical shock, temperature cycle; thermal shock; vibration (variable frequency, fatigue)
Evaluation: vibration (variable frequency); visual inspection
DESCRIPTIVE

69S5 Speer, R. D.
CHIP BONDING: PROMISES AND PERILS
Electronic Design, vol. 17, pp. 61-79, Oct. 25, 1969.
FABRICATION-bond: TC, US
Evaluation: wire bond
REVIEW

69T1 Tamburrine, A. L. and V. C. Kapfer
FAILURE MECHANISMS IN PLASTIC ENCAPSULATED MICROCIRCUITS
Contract No. AF-5519, May 1969.
AD 689224
DEGRADATION-bond: TC; wire: Au; film: Ag, Al, Au, Ni; application: plastic devices
Stress: moisture; test (thermal shock); thermal
Part: wire; bond
Mechanism: corrosion; thermal mismatch
ANALYTIC

69T2 Tarowsky, N.
HOW TO ASSEMBLE HYBRID MICROWAVE IC's
Microwaves, vol. 8, pp. 52-62, Aug. 1969.
FABRICATION-bond: TC, US; application: hybrids
Evaluation: TC; US
DESCRIPTIVE

69U1 Uthe, P. M.
VARIABLES AFFECTING WELD QUALITY IN ULTRASONIC ALUMINUM WIRE BONDING
Solid State Technol., vol. 12, pp. 72-76, Aug. 1969.
FABRICATION-bond: US; wire: Al, Al/Mg, Au; film: Al, Au
Theory
Evaluation: wire
Schedule
Apparatus: adjustment; description; design
Tool: adjustment
Rigidity: apparatus; package
Wire: mechanical characteristics
Test: pull, visual inspection
Trouble Shooting
DEGRADATION-bond: US; wire: Al, substrate: Si
Stress: process
Part: substrate
DESCRIPTIVE

69U2 Uthe, P. M., Jr., L. G. Wright, and R. E. Greenan
ULTRASONIC FREQUENCY POWER SUPPLY
U.S. Patent 3,445,750; May 20, 1969.
FABRICATION-bond: US
Apparatus: design
PATENT

70A1 Adams, M. A.
AN INVESTIGATION OF THE STRENGTH OF ALUMINUM WIRE USED IN INTEGRATED CIRCUITS
NASA Tech. Brief 70-10275, Aug. 1970. [9]
TEST-bond: TC, US; wire: Al, Au; film: Al, Au
Description: pull
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au
Stress: test (pull); thermal
Part: wire
Mechanism: anneal; grain growth
Test: visual inspection (SEM)
DESCRIPTIVE

70A2 Anderson, Jr., J. H., T. G. Maple, and W. P. Cox
AGING EFFECTS IN GOLD THERMOCOMPRESSION BONDS TO COMPLEX METALLIZATIONS
IEEE Trans. Reliability, vol. R-19, pp. 32-34, Feb. 1970.
DEGRADATION-bond: TC; wire: Au; film: Al, Au/Mo/Al, Au/Ti/Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: pull; resistance
FABRICATION-bond: TC; wire: Au; film: Al, Au/Mo/Al; Au/Ti/Al
Evaluation: metal system
Bonding Surface: preparation
EXPERIMENTAL

70A3 ASTM
STANDARD SPECIFICATION FOR GOLD WIRE FOR SEMICONDUCTOR LEAD-BONDING (ASTM DESIGNATION: F72-69)
1970 Annual Book of ASTM Standards, part 8, 1970. [11]
FABRICATION-wire: Au
Wire: care; contamination; mechanical characteristics; size
STANDARD

70A4 ASTM
STANDARD METHODS OF TESTING FINE ROUND AND FLAT WIRE FOR ELECTRON DEVICE AND LAMPS (ASTM DESIGNATION: F219-67)
1970 Annual Book of ASTM Standards, part 8, 1970. [11]
FABRICATION
Wire: mechanical characteristics, size
STANDARD

70A5 ASTM
STANDARD METHOD FOR MEASURING DIAMETER OF FINE WIRE BY WEIGHING (ASTM DESIGNATION: F205-63)
1970 Annual Book of ASTM Standards, part 8, 1970. [11]
FABRICATION
Wire: size
STANDARD

70A6 ASTM
STANDARD METHODS OF TENSION TESTING OF METALLIC MATERIALS (ASTM DESIGNATION: E8-69)
1970 Annual Book of ASTM Standards, part 31, 1970. [11]
Test
Application: pull
STANDARD

70A7 ASTM
STANDARD METHOD OF TEST FOR RESISTIVITY OF ELECTRICAL CONDUCTOR MATERIALS (ASTM DESIGNATION: B193-65)
1970 Annual Book of ASTM Standards, part 8, 1970. [11]
FABRICATION
Wire: electrical characteristics
STANDARD

70B1 Bevington, J. R., J. P. Cook, and D. R. Little
PLASTIC IC RELIABILITY EVALUATION AND ANALYSIS
8th Annual Proc. Reliability Physics, IEEE Catalog No. 70C59-PHY, pp. 73-80, 1970. [abbreviated version of 71B3] [2]
TEST-bond: TC; wire: Au; film: Au, Ag; application: plastic devices
Evaluation: thermal shock
DEGRADATION-bond: TC; wire: Au; film: Au; application: plastic devices
Stress: test (thermal shock)
Part: bond; wire
Mechanism: thermal mismatch
EXPERIMENTAL

70B2 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 520, Quarterly Rpt. (July 1-Sept. 30, 1969), March 1970. [see pp. 32-43] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Apparatus: design
Tool: adjustment; design; oscillation
Rigidity: apparatus
Test: interferometry
DEGRADATION-bond: US; wire: Al; film: Al
Stress: thermal
Part: wire
Mechanism: anneal
Test: pull
TEST-bond: US; wire: Al; film: Al
Description: resistance
EXPERIMENTAL

70B3 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 527, Quarterly Rpt. (Oct. 1-Dec. 31, 1969), May 1970. [see pp. 31-47] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Theory
Apparatus: adjustment
Tool: adjustment; oscillation
Rigidity: apparatus
Wire: contamination; mechanical characteristics
Bonding Surface: preparation
Test: pull
EXPERIMENTAL

70B4 Brauer, J. B., V. C. Kapfer, and A. L. Tamburrino
CAN PLASTIC ENCAPSULATED MICROCIRCUITS PROVIDE RELIABILITY WITH ECONOMY?
8th Annual Proc. Reliability Physics, IEEE Catalog. No. 70C59-PHY, pp. 61-72, 1970. [2] (27)
DEGRADATION-application: plastic devices
Stress: moisture, process, test (temperature cycle)
Part: metallization, wire
Mechanism: corrosion; fatigue; thermal mismatch
Test: resistance, x-ray
Failure Rates: general
DESCRIPTIVE

70B5 Bradfield, G.
ULTRASONIC TRANSDUCERS — 1. INTRODUCTION TO ULTRASONIC TRANSDUCERS, PART A
Ultrasonics, vol. 8, pp. 112-123, April 1970.
FABRICATION-bond: US
Apparatus: design
REVIEW

70B6 Bradfield, G.
ULTRASONIC TRANSDUCERS — 1. INTRODUCTION TO ULTRASONIC TRANSDUCERS, PART B
Ultrasonics, vol. 8, pp. 177-189, July 1970.
FABRICATION-bond: US
Apparatus: design
REVIEW

70B7 Bullis, W. M. and A. J. Baroody, Jr., Eds.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 555, Quarterly Rpt. (Jan. 1 to March 31, 1970), Sept. 1970. [see pp. 27-36] [30] (29)

70B7 (cont.)

TEST
Description: centrifuge; pull; US stress
Application: bond monitor
FABRICATION-bond: US
Tool: design
Rigidity: apparatus
Test: pull; visual inspection (SEM)
DESCRIPTIVE

70B8 Bullis, W. M. and A. J. Baroody, Jr., Eds.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 560, Quarterly Rpt. (April 1 to June 30, 1970), Nov. 1970. [see pp. 29-38] [30] (29)
FABRICATION-bond: US
Theory: US
Schedule
Wire: mechanical characteristics
Rigidity: apparatus
Test: pull; visual inspection (SEM)
TEST
Evaluation: pull
Application: pull
DEGRADATION
Stress: process; test (pull)
Part: bond
Test: visual inspection (SEM)
DESCRIPTIVE

70C1 Cox. W. P., E. E. Anderson, and J. H. Anderson, Jr.
ULTRASONIC ALUMINUM WIRE BONDING FOR MICROELECTRONIC APPLICATIONS
Proc. 1970 Annual Symp. on Reliability, Los Angeles, Calif., vol. 3, pp. 228-236, Feb. 1970. (31)
FABRICATION-bond: US; wire: Al; film: Al
Evaluation: wire
Control: force, power, time
Test: pull; resistance; visual inspection
DEGRADATION-bond: US; wire: Al; film: Al
Stress: process, thermal
Part: wire; substrate
Mechanism: anneal
Test: pull, resistance; visual inspection
EXPERIMENTAL

70C2 Curran, L.
PLASTIC IC'S GET FOOT IN MILITARY DOOR
Electronics, vol. 43, pp. 127-130, May 11, 1970.
TEST-application: plastic devices
Description: Mil-Std-883
DESCRIPTIVE

70D1 Devaney, J. R.
APPLICATION OF SCANNING ELECTRON MICROSCOPY TO INTEGRATED CIRCUIT FAILURE
Solid State Technol., vol. 13, pp. 73-77, March 1970.
DEGRADATION-bond: TC; wire: Au; film: Al
Part: bond
Mechanism: contamination
Test: visual inspection (SEM)
DESCRIPTIVE

70D2 Davis, D.
FACTORS IN HIGH RELIABILITY WIRE BONDING
8th Annual Proc. Reliability Physics, IEEE Catalog No. 70C59-PHY, pp. 170-176, 1970. [similar to 69P1] [2] (28)
FABRICATION-bond: US; wire: Al; film: Al, Au
Schedule
Variables
Apparatus: adjustment, design
Tool: adjustment; design; oscillation
Rigidity: apparatus, terminal, package
Bonding Surface: contamination; thickness; topography
Test: pull; visual inspection
TEST-bond: US; wire: Al; film: Al, Au
Correlation: pull; mechanical shock (radiation induced); visual inspection
REVIEW

70D3 Department of Defense
MILITARY STANDARD — TEST METHODS FOR SEMICONDUCTOR DEVICES
Military Standard 750B, Feb. 27, 1970. [1]
TEST
Description: centrifuge; mechanical shock; thermal shock; vibration (fatigue, monitored, variable frequency)
STANDARD

70D4 Dicken, H. K.
SURVEYING CHIP INTERCONNECTION TECHNIQUES
Electron. Packag. Prod., vol. 10, sect. 1, pp. 34-45, Oct. 1970.
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au
Evaluation: TC, US, wire bond
REVIEW

70H1 Hnatek, E. R.
PLASTIC IC'S ENTICE MILITARY
EDN, vol. 15, pp. 43-47, Nov. 15, 1970.
DEGRADATION-application: plastic devices
Stress: test (temperature cycle, thermal shock)
Failure Rates
DESCRIPTIVE

70H2 Haberer, J. R.
STRESS INDUCED INTERMITTENT FAILURES IN ENCAPSULATED MICROCIRCUITS
Report No. RADC-TR-70-213, pp. 1-49, Oct. 1970. AD 715984 [see also 71H2] [1] (27)
TEST-bond: TC; wire: Au; application: plastic devices
Description: resistance; temperature cycle
Evaluation: resistance; temperature cycle
DEGRADATION-bond: TC; wire: Au; application: plastic devices
Stress: moisture, test (temperature cycle)
Part: bond; metallization; wire
Mechanism: corrosion; thermal mismatch
EXPERIMENTAL

70M1 Miller, L. F.
A CRITIQUE OF CHIP-JOINING TECHNIQUES
Solid State Technol., vol. 13, pp. 50-62, April 1970.
FABRICATION
Evaluation: wire bond
REVIEW

70M2 Mann-Nachbar, P., and W. Nachbar
THERMAL SHOCK FOLLOWING RAPID UNIFORM HEATING OF SPHERES AND LONG CYLINDRICAL RODS
Rpt. (April-August, 1968), Contract No. F04701-69-C-0066, Feb. 1970. AD 702170
TEST
Application: mechanical shock (radiation-induced)
THEORETICAL

70P1 Pankratz, J. M. and D. R. Collins
A COMPARISON OF 1% MG-Al AND 1% SI-Al WIRE INTERCONNECTS
8th Annual Proc. Reliability Physics, IEEE Catalog No. 70C59-PHY, pp. 163-169, 1970. [also published in IEEE Trans. Reliability, vol. R-19, pp. 89-94, Aug. 1970] [2] (32)
FABRICATION-bond: US; wire: Al, Al/Mg
Evaluation: wire
Bonding Surface: topography
DEGRADATION-bond: US; wire: Al/Mg
Stress: thermal
Part: device
Mechanism: contamination
EXPERIMENTAL

70P2 Philofsky, E.
INTERMETALLIC FORMATION IN GOLD-ALUMINUM SYSTEMS
Solid State Electron., vol. 13, pp. 1391-1399, Oct. 1970. [also 8th Annual Proc. Reliability Physics Symp., pp. 177-185, 1970]
DEGRADATION-wire: Al, Al (pure), Au
Stress: thermal
Mechanism: intermetallics
Test: metallurgical exam; pull
TEST
Application: temperature cycle; thermal shock
EXPERIMENTAL

70R1 Rossiter, T. J.
AMBIENT EFFECTS ON GOLD-ALUMINUM BONDS
8th Annual Proc. Reliability Physics, IEEE Catalog No. 70C59-PHY, pp. 186-190, 1970. [2] (27)
DEGRADATION-bond: TC; wire: Au; film: Al
Stress: thermal
Part: bond
Mechanism: intermetallics
Test: pull; resistance
EXPERIMENTAL

70S1 Spectrum
HIGH-PRESSURE PROCESS MAKES WIRE BY SQUEEZING
Spectrum, vol. 7, pp. 21, Aug. 1970.
FABRICATION
Wire: fabrication
DESCRIPTIVE

70S2 Straub, R. J.
RELIABILITY OF HYBRID MICROCIRCUITS IN USE TODAY
Proc. Electronic Components Conf., May 1970. [2] (33)
TEST-application: hybrids
Evaluation: Mil-Std 883
Screening Procedures
DEGRADATION-bond: TC; application: hybrids
Failure Rates
DESCRIPTIVE

70V1 Villella, F. and M. F. Nowakowski
INVESTIGATION OF FATIGUE PROBLEM IN 1-MIL DIAMETER THERMOCOMPRESSION AND ULTRASONIC BONDING OF ALUMINUM WIRE
NASA Technical Memorandum, NASA TM X-64566, pp. 1-45, Nov. 30, 1970. N71-16494
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al
Stress: thermal
Part: wire
Mechanism: fatigue
Test: pull; visual inspection (SEM)
Failure Rates
TEST
Application: temperature cycle
EXPERIMENTAL

70W1 Wilson, A. D., B. D. Martin, and D. H. Strope
HOLOGRAPHIC INTERFEROMETRY APPLIED TO MOTION STUDIES OF ULTRASONIC BONDERS
IEEE Ultrasonics Symp., San Francisco, Calif., Oct. 21-23, 1970. [2] (34)
FABRICATION-bond: US
Apparatus: design
Tool: oscillation
Test: interferometry
DESCRIPTIVE

70W2 Wood, W. A.
FATIGUE CRACK INITIATION AS VIEWED BY SCANNING ELECTRON MICROSCOPY
Contract N-00014-67-A-0214-0011, Rpt., Jan. 1970. AD 704789
DEGRADATION
Stress: mechanical
Part: wire
Mechanism: fatigue
ANALYTIC

71B1 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
NBS Technical Note 571, Quarterly Rpt. (July 1-Sept. 30, 1970), April 1971. [see pp. 23-32] [30] (29)
FABRICATION-bond: US; wire: Al; film: Al
Tool: design; oscillation
Rigidity: apparatus
TEST-bond: US; wire: Al; film: Al
Evaluation: pull
DEGRADATION-bond: US; wire: Al; film: Al
Stress: process
Part: wire
EXPERIMENTAL

71B2 Boylan, J. R.
THERMOCOMPRESSION BONDING
IEEE Intern. Conv. Digest, New York, Session 7C1, pp. 598-599, March 1971. [2]
FABRICATION-bond: TC, US; wire: Al, Au
Evaluation: TC, US; wire bond; temperature control
Procedure: TC
Tool: design (TC)
Rigidity: terminal
REVIEW

71B3 Bevington, J. R., J. P. Cook, D. R. Little, and L. V. Ingle
RELIABILITY EVALUATION OF PLASTIC INTEGRATED CIRCUITS
Rpt. (Jan. 9, 1969 to Sept. 9, 1970) Contract No. F30602-69-C-0154, pp. 1-154, Jan. 1971. AD 722043 [70B1 is abbreviated version] [1]
TEST-bond: TC; wire: Au; film: Ag, Au; application: plastic devices
Evaluation: thermal shock
DEGRADATION-bond: TC; wire: Au; film: Au; application: plastic devices
Stress: test (thermal shock)
Part: bond; wire
Mechanism: thermal mismatch
EXPERIMENTAL

71B4 Bullis, W. M., Ed.
METHODS OF MEASUREMENT FOR SEMICONDUCTOR MATERIALS, PROCESS CONTROL, AND DEVICES
Quarterly Rpt. (Oct. 1-Dec. 31, 1970) NBS Technical Note 592. [see pp. 34-45], [30] (29)
TEST-bond: US; wire: Al; film: Al
Description: bond monitor
Application: pull
FABRICATION-bond: US
Apparatus: adjustment (US); design (US)
Rigidity: apparatus
Wire: mechanical characteristics
DEGRADATION: bond: US; wire: Al; film: Al
Stress: process
Part: bond; wire
Mechanism: anneal
Test: pull
DESCRIPTIVE

71D1 Dushkes, S. Z.
A DESIGN OF ULTRASONIC BONDING TIPS
IBM J. Res. Develop., vol. 15, pp. 230-235, May 1971.
FABRICATION-bond: US; wire: Au/CuBeO; film: Au/Cu; substrate: epoxy
Tool: design; oscillation
Test: pull
EXPERIMENTAL

71G1 Glass, R. A., T. G. Maple, and R. D. Wales
INTERCONNECTION PROBLEM AREAS IN MICROCIRCUITS
IEEE Intern. Conv. Digest, New York, Session 5B, pp. 248-249, March 1971. [2]
FABRICATION-bond: US; wire: Al; film: Al, Au; substrate: Fe/Ni/Co
Tool: design
Bonding Surface: contamination; film thickness; metal system; preparation
Test: pull, visual inspection
DEGRADATION-bond: US
Stress: process
Part: wire
TEST-bond: US; wire: Al; film: Al
Correlation: pull, visual inspection
EXPERIMENTAL

71G2 Goldfarb, S.
WIRE BONDS ON THICK FILM CONDUCTORS
Proc. Electronic Components Conf., Washington, D. C., pp. 295-302, May 1971. [2] (36)
DEGRADATION-bond: US; wire: Al, Au; thick film: Au
Stress: thermal
Part: bond; wire
Test: pull; resistance
EXPERIMENTAL

71H1 Harman, G. G. and H. K. Kessler
APPLICATION OF CAPACITOR MICROPHONES AND MAGNETIC PICKUPS TO TUNING AND TROUBLE SHOOTING OF MICROELECTRONIC ULTRASONIC BONDING EQUIPMENT
NBS Tech. Note 573, pp. 1-22, May 1971. [30] (29)
FABRICATION-bond: US
Apparatus: adjustment
Tool: adjustment, oscillation
Trouble Shooting
DESCRIPTIVE

71H2 Haberer, J. R.
TECHNIQUES FOR DETECTING STRESS INDUCED INTERMITTENT FAILURES IN ENCAPSULATED DEVICES
IEEE Intern. Conv. Digest, New York, Session 7CJ, pp. 612-613, March 1971. [see also 70H2]
TEST-bond: TC; wire: Au; application: plastic devices
Description: resistance; temperature cycle
Evaluation: resistance; temperature cycle
DEGRADATION-bond: TC; wire: Au; application: plastic devices
Stress: moisture, test (temperature cycle)
Part: bond; metallization; wire
Mechanism: corrosion; thermal mismatch
EXPERIMENTAL

71H3 Hart, R. R.
A WIRE EXTENSOMETER FOR DETERMINING THE MECHANICAL PROPERTIES OF FINE WIRES
Mater. Res. Std., vol. 11, pp. 26-28, April 1971.
FABRICATION
Wire: mechanical characteristics
EXPERIMENTAL

71J1 Johannesen, F.
ULTRASONIC ALUMINUM WIRE BONDING
IEEE Intern. Conv. Digest, Session 7CI, pp. 600-601, March 1971.
FABRICATION-bond: US; wire: Al; film: Al, Au; substrate: Fe/Ni/Co
Variables
Apparatus: design
Tool: design, wear
Rigidity: apparatus, package
Bonding Surface: topography
REVIEW

71K1 Kalvelage, B. F.
A PNEUMATIC SHOCK TESTER FOR ELECTRON DEVICES
Solid State Technol., vol. 14, pp. 57-59, March 1971.
TEST
Description: mechanical shock
DESCRIPTIVE

71K2 King, C. M.
DYNAMIC SIMULATION OF AN ULTRASONIC WIRE BONDING TOOL
Raytheon Report ER71-4135, Contracts N0003070-C0055 and N0003071-C0061, Jan. 25, 1971. (35)
TEST
Application: bond monitor
THEORETICAL

71L1 Leyshon, W. E., and R. E. Warr
AN OVERVIEW OF HYBRID INTEGRATED CIRCUIT RELIABILITY PROBLEMS AND SOLUTIONS
IEEE Intern. Conv. Digest, New York, Session 7CJ, pp. 606-607, March 1971.
DEGRADATION-application: hybrid devices
Stress: moisture; test (temperature cycle)
Part: metallization, wire
Mechanism: contamination; corrosion; fatigue; intermetallics
Test: resistance
REVIEW

71M1 Matcovich, T. J.
INTERCONNECTIONS IN HYBRID CIRCUITS
IEEE Intern. Conv. Digest, New York, Session 5B, pp. 240-241, March 1971.
FABRICATION-bond: TC, US
Evaluation: wire bond
REVIEW

71N1 NASA
LINE CERTIFICATION REQUIREMENTS FOR MICROCIRCUITS
NHB 5300.4(3C), May 1971. [30]
TEST
Description: Mil-Std-883; pull; resistance; visual inspection; visual inspection (SEM)
Application: Mil-Std-883
Screening Procedures
STANDARD

71N2 NASA
TEST STANDARDS FOR MICROCIRCUITS
NHB 5300.4(3D), May 1971. [30]
TEST
Description: mechanical shock; pull; resistance
STANDARD

71P1 Philofsky, E.
DESIGN LIMITS WHEN USING GOLD-ALUMINUM BONDS
9th Annual Proc. Reliability Physics Symp., Las Vegas, IEEE Catalog No. 71-C-9-PHY, 1971. [2] (37)
FABRICATION-bond: TC, US; wire: Al, Au; film: Al, Au
Bonding Surface: film thickness
DEGRADATION-bond: TC, US; wire: Al, Au; film: Al, Au
Stress: test (temperature cycle); thermal
Part: bond; wire
Mechanism: fatigue; intermetallics
ANALYTIC

71P2 Philofsky, E., R. Bowman, and W. Miller
ALUMINUM ULTRASONIC JOINING IN SPIDER AND WIRE CONNECTIONS
Proc. Electronic Components Conf., Washington, D. C., pp. 289-294, May 1971. [2] (37)
FABRICATION-bond: US; wire: Al; film: Al
Theory: US
Evaluation: US
Bonding Surface: topography
REVIEW

71R1 Ravi, K. V. and E. Philofsky
THE STRUCTURE AND MECHANICAL PROPERTIES OF FINE DIAMETER ALUMINUM – 1 PCT SI WIRE
Metallurgical Transactions, vol. 2, pp. 711-717, March 1971.
FABRICATION-bond: TC, US; wire: Al
Evaluation: wire
Wire: mechanical characteristics
DEGRADATION-bond: TC, US; wire: Al
Stress: thermal
Part: wire
Mechanism: anneal; fatigue; grain growth
Test: pull
EXPERIMENTAL

71S1 Straub, R. J. and J. P. Farrell
THE EFFECTIVITY OF SCREENING HYBRID MICROCIRCUITS PER MIL-STD-883
Proc. Electronics Components Conf., Washignton, D. C., pp. 17-26, May 1971. [2] (38)
TEST-bond: TC; wire: Au; film: Al, Au; application: hybrid devices
Screening Procedures
DEGRADATION-bond: TC; wire: Au; film: Al, Au application: hybrid devices
Stress: test (centrifuge, mechanical shock, temperature cycle, thermal shock)
Part: bond, wire
EXPERIMENTAL

Appendix A. Organization of Bibliography

Each entry has been given an *identification code* which consists of a sequence of two digits, a letter, and another digit. The first two digits indicate the year of publication and the letter is the initial of the first author's surname. The last digit is used to distinguish those papers which would otherwise have the same code. No rule was used in the assignment of the last digit. The papers in the bibliography are arranged according to their codes. The codes are grouped first by year, then in alphabetical order by letter, and then in numerical order by the last digit.

Key words (or phrases) are listed beneath each reference in the bibliography to indicate the contents and approach of the paper. Three levels of key words are used to indicate the subject matter of the entries at three levels of detail. These levels and the key words assignments are discussed in Appendix D. A *Key Word Index* is provided and presented in two parts. The first part lists the key words in alphabetical order with the page number where the same key word may be found in the second part of the Index. This second part lists the key words by subject area. With each key word is a tabulation of literature citations (using their identification codes). In both parts of the Index, key words that may require additional definition are followed by clarifying notes, in brackets, except for those for the test methods. Brief descriptions of the test methods may be found in *Table 4*. Here, key words for the test methods are listed in alphabetical order with a brief description for each. The test methods listed are not necessarily restricted to testing wire bonds. However, the descriptive phrases are directed to the particular function described in the papers compiled.

Reading priority is suggested by giving prominence to those papers that are of such scope or relative importance in a particular area that they should be seen first. These papers are so indicated by underlining the identification code for the paper listed under the appropriate key word in the Key Word Index. They are also indicated by underlining the code of the citation and the appropriate key word(s) in the bibliography.

Some citations are followed by notes which refer to additional information intended to assist in obtaining the referenced work. This and other information related to *availability* is included in Appendix C.

A complete *Author Index* is also provided.

Appendix B. Sources for Bibliography and Abbreviations

The *sources* of the bibliography are listed in *Table 1*. Emphasis was placed on searching the report and journal literature from 1965 to 1970. Citations to much of the important earlier work were found in the articles published during this period. Another source of papers was a number of restricted bibliographies, containing references to unrestricted literature, and personal files.

The journal or conference *abbreviations* generally follow those of the *Chemical Abstracts*. In order to minimize any possible confusion, those journals abbreviated are listed in alphabetical order by their abbreviations in *Table 2*. Additional abbreviations are included which are used in citations to some conference meetings. Another purpose of this Table is to indicate those journals which have been scanned completely at least over the period from 1965 to 1970, inclusive. They are indicated by an asterisk in the left-hand margin.

Appendix C. Availability

Some entries in the bibliography have availability notices after the citation to assist in procurement.

The citations to reports available from the *National Technical Information Service (NTIS)*, Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151, are followed by a number preceded by the letters AD or PB, or the letter N. This is the NTIS Acession number which should be used when ordering.

A number of other entries, generally to conference papers, have the citation followed by a number either in brackets or parentheses The number refers to an address listed in *Table 3*. If the number is in brackets the address listed is one to which an order may be placed for the paper or the conference proceedings. If the number is in parentheses the address is that of the first author's place of work at the time the paper was published.

TABLE 1. SOURCES FOR BIBLIOGRAPHY

1. Bibliographic search by the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. A data bank and a report bibliographic search was performed in May, 1969 and updated in June, 1970. A two level search strategy was used: level one - 1. integrated circuits, 2. microelectronics; level two - 1. circuit interconnections, 2. bonding, 3. bonded joints, 4. ultrasonic welding.

2. Bibliographic search by the Reliability Analysis Center, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616. Performed in June 1969.

3. U. S. Patent search. Performed May, 1969.

4. Scientific and Technical Aerospace Reports for the years 1965-1970. Subject categories were: electronics, electronic equipment, and physics.

5. U. S. Government Research and Development Reports for at least the period from 1969-1970. Earlier entries would be included in item 1. Subject fields were electronic and electrical engineering, methods and equipment, and physics

6. Journals in Table 2 that are preceded by an asterisk. Issues of these journals published in the period from 1965 to 1970, inclusive, were examined.

TABLE 2. ABBREVIATIONS AND JOURNALS SEARCHED

AIME - American Institute of Mining, Metallurgical and Petroleum Engineers
ASME - American Society of Mechanical Engineers
ASTM - American Society for Testing and Materials
ASTME - American Society of Tool and Manufacturing Engineers
Appl. Phys. Lett. - Applied Physics Letters
*Bell Lab. Rec. - Bell Laboratories Record
*Bell System Technical Journal
Brit. Commun. Electron. - British Communication and Electronics
Brit. J. Appl. Phys. - British Journal of Applied Physics
Circuits Mfg. - Circuits Manufacturing
Conf. - Conference
*EDN - (formerly Electrical Design News)
*EE - (now, The Electronic Engineer; formerly, Electronic Industries)
*EEE
*Electron. Packag. Prod. - Electronic Packaging and Production
*Electron. Prod. - Electronic Products Magazine
*Electronic Design
*Electronic Engineer - The Electronic Engineer (formerly EE, formerly Electronic Industries)
*Electron. Lett. - Electronics Letters
*Electronics
*Electro-technol. - Electro-technology (New York)
Eval. Eng. - Evaluation Engineering
*IBM Journal of Research and Development
IEEE - Institute of Electrical and Electronics Engineers (formerly IRE)
IEEE Intern. Conv. Record - IEEE International Convention Record (formerly IRE . . .)
*IEEE Trans. Electron Devices -IEEE Transactions on Electron Devices (formerly IRE . . .)
*IEEE Trans. Nucl. Sci. - IEEE Transactions on Nuclear Science
*IEEE Trans. Pts. Materials Packaging - IEEE Transactions on Parts, Materials and Packaging
*IEEE Trans. Sonics Ultrason. - IEEE Transactions on Sonics and Ultrasonics
*Industrial Research
*International Journal of Nondestructive Testing
Int. - International
IEC - International Electrotechnical Commission
IRE - Institute of Radio Engineers
IRE Intern. Conv. Record - IRE International Convention Record
IRE Trans. Electron Devices - IRE Transactions on Electron Devices
J. Appl. Phys. - Journal of Applied Physics
*J. Electrochem. Soc. - Journal of the Electrochemical Society
J. Sci. Instrum. - Journal of Scientific Instruments
Mater. Eval. - Materials Evaluation
*Mater. Res. Std. - Materials Research and Standards
Metals Eng. Quart. - Metals Engineering Quarterly
*Microelectronics and Reliability
Nat. Electron. Conf. - National Electronics Conference
Mfg. - Manufacturing
NEPCON - National Electronic Packaging and Production Conference
Philips Tech. Rev. - Philips Technical Review
Proc. IEEE - Proceedings of the Institute of Electrical and Electronics Engineers
*Prod. Eng. - Product Engineering
*RCA Review
*Rev. Sci. Instr. - The Review of Scientific Instruments
Rev. Elec. Commun. Lab. - Review of the Electrical Communication Laboratory. Tokyo. (Denki Tsushin Kenkyujo)
SAE - Society of Automotive Engineers
Semicond. Prod. - Semiconductor Products
*Semicond. Prod. Solid State Technol. - Semiconductor Products . . Solid State Technology
Soc. - Society
*Solid State Abstracts
*Solid State Electron. - Solid State Electonics
Solid State Technol. - Solid State Technology
Symp. - Symposium
Technol. - Technology
*Trans. Met. Soc. AIME - Transactions of the Metallurgical Society of the AIME
*Ultrasonics
Welding J. - Welding Journal
WESCON - Western Electric Show and Convention

*Journals searched completely for period 1965-1970.

TABLE 3. AVAILABILITY NOTES

[1] U. S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.
[2] Publications Sales Department, The IEEE, 345 East 47th Street, New York, New York 10017.
[3] American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.
[4] Industrial and Scientific Conference Management, Inc., 222 West Adams Street, Chicago, Illinois 60606.
(5) Uthe Technology, Inc., 670 Almanor Ave., Sunnyvale, California 94086.
[6] Illinois Institute of Technology, Chicago, Illinois 60606.
[7] ASME Order Dept., 345 47th Street, New York, New York 10017.
[8] American Welding Society, 345 East 47th Street, New York, New York 10017.
[9] Technology Utilization Division, NASA, Code UT, Washington, D. C. 20546.
[10] Gordon and Breach, Science Publishers, Inc., New York, New York 10001.
[11] ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.
(12) MIT Instrumentation Laboratories, Cambridge, Massachusetts 02142.
(13) North American Aviation/Autonetics, Anaheim, California 92803.
(14) Norden Division of United Aircraft Corp., Norwalk, Connecticut.
(15) Philco-Ford Corp., Microelectronics Div., Blue Bell, Pennsylvania 19422.
(16) Westinghouse Electric Corp., Baltimore, Maryland.
(17) Weltek Div., Wells Electronics Inc., South Bend, Indiana.
(18) Aeroprojects Inc., West Chester, Pennsylvania.
(19) Weldmatic Div., Unitek Corp., Monrovia, California.
(20) Martin Marietta Corp., Quality Engineering Dept., Orlando, Florida.
(21) Lockheed Missiles and Space Co., Lockheed Palo Alto Research Laboratories, Palo Alto, California 94304.
[22] Sandia Labs., Albuquerque, New Mexico 87115.
(23) Hughes Aircraft Co., Welder Dept., Oceanside, California 92054.
(24) United Aircraft Corp., Electronic Components Div., Trevose, Pennsylvania.
(25) Westinghouse Defense and Space, Mfg., Research and Development, Baltimore, Maryland.
(26) McDonnell Douglas Astronautics Co., Western Div., Santa Monica, California.
(27) RADC, Griffiss Air Force Base, Rome, New York 13440.
(28) Fairchild Semiconductor, Research and Development Laboratories, Palo Alto, California 94304.
(29) National Bureau of Standards, Washington, D. C. 20234.
[30] Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.
(31) Lockheed Missiles and Space Co., Sunnyvale, California.
(32) Texas Instruments, Inc., Dallas, Texas 75222.
(33) AC Electrics Div., General Motors Corp., Milwaukee, Wisconsin.
(34) IBM Corp., Endicott, New York 13760.
(35) Raytheon Co., Sudbury, Massachusetts 01776.
(36) RCA, Somerville, New Jersey 08876.
(37) Motorola Inc., Phoenix, Arizona 85008.
(38) Delco Electronics Division, General Motors Corp., Milwaukee, Wisconsin.

Appendix D. Key Word Selection and Use

Three levels of key words are used in the bibliography to indicate the subject material in the works compiled, each successive level being less broad in scope. To help identify key words of different levels, all the letters are capitalized for first-level key words while only the first letter of the second-level key words is capitalized. The third-level key words are all in lower-case.

First-level key words are used to indicate general subject areas discussed; they are TEST, FABRICATION, and DEGRADATION. One or more of these key words may be used, depending on the contents of the work. The order of listing is meant to indicate the relative emphasis given each area if more than one is listed.

The *kind of wire bonds* involved in the discussions of a given subject is described by a series of *descriptors* arranged on the same line and following the first-level key word describing the subject area. The descriptions that may be used, depending on what is discussed, are: *bond, wire, film, thick film, substrate, and application*. They refer, respectively, to the bond involved; the wire material; the metallization film(s) on the bonding surface or the material on which the wire is bonded if no metallization film is used; the thick-film (>> 1 μm) conductive composition, if used; the substrate material under the conducting film; and the application or use of the wire bond in hybrid circuits or plastic devices. Following each of these descriptors are symbols or words to indicate the kinds of bonds, materials, and applications that are used or discussed. If the comments are of a general nature and no particular wire bond is mentioned in the entry then descriptors are not given.

If a *test method* is discussed in the context of testing or evaluating the wire bond then the first-level key word TEST is listed under the entry in the bibliography. As appropriate, one or more of the following *second-level* key words is listed below TEST: *Description, Evaluation, Correlation, Application, Precautions, and Screening Procedures;* in that order. The key words (third-level) for the test methods are arranged in alphabetical order after and on the same line with the appropriate second-level key words listed above. If the entry describes a test method in any detail, the key word for the method will follow Description; if it evaluates the methods the key word will follow Evaluation; if it presents correlation information with other methods for the same type of wire bond, then key words for these methods will follow Correlation. If the material in the entry is or may be applicable to a test method, its key word will follow Application, while if the material deals with precautions in the use of a method its key word will follow Precautions. Finally, if the material in the entry deals with procedures in which several tests are performed as a means of culling out weak wire bonds then Screening Procedures will be listed without an indication of the test methods involved.

If material in the entry deals with some aspect of the fabrication of wire bonds then the first-level key word FABRICATION is used. The *second-level* key words that have been selected are as follows: *Theory, Evaluation, Procedure, Schedule, Variables, Apparatus, Control, Tool, Rigidity, Wire, Bonding Surface, Test, and Trouble Shooting.* Without mentioning the third-level key words in any detail, the meaning and intent of the above listed second-level key words will now be indicated. The key word *Theory* relates to the theory of making a bond while *Evaluation* relates to the evaluation of such things as the type of bonding process, the type of bond, the metal systems used, etc. The key word *Procedure* refers to the procedures or steps in making a particular type of wire bond. The key word *Schedule* refers to the optimization of the fabrication processes and procedures for making wire bonds, while the key word *Variables* refers to the effects that specific variables have on the quality or strength of a wire bond. The key word *Apparatus* refers to the bonding machine and its accessories; *Control* refers to the importance of controlling specific parameters; *Tool* refers to the tool used to press against the wire while the bond is made; *Rigidity* refers, generally, to the importance of mechanical rigidity and positional control in the fabrication of the wire bond; *Wire* refers to the wire used; and *Bonding Surface* to the characteristics of the bonding surface pertinent to good bonding. If test methods are used to evaluate the fabrication procedures their key words are listed after *Test*. Finally, if the entry discusses hints or methods for locating and correcting deficiencies in the fabricating procedures, the key word *Trouble Shooting* will be used.

If material in the entry deals with some aspect of the degradation or failure of wire bonds then the first-level key word DEGRADATION is used. The *second-level* key words that have been selected are as follows: *Stress, Part, Mechanism, Test, and Failure Rates*. The third-level key words for the first three of these were selected to be more specific in terms of, respectively, (1) the kind of stress that produces a weakened wire bond as a result of the fabrication process or that results in degradation or failure of an already completed wire bond; (2) the part or component, primarily of the wire bond, that is or has been affected by the stress; and (3) the mechanism, if defined, that is involved in the degradation or failure. If a test method is used to detect or measure this degradation or failure then the key words of the test methods used will follow Test. If general reliability data, such as failure rates of specific kinds of wire bonds under specific conditions or stress, are included in the entry then the key word Failure Rates is used; third-level key words follow to indicate if the information pertains to thermocompression or ultrasonic wire-bonds, or if the kinds of wire bonds are not indicated.

The *first-level* key words used to indicate the approach or the type of the entry are ANALYTIC, DESCRIPTIVE, EXPERIMENTAL, and THEORETICAL; and PATENT, REVIEW, and STANDARD. Only one of these key words is used and it is listed last.

TABLE 4. TEST METHODS AND BRIEF DESCRIPTIONS

air blast
A jet of gas, usually air or nitrogen, is directed at the wire.

bond monitor
Some measure of the mechanical coupling between the tool, wire, and metal film is monitored during ultrasonic bonding.

centrifuge
A constant centrifugal force is applied to the device.

electrical parameter
A device performance test is used to determine device degradation caused in some way by the wire bond.

electron microprobe
An electron microprobe is used to identify contaminants in the wire bond.

IR monitor
The infrared radiation from a bond is used to obtain a measure of the thermal resistance of the bond interface and hence the area of contact and the quality of the bond of the wire to the bonding surface.

interferometry
The motion of ultrasonic bonding tools and velocity transformers in ultrasonic bonding machines is studied with use of interferometry.

mechanical shock
A large, short-duration deceleration is applied to the device.

mechanical shock (radiation-induced)
The absorption of a short pulse of high-energy electrons in a plate fastened to the base of the device header is used to generate thermally-induced stress waves which are used to stress the wire bond.

metallurgical exam
The structure and interface of wire bonds are examined metallurgically.

Mil-Std-750B
Military standard test methods for discrete devices.

Mil-Std-883
Military standard test methods for integrated circuits.

noise
Electrical noise measurements are used to detect abnormalities in the wire bond.

photoelastic stress analysis
Stress distributions in the vicinity of the bond are studied.

pull
The wire is pulled by a probe, usually hook-like, until some part of the wire bond ruptures.

pull (nondestructive)
The wire is pulled by a probe to a predetermined tensile stress.

radiotracer
Radiotracers are used to detect the distribution of contaminants and to study interfacial displacements.

resistance
The contact or bond-interface resistance is measured (directly or indirectly).

temperature cycle
The device is exposed alternately between two temperature extremes to test the ability of the wire bond to sustain the mechanical stresses that result from differences in the thermal coefficients-of-expansion of the constituent parts.

thermal shock
Same as temperature cycle except that the transfer time between temperature extremes is shorter.

US probe
Ultrasonic energy is used to test (probe) the mechanical quality of bonds.

US stress
Ultrasonic energy is used to stress wire bonds.

vibration (fatigue)
The device is vibrated at a fixed frequency for long periods of time at a relatively low maximum acceleration level.

vibration (monitored)
The electrical parameters of the device are monitored while it is being vibrated.

vibration (variable frequency)
The device is vibrated thru a frequency range at a relatively constant, maximum acceleration.

visual inspection
Wire bonds are examined under a microscope to determine if they conform to predetermined criteria of physical appearance, location, and orientation.

visual inspection (SEM)
The same as the visual inspection test except a scanning electron microscope (SEM) is used.

x-ray exam
X-rays are used to look for abnormalities in wire routing and orientation in encapsulated devices.

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