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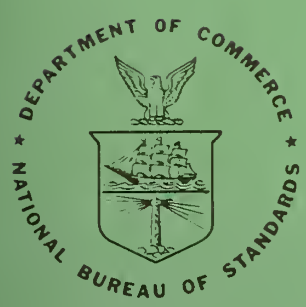
Second Breakdown in Semiconductor Devices - A Bibliography



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TECHNICAL NOTE 431

ISSUED OCTOBER 1967

Second Breakdown in Semiconductor Devices — A Bibliography

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Second Breakdown in Semiconductor Devices - A Bibliography

Harry A. Schafft

Almost 200 references with appropriate key words are listed which provide, it is believed, a comprehensive coverage of the literature of second breakdown in transistors and other semiconductor devices from 1958 through much of 1967. A representative list of earlier papers dealing with what appears to be second breakdown in point-contact and p-n junction diodes is also included. The indexes consist of an author index and an index to subject matter with reference tabulations and with key word assignments.

Key Words: bibliography, semiconductor devices, transistors, diodes, second breakdown, thermal breakdown, device reliability, failure modes, failure mechanisms.

1. Introduction

Second breakdown is generally recognized as a mode of operation in bipolar devices whose initiation is characterized by an apparently spontaneous decrease in voltage to a low sustaining voltage and a simultaneous constriction of current. Its occurrence can cause circuit malfunction and device damage. Thornton and Simmons in 1958 first reported the phenomenon in transistors, calling it a "new high current mode of transistor operation." They suggested that the occurrence of this mode was responsible for the mysterious failures that were observed in certain applications.

A full understanding of the nature and initiating mechanisms of second breakdown has still not been achieved despite the existence of the problem for these many years and despite the many workers who have been involved in the problem. The conditions that make a transistor more susceptible to second breakdown are usually those which are typical of higher power and higher frequency transistors. The problem has therefore grown, with the increase in transistor power and frequency capabilities, from one which was initially of little more than academic interest to one which has come to be of critical importance in the design, fabrication, testing, and application of a wide range of transistor types. As a result there has been a proliferation of papers on the subject to the point where it is believed that a bibliography of publications on second breakdown will now be of assistance to those concerned with the problem.

Under some operating conditions a decrease in voltage and a current constriction occur in diodes which is suggestive of second breakdown in

transistors. English, in 1963, proposed that the same phenomenon occurs in both types of devices. In 1965 Agatsuma et al. saw a similar effect in n+-n-n+ structures which led them to the generalization that second breakdown is a phenomenon that can occur in any semiconductor device. This bibliography includes therefore those papers from 1958 through much of 1967 which appear to deal with second breakdown in transistors, diodes and other structures. Considerable effort has been made to search the published literature (including many of the "trade" journals) to make the bibliography on second breakdown during this period as comprehensive as possible. A few company application notes, theses, and contract reports have also been included. Any suggestions regarding additions or corrections would be appreciated.

A number of papers are also included which were published prior to and a few years after Thornton and Simmons' paper that describe a similar voltage drop in point-contact and p-n junction diodes, usually referred to in that period as thermal breakdown or a turnover phenomenon. For convenience in the construction of this bibliography, these phenomena will also be called second breakdown. The selection in this group of earlier papers is meant to be representative rather than complete.

2. Organization of the Bibliography

Each reference is given a "name" which consists of a sequence of two digits, a letter and, if needed, another digit. The first two digits indicate the year of publication and the letter is the first letter of the first author's surname. The last digit is added to distinguish those references that would otherwise have the same "name." No rule was used in the assignment of this digit. The references in the bibliography are arranged according to their "names." The "names" are grouped first by year then in alphabetical order by letter and, if required, in numerical order by the last digit.

The subject matter covered by the references are divided into eight main topics some of which are divided into sub-topics. All topics are defined briefly and assigned key words in the Index to Subject Matter, Key Word Assignments, and Reference Tabulation. Also included in the Index is a tabulation of the reference "names" by the appropriate topics and sub-topics.

Appropriate key words are arranged in a column just below each reference in the bibliography. The key word for each main topic is capitalized while the key words for the sub-topics follow in lower-case, except for a few letter symbols. If no key words follow then the reference deals with all the sub-topics under the given main topic. If the reference contains an extensive review of earlier work in its introduction or discussion sections then the key word, SURVEY, will follow the others listed. A survey paper will have only one main keyword, i.e., SURVEY, followed by appropriate minor key words.

If second breakdown is not the major subject of the reference then the journal citation is followed by the symbol, (-). When those parts that do deal with second breakdown can be conveniently identified in

these papers then the journal citation is followed by the appropriate page, table or figure numbers in parenthesis.

Journal abbreviations follow those of Science Abstracts if they are contained therein. Otherwise, the abbreviations in the Chemical Abstracts List of Periodicals are used. One exception is made in the case of the Institute of Electrical and Electronics Engineers, which is abbreviated IEEE. For those publications which are not listed and where confusion might arise, no abbreviations are made.

The "name" assignments used in this bibliography are the same as those used in a survey paper [1] except for the following, where the "name" used in the survey paper is in parenthesis: 66C(66C1), 65F(66F), 65S4(66S9), 66B4(66B5), 66F(66F2), 66H(66H4), 66S(66S10), 67S2(66S).

The author gratefully acknowledges the helpful comments and suggestions of the many people who were consulted about the format of this bibliography.

[1] H. A. Schafft, "Second Breakdown - A Comprehensive Review," Proc. IEEE, vol. 55, pp. 1272-1288, August 1967.

3. Index to Subject Matter, Reference Tabulation and Key Word Assignments

Subject Matter ---------- Key Word

I. Theory of or comments relevant to--------------------THEORY

65W, 66J

1. initiating mechanisms.-----------------------------mechanisms

   65J, 65W, 66J

   a. critical triggering temperature.---------------trigger temperature

      51B, 53T, 54K, 54L, 55K, 59Y, 59Y1, 63B1, 63E, 63F, 63K1, 63S2, 64M, 64M1, 64R2, 64W, 64A, 65J, 65R, 65W, 65A2, 66J, 66K, 66W

   b. lateral thermal instability.------------------instability

      63B, 63S, 63S1, 63S4, 64S, 65G1, 65J, 65S1, 65W, 66B2, 66F, 66J, 66S6, 67M2, 67S, 67S2

   c. thermal effects excluding items a and b.--thermal

      49B, 51B, 52B, 54L, 57M, 57T, 60B, 60T, 62O, 62S, 63B1, 63E1, 63S2, 64F, 64M1, 64R1, 65H4, 65J, 65T, 65W, 66F1, 66J, 66K, 66O, 66S5, 66T, 66T1, 66W, 67W

   d. "pinch-in" effect.------------------------------pinch

      58T, 60L, 61T, 62S, 62W, 62W2, 63S2, 64W3, 65J, 65J1, 65W, 66G, 66J, 66T1, 66W, 67S, 67S2

   e. free charge carrier effects.------------------charge carriers

      55K, 59Y, 60L, 61T, 63S2, 64S2, 65J, 65J1, 65W, 66E, 66G, 66J, 66S, 67H2, 67S

f. non-thermal effects excluding items d and e.--non-thermal

60B, 60L1, 61T, 62S, 63M, 64P2, 64R, 64R1, 65J, 65W, 66H2, 66J, 66L, 66S5, 66W, 67H2, 67S2

g. interactions of the above mechanisms.-----------interaction

60B, 65J, 65W, 66J, 66P, 66S2, 67S2

2. the physical state or electrical characteristics of the device while in second breakdown.--SB state

53T, 57M, 57T, 58T, 59Y, 60B, 60T, 61T, 62O, 62S, 63B1, 63E, 63E1, 63S, 63S1, 64M, 64M1, 64P2, 64R2, 64S, 65H4, 65W, 66E, 66E1, 66J, 66K, 66S2, 66S6, 66W

II. Electrical characteristics associated with second breakdown------------------------------------CHARACTERISTICS

1. of particular devices.

a. bipolar transistors.----------------------------transistor

55K, 58K, 60F, 60L, 60L1, 61G, 61T, 62H1, 62I, 62M1, 62S, 62W2, 63B, 63B1, 63D, 63E1, 63F, 63K, 63K1, 63M, 63S, 63S1, 63S2, 63S3, 63S4, 64A, 64H, 64M, 64M1, 64M4, 64N, 64P2, 64R, 64R1, 64R2, 64R3, 64S, 64S1, 64S2, 65A1, 65B, 65B1, 65F, 65G, 65G1, 65H, 65H5, 65H6, 65P, 65R, 65R2, 65R3, 65S2, 65S4, 65T, 65T1, 66A1, 66A2, 66B2, 66C, 66F, 66F1, 66G, 66H1, 66J, 66K, 66L, 66L1, 66N1, 66N3, 66O, 66P, 66P1, 66R, 66R1, 66S1, 66S2, 66S4, 66S5, 66S6, 66S7, 66S8, 66T, 66T1, 66V, 67E, 67G, 67H2, 67K, 67M, 67M2, 67N, 67S, 67S2, 67S4, 67W

b. p-n junction diodes.----------------------------diode

57M, 57T, 59Y, 59Y1, 60T, 62O, 63B1, 63E, 63E1, 63F, 64M, 64M1, 64P2, 64R1, 64W, 65C, 65F, 65H4, 66E, 66E1, 66F1, 66K, 66R, 66S6

c. <u>point-contact diodes</u>.--------------------------point contact

49B, 51B, 52B, 53T, 54K, 54L, 55K,
59Y1, 66A, 66A2

d. <u>MOS transistors</u>.--------------------------------MOS

66A4

e. <u>p-n-p-n type structures</u>.----------------------p-n-p-n

65S1

f. <u>n^+-n-n^+ or equivalent type structures</u>.---------n^+-n-n^+

64F, 65A, 65A1, 66A2, 67H2

2. <u>during the development of second breakdown</u>,

a. <u>for rectangular pulsed operating contions</u>.--pulsed

49B, 52B, 53T, 54K, 54L, 55K, 57M, 59Y,
61T, 62M1, 62O, 62S, 62W2, 63B1, 63E1,
63F, 63K, 63S, 63S1, 64A, 64M, 64S, 64S1,
64W, 65A1, 65G, 65R3, 65T, 66A, 66A2,
66A3, 66E, 66F, 66F1, 66G, 66N1, 66N3,
66O, 66S1, 66S2, 66S6, 66T, 66T1, 67M2,
67S4

b. <u>for other than rectangular pulsed and a variʾty of swept operating conditions</u>.---------swept

49B, 52B, 54L, 57T, 58T, 60F, 60L1, 60T,
61G, 61T, 62H1, 62I, 62M1, 62O, 62S,
62W2, 63E, 63E1, 63F, 64A, 64M4, 64P2,
64R1, 64R2, 64S1, 65A, 65A1, 65H4, 65P,
65R, 65R3, 65S2, 65T, 66A, 66A1, 66A2,
66A3, 56A4, 66F, 66J, 66K, 66L, 66R,
66S5, 66S8, 67G, 67M, 67N, 67S, 67S2,
67S4

3. <u>during second breakdown where</u>

a. <u>a single continuous V-I characteristic is observed</u>.------------------------------------SB

49B, 53T, 57M, 57T, 58T, 59Y, 60T, 51T,
62O, 63B1, 63E, 63E1, 63S, 63S1, 63S3,
64P2, 64R1, 64S, 65G, 65H6, 65P, 66E,
66E1, 66J, 66K, 66S1, 66S2, 66T1

b. multiple voltage levels are observed.----------multiple levels

49B, 63E1, 64M1, 64N, 64P2, 65G, 66A3, 66E1, 66F1, 66J, 66N1, 66S2,

4. observed by measurement techniques which are discussed in detail or which are original.----------measurement

58T, 59Y, 62S, 64A, 64S1, 65T, 66J, 66N3, 66S4, 66S5, 66S6, 66T, 66T1, 67G

5. of oscillations observed prior to or during second breakdown operation.----------oscillations

49B, 55K, 59Y, 62M1, 64M, 64M4, 65H4, 66A3, 66E, 66G, 66L1, 66S4, 67S2

6. used as indicators of second breakdown imminence.----------indicator

63S, 63S1, 63S4, 64M4, 64S, 64S1, 65B, 66N1, 66R, 66S4, 66S6, 66S8, 66V, 67S

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a. resistive ballasting.----------ballast

65G1, 65R2, 65S4, 65T1, 66B2, 66N1, 66R1, 66S6, 66S7, 66S8, 67S

b. device design excluding resistive ballasting.----------design

58T, 60L1, 61T, 62H1, 62W2, 63B, 63B1, 63S, 63S1, 63S4, 64M, 64R, 64R1, 64R2, 64R3, 64S, 64S1, 65B1, 65G1, 65H, 65H5, 65R2, 65R3, 65S1, 65T, 66A, 66B2, 66E, 66E1, 66G, 66H1, 66J, 66K, 66N1, 66P, 66R, 66R1, 66S1, 66S2, 66S5, 66S6, 66S7, 66T1, 67E, 67H2, 67K, 67M2, 67S, 67S2, 67W

c. internal current distributions.----------current distribution

58T, 59Y1, 62S, 62W2, 63B, 63E1, 63F, 63S, 63S1, 63S3, 64A, 64R1, 64R2, 64S, 64S1, 65G1, 65P, 65R2, 65R3, 65S4, 65T, 66B2, 66N1, 66P, 66S1, 66S2, 66S6, 66S7, 66V, 67M2, 67S2, 67W

d. design deficiencies and material defects.------defect

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e. nuclear radiation.-------------------------------radiation

64H, 64R3, 66C

f. a magnetic field.--------------------------------magnetic field

63E1, 65G

g. surface arcs spanning a p-n junction.----------arc

63E, 63E1

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66S6

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53T, 57T, 59Y, 59Y1, 60T, 63E2, 63F, 63F1, 63K1, 63S, 63S1, 63S4, 64B1, 64M, 64R, 64R1, 64R2, 64S, 65A, 65H3, 65H4, 65P1, 65R, 65T, 65A2, 66P1, 66R, 66S4, 66S6, 66T, 66T1, 67H1, 67N, 67P, 67W1

2. the light emission from the device.---------------light

57T, 60T, 63E, 63E1, 63H, 64P2, 65H6, 65V, 66A4, 66E1, 66S6

3. the internal current distribution via an intermediary sensor.--------------------------------current distribution

62T, 63E2, 63F, 63F1, 63M, 63S, 63S1, 63S3, 63S4, 64B1, 64M2, 64S, 65G, 65H3, 65P1, 65R2, 65S4, 66A2, 66N, 66P, 66P1, 66S2, 66S6, 66S8, 67H1, 67N, 67P

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65B, 65R3, 65S, 66B1, 66N2, 66S, 66V, 67T

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66B1, 66B2, 66N2, 66O, 66R1, 66S, 66S4,
66V, 67E, 67S4, 67T

2. specifications for reverse base drive operation.---R

62G, 62H, 63C, 63G, 63L, 63M1, 63N, 63W,
64B, 64B2, 64B3, 64G, 64M4, 64P1, 64S1,
64S3, 64W2, 65B, 65R1, 65R3, 65S, 66B1,
66F, 66N2, 66S, 66S4, 66V, 67T, 67V

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CHARACTERISTICS: diode, pulsed.

64W1 Wheatley, C. F.
DESIGN CONSIDERATIONS FOR TRANSISTORIZED TELEVISION DEFLECTION CIRCUITS PART I
Solid State Design, vol. 5, pp. 39-44, October 1964. (-)
PRECAUTIONS

64W2 Wheatley, C. F.
DESIGN CONSIDERATIONS FOR TRANSISTORIZED TELEVISION DEFLECTION CIRCUITS PART II
Solid State Design, vol. 5, pp. 38-42, November 1964. (pp. 38-39)
PRECAUTIONS
SPECIFICATIONS: R, test.

64W3 Wolff, K., and F. Weitzsch
RECHNUNGEN ZUM EINSCHNUREFFECT BEI TRANSISTOREN
Valvo Berichte, vol. 10, pp. 357-363, December 1964.
THEORY: pinch

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65A Agatsuma, T., T. Kohisa, and A. Sugiyama
TURNOVER PHENOMENON OF $N^{+}NN^{+}$ PLATE CONTACT SILICON DEVICE AND SECOND BREAKDOWN IN TRANSISTORS
Proc. IEEE, vol. 53, p. 95, January 1965.
THEORY: trigger temperature.
CHARACTERISTICS: n^{+}-n-n^{+}, swept.
OBSERVATION: temperature.

65A1 Agatsuma, T.
THE SECOND BREAKDOWN V-I CHARACTERISTICS IN THE TRIPLE DIFFUSED SI TRANSISTOR
Proc. IEEE, vol. 53, pp. 2142-2143, December 1965.
CHARACTERISTICS: transistor, n^{+}-n-n^{+}, pulsed, swept.

65B Balthasar, P. P.
SELECTING SWITCHING CIRCUIT TRANSISTORS
Electrical Design News, vol. 10, pp. 72-76, November 1965.
CHARACTERISTICS: transistor, indicator.
PRECAUTIONS
SPECIFICATIONS

65B1 Borofsky, A. J., and D. C. Fleming
DESIGN AND PROCESS CONTRIBUTION TO INHERENT FAILURE MECHANISMS OF MICROMINIATURE ELECTRONIC COMPONENTS FOR MINUTEMAN II
Presented at the Physics of Failure in Electronics Symposium (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965. (-)
CHARACTERISTICS: transistor, design, defect.

65C Chu, T. L., and P. J. Kannam
FAILURE OF LARGE-AREA EPITAXIAL-DIFFUSED SILICON DEVICES
Presented at the Physics of Failure in Electronics, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965. (-)
CHARACTERISTICS: diode, defect.

65F Faust, J. W., Jr., H. F. John, and R. Stickler
THE ROLE OF MICRODEFECTS IN SILICON STARTING MATERIALS AS QUALITY REDUCING FACTORS IN SEMICONDUCTOR DEVICES
Presented at the Physics of Failure in Electronics Symposium, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965. (-)
CHARACTERISTICS: transistor, diode, defect.

65G Goryunov, N. N., Yu. A. Ovechkin, A. M. Savchenko, A. V. Stankova, Ya. A. Tolkacheva, and Yu. F. Feoktistov
INVESTIGATION OF THE SECONDARY BREAKDOWN PHENOMENON IN TRANSISTORS
Radio Engng. Electronic Phys., vol. 10, pp. 1139-1141, July 1965.
CHARACTERISTICS: transistors, pulsed, SB, multiple levels, magnetic field.
OBSERVATION: current distribution.

65G1 Gerstner, D.
HF-LEISTUNGSTRANSISTOREN - NEUE ENTWICKLUNGEN MIT TECHNIKEN DER MIKROELEKTRONIK
Internat. Elektronische Rundschau, vol 9, pp. 495-501, September 1965.
THEORY: instability.
CHARACTERISTICS: transistor, ballast, design, current distribution.
SPECIFICATIONS: F, O.

65H Hakim, E. B., L. K. McSherry, and B. Reich
SOLDER BALL FORMATION IN SILICON ALLOY TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-12, pp. 369-372, June 1965.
CHARACTERISTICS: transistor, design.
PRECAUTIONS
DAMAGE

65H1 Hakim, E. B.
TRANSISTOR-SURFACE ANALYSIS AFTER SECONDARY BREAKDOWN
Proc. IEEE, vol. 53, p. 1226, September 1965.
DAMAGE

65H2 Hakim, E. B., L. K. McSherry, and B. Reich
SOLDER BALL FORMATION IN SILICON ALLOY TRANSISTORS
IEEE International Electron Devices Meeting, Washington, D. C., October 1965.
DAMAGE

65H3 Howarth, D. W.
A SIMPLE TECHNIQUE FOR THE DIRECT OBSERVATION OF TEMPERATURE DISTRIBUTION IN MICROELECTRONIC STRUCTURES
Presented at the Physics of Failure in Electronics Symposium, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965. [1]
OBSERVATION: temperature, current distribution.

65H4 Haitz, R. H.
MECHANISMS CONTRIBUTING TO THE NOISE PULSE RATE OF AVALANCHE DIODES
J. Appl. Phys., vol. 36, pp. 3123-3131, October 1965. (pp. 3127-3129)
THEORY: thermal, SB state.
CHARACTERISTICS: diode, swept, oscillation.
OBSERVATION: temperature.
DAMAGE

65H5 Hakim, E. B., L. K. McSherry, and B. Reich
SOLDER BALL FORMATION IN SILICON ALLOY TRANSISTORS
Proc. IEEE, vol. 53, p. 389, April 1965.
CHARACTERISTICS: transistor, design.
PRECAUTIONS
DAMAGE

65H6 Hakim, E. B.
HOT SPOT MESOPLASMA FORMATION IN SILICON PLANAR TRANSISTORS
Presented at the Physics of Failure in Electronics Symposium, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965.
CHARACTERISTICS: transistor, SB.
OBSERVATION: light.
DAMAGE

65J Josephs, H. C.
A SIMPLE MODEL FOR SECOND BREAKDOWN
Proc. IEEE, vol. 53, p. 1225, September 1965.
THEORY: mechanisms.

65J1 Josephs, H. C.
THE EFFECT OF FREE CHARGE ON COLLECTOR MULTIPLICATION
Proc. IEEE, vol. 53, pp. 1732-1733, November 1965.
THEORY: pinch, charge carriers.

65P Perkins, C.
BREAKDOWN PHENOMENA IN SILICON SEMICONDUCTOR DEVICES
Semiconductor Prod. Solid State Technol., vol. 8, pp. 32-37, February 1965. (pp. 36-37)
CHARACTERISTICS: transistor, swept, SB, current distribution.

65P1 Peterman, D. A.
THERMOPHYSICS OF SILICON POWER TRANSISTORS
Presented at the Physics of Failure in Electronics Symposium, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965. (-)
OBSERVATION: temperature, current distribution.

65R Reich, B., and E. B. Hakim
AN EXPLANATION OF THE ENERGY DEPENDENCE OF SECONDARY BREAKDOWN IN TRANSISTORS
Proc. IEEE, vol. 53, pp. 624-625, June 1965.
THEORY: trigger temperature.
CHARACTERISTICS: transistor, swept.
OBSERVATION: temperature.

65R1 Resch, W.
POWER RATING OF TRANSISTORS FOR PULSED OPERATION
Electro-Technology, (New York), vol. 76, pp. 86-88, November 1965. (-)
SPECIFICATIONS: F, O, R, test.

65R2 Rosenzweig, R., and D. R. Carley
DESIGN OF A VHF POWER TRANSISTOR WITH SECOND-BREAKDOWN PROTECTION
IEEE International Electron Devices Meeting, Washington, D. C., October 1965.
CHARACTERISTICS: transistor, ballast, design, current distribution.
OBSERVATION: current distribution.

65R3 RCA
HOMETAXIAL-BASE SILICON POWER TRANSISTORS
RCA Application Note HBT-400, pp. 1-4, December 1965.
CHARACTERISTICS: transistor, pulsed, swept, design, current distribution.
SPECIFICATIONS

65S Schafft, H. A., and J. C. French
BREAKDOWN CHARACTERISTICS OF SEMICONDUCTOR MATERIALS
Electro-Technology, (New York), vol. 75, pp. 77-82, June 1965.
PRECAUTIONS
SPECIFICATIONS
SURVEY: characteristics, specifications.

65S1 Schroen, W., J. Beaudouin, and K. Hubner
FAILURE MECHANISMS IN HIGH POWER FOUR-LAYER DIODES
Physics of Failure in Electronics, vol. 3, RADC Series in Reliability, M. F. Goldberg and J. Vaccaro, Eds., 1965, pp. 389-403.
AD 617 715 [2] (pp. 295-398)
THEORY: instability.
CHARACTERISTICS: p-n-n-n, design, defect.
DAMAGE

65S2 Seneret, J.
UTILISATION DES TRANSISTORS DE PUISSANCE EN VHF
Onde Elect., vol. 45, pp. 311-317, March 1965.
CHARACTERISTICS: transistor, swept.
PRECAUTIONS

65S3 Schroen, W., and W. W. Hooper
FAILURE MECHANISMS IN SILICON SEMICONDUCTORS
Shockley Research Labs., Palo Alto, Calif., Final Rept., Contract AF30(602)-3016, March 1965. AD 615 312 [2] (pp. 1-125)
THEORY: instability, SB state.
CHARACTERISTICS: transistor, diode, pulsed, design, defect.
OBSERVATION: temperature, current distribution.
DAMAGE

65S4 Stolnitz, D.
ELIMINATION OF FORWARD-BIASED SECOND BREAKDOWN BY RESISTIVE BALLASTING OF SILICON POWER TRANSISTORS
Presented at the Physics of Failure in Electronics Symposium, (Co-sponsored by the Rome Air Development Center and the Illinois Institute of Technology), Chicago, November 1965.
CHARACTERISTICS: transistor, ballast, current distribution.
OBSERVATION: current distribution.

65T Takagi, K., and K. Mano
TRANSIENT JUNCTION TEMPERATURE RISE AND FAILURE ENERGY OF TRANSISTORS
J. Inst. Elect. Commun. Engrs. Japan, vol. 48, pp. 33-41, October 1965.
THEORY: thermal.
CHARACTERISTICS: transistor, pulsed, swept, measurement, design, current distribution, defects.
OBSERVATION: temperature.
DAMAGE

65T1 Tatum, J. G.
CIRCUIT IMPROVEMENTS UTILIZING THE NEW RESISTOR STABILIZED VHF POWER TRANSISTOR
Proc. Nat. Electronics Conf., vol. 21, 1965, pp. 73-78.
CHARACTERISTICS: transistor, ballast.
PRECAUTIONS

65V Van Wyk, J. D.
RECOMBINATION EMISSION FROM SILICON TRANSISTORS
Proc. IEEE, vol. 53, pp. 307-308, March 1965. (-)
OBSERVATIONS: light.

65W Weitzsch, F.
ZUR THEORIE DES ZWEITEN DURCHBRUCHS BEI TRANSISTOREN
Arch. Elekt. Ubertragung, vol. 19, pp. 27-42, January 1965.
THEORY
SURVEY: theory.

65W1 Wheatley, C. F.
DESTRUCTIVE CIRCUIT MALFUNCTIONS AND CORRECTIVE TECHNIQUES IN HORIZONTAL DEFLECTION
IEEE Trans. Broadcast Televis. Receivers, vol. BTR-11, pp. 102-111, July 1965. (-)
PRECAUTIONS

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66A Agatsuma, T.
SECOND BREAKDOWN PHENOMENON OF POINT CONTACT NN^+ SI WAFERS
Proc. IEEE, vol. 54, pp. 1206-1207, September 1966.
CHARACTERISTICS: point contact, pulsed, swept, design.

66A1 Agatsuma, T.
A CHARACTERIZATION TECHNIQUE FOR SECOND BREAKDOWN IN GE ALLOYED JUNCTION TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 648-650, August/September 1966.
CHARACTERISTICS: transistor, swept.
SPECIFICATION: O.

66A2 Agatsuma, T.
TURNOVER PHENOMENA IN NVN SILICON DEVICES AND SECOND BREAKDOWN IN TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 748-753, November 1966.
THEORY: trigger temperature.
CHARACTERISTICS: transistor, n^+-n-n^+, pulsed, swept.
OBSERVATION: temperature, current distribution.

66A3 Anupyl'd, A. Yu.
ON SECOND BREAKDOWN AND RELAXATION OSCILLATIONS IN POINT-CONTACT DIODES
Radio Engng. Electronic Phys., vol. 11, pp. 837-839, May 1966.
CHARACTERISTICS: point contact, pulsed, swept, multiple levels, oscillations.

66A4 Asakawa, T., and N. Tsubouchi
SECOND BREAKDOWN IN MOS TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 811-812, November 1966.
CHARACTERISTICS: MOS, swept.
OBSERVATION: light.

66B Balthasar, P. P.
AVOID POWER TRANSISTOR FAILURE! USE THESE APPLICATION-ORIENTED GUIDELINES TO ESTABLISH THE DEVICE'S SAFE OPERATING AREA (SOAR)
Electronic Design, vol. 14, pp. 52-56, August 2, 1966.
PRECAUTIONS
SPECIFICATIONS: F, use, test.

66B1 Balthasar, P. P.
CUT TRANSISTOR-REPLACEMENT COSTS DUE TO DEVICE FAILURE. USE SAFE-OPERATING-AREA PRINCIPLES TO DESIGN POWER-TRANSISTOR SWITCHING CIRCUITS
Electronic Design, vol. 14, pp. 192-197, August 16, 1966.
PRECAUTIONS
SPECIFICATIONS

66B2 Bergmann, F., and D. Gerstner
SOME NEW ASPECTS OF THERMAL INSTABILITY OF THE CURRENT DISTRIBUTION IN POWER TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 630-634, August/September 1966.
THEORY: instability.
CHARACTERISTICS: transistor, ballast, design, current distribution.
SPECIFICATIONS: F, O.

66B3 Bolvin, R.
SECOND-BREAKDOWN TESTING NEED NOT BE DESTRUCTIVE
Electronic Design, vol. 14, p. 66, August 30, 1966.
SPECIFICATIONS: O, test.

66B4 Brown, H. E., R. A. Bond, and J. C. Bloomquist
AVALANCHE TRANSISTORS DRIVE LASER DIODES HARD AND FAST
Electronics, vol. 39, pp. 137-139, November 14, 1966. (-)
APPLICATION

66C Caldwell, R. S., W. C. Bowman, and J. A. Folsom
MECHANISM FOR RADIATION-INDUCED LATCHUP IN A MICROCIRCUIT
Northeast Electronic Research Engineering Meeting Record, (Boston, Mass.), vol. 8, pp. 28-29, November 1966.
CHARACTERISTICS: transistor, radiation.
PRECAUTIONS

66E Egawa, H.
AVALANCHE CHARACTERISTICS AND FAILURE MECHANISM OF HIGH VOLTAGE DIODES
IEEE Trans. Electron Devices, vol. ED-13, pp. 754-758, November 1966.
THEORY: charge carriers, SB state.
CHARACTERISTICS: diode, pulsed, SB, oscillations, design.
DAMAGE

66E1 English, A. C.
PHYSICAL INVESTIGATION OF THE MESOPLASMA IN SILICON
IEEE Trans. Electron Devices, vol. ED-13, pp. 662-667, August/September 1966.
THEORY: SB state.
CHARACTERISTICS: diode, SB, multiple levels, design.
OBSERVATION: light.

66F Fujinuma, K.
TRANSISTOR FAILURE BY SECONDARY BREAKDOWN
IEEE Trans. Electron Devices, vol. ED-13, pp. 651-655, August/September 1966. (Correction in IEEE Trans. Electron Devices, vol. ED-14, p. 170, March 1967.)
THEORY: instability.
CHARACTERISTICS: transistor, pulsed, swept.
PRECAUTIONS
SPECIFICATIONS: R, test.

66F1 Ferry, D. K., and A. A. Dougal
INPUT POWER INDUCED THERMAL EFFECTS RELATED TO TRANSITION TIME BETWEEN AVALANCHE AND SECOND BREAKDOWN IN P-N SILICON JUNCTIONS
IEEE Trans. Electron Devices, vol. ED-13, pp. 627-629, August/September 1966.
THEORY: thermal.
CHARACTERISTICS: transistor, diode, pulsed, multiple levels.
DAMAGE

66G Grutchfield, H. B., and T. J. Moutoux
CURRENT MODE SECOND BREAKDOWN IN EPITAXIAL PLANAR TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 743-748, November 1966.
THEORY: pinch, charge carriers.
CHARACTERISTICS: transistor, pulsed, oscillations, design.

66H Huenemann, R. G.
TRANSISTOR DEGRADATION FOLLOWING SECOND BREAKDOWN
IEEE Trans. Electron Devices, vol. ED-13, p. 605, July 1966.
DAMAGE

66H1 Hakim, E. B.
THE APPLICATION OF MOLYBDENUM CONTACTS FOR IMPROVED SECOND BREAKDOWN PERFORMANCE
Proc. IEEE, vol. 54, pp. 880, June 1966.
CHARACTERISTICS: transistor, design.
DAMAGE

66H2 Harmon, G. G.
AVALANCHE RADIATION FROM THE BULK OF LONG, THIN, FORWARD-BIASED P^{+}-P-N^{+} SILICON DIODES
Appl. Phys. Letters, vol. 9, pp. 207-209, September 1, 1966. (p. 208)
THEORY: non-thermal.

66J Josephs, H. C.
ANALYSIS OF SECOND BREAKDOWN IN TRANSISTORS USING A SIMPLE MODEL
IEEE Trans. Electron Devices, vol. ED-13, pp. 778-787, November 1966.
THEORY
CHARACTERISTICS: transistor, swept, SB, multiple levels, measurement, design.

66K Khurana, B. S., T. Sugano, and H. Yanai
THERMAL BREAKDOWN IN SILICON P-N JUNCTION DEVICES
IEEE Trans. Electron Devices, vol. ED-13, pp. 763-770, November 1966.
THEORY: trigger temperature, thermal, SB state.
CHARACTERISTICS: transistor, diode, swept, SB, design.

66L Lewis, E. T.
A PHYSICAL EXPLANATION OF SECONDARY BREAKDOWN IN TRANSISTORS
Proc. IEEE, vol. 54, pp. 788-789, May 1966.
THEORY: non-thermal.
CHARACTERISTICS: transistor, swept, defect.
DAMAGE

66L1 Lohrmann, D. R.
PARAMETRIC OSCILLATIONS IN VHF TRANSISTOR POWER AMPLIFIERS
Proc. IEEE, vol. 54, pp. 409-410, March 1966. (-)
CHARACTERISTICS: transistor, oscillations.

66M Matyckas, S.
RF POWER TRANSISTORS IN VEHICULAR RADIO COMMUNICATIONS EQUIPMENT
IEEE Wescon Conv. Record, vol. 10, pt. 8.1, pp. 1-5, 1966. (-)
PRECAUTIONS

66N Neve, N. F. B., D. V. Sulway, K. A. Hughes, and P. R. Thornton
THE SCANNING ELECTRON MICROSCOPE AS A MEANS OF INVESTIGATING SECOND BREAKDOWN AND SIMILAR PHENOMENA
IEEE Trans. Electron Devices, vol. ED-13, pp. 639-642, August/September 1966. (p. 642)
OBSERVATION: current distribution.

66N1 Nienhuis, R. J.
SECOND BREAKDOWN IN THE FORWARD AND REVERSE BASE CURRENT REGION
IEEE Trans. Electron Devices, vol. ED-13, pp. 655-662, August/September 1966.
CHARACTERISTICS: transistor, pulsed, multiple levels, indicator, ballast, design, current distribution.

66N2 Newman, R. A.
SAFE OPERATION WITH HIGH VOLTAGE TRANSISTORS
Proc. Nat. Electronics Conf., vol. 22, pp. 139-143, 1966.
PRECAUTIONS
SPECIFICATIONS

66N3 Novo, D. Domingues, and M. Corazza
DISPOSITIF D'ETUDE DU PHENOMENE DE DEUXIEME AVALANCHE DANS LES TRANSISTORS (STUDY OF SECONDARY BREAKDOWN IN TRANSISTORS)
Electronics Letters, vol. 2, pp. 217-218, June 1966.
CHARACTERISTICS: transistor, pulsed, measurement.

66O Oda, H.
THE AREA OF SAFE OPERATION OF TRANSISTORS FOR SWITCHING OPERATION
IEEE Trans. Electron Devices, vol. ED-13, pp. 776-777, November 1966.
THEORY: thermal.
CHARACTERISTICS: transistor, pulsed.
SPECIFICATIONS: F.

66P Peterman, D. A., and H. R. Plumlee
INFRARED MICRORADIOMETER STUDIES OF OPERATING POWER TRANSISTORS
IEEE International Electron Devices Meeting, Washington, D. C., October 1966.
THEORY: interaction.
CHARACTERISTICS: transistor, design, current distribution, defect.
OBSERVATION: current distribution.

66P1 Plumlee, H. R., and D. A. Peterman
ACCURACY OF JUNCTION TEMPERATURE MEASUREMENT IN SILICON POWER TRANSISTOR
IEEE International Electron Devices Meeting, Washington, D. C., October 1966. (-)
CHARACTERISTICS: transistor.
OBSERVATION: temperature, current distribution.

66R Reich, B., and E. B. Hakim
SECONDARY BREAKDOWN THERMAL CHARACTERIZATION AND IMPROVEMENT OF SEMICONDUCTOR DEVICES
IEEE Trans. Electron Devices, vol. ED-13, pp. 734-737, November 1966.
CHARACTERISTICS: transistor, diode, swept, indicator, design.
OBSERVATION: temperature.

66R1 Reich, B.
ADVANCES IN DISCRETE SEMICONDUCTOR DEVICES
Semiconductor Prod. Solid State Technol., vol. 9, pp. 19-26, February 1966. (pp. 20-21)
CHARACTERISTICS: transistor, ballast, design.
SPECIFICATION: F, O.

66R2 Reich, B.
FACTORS AFFECTING TRANSISTOR FAILURE
Electro-Technology, (New York), vol. 78, pp. 43-44, December 1966.
PRECAUTIONS

66R3 Richards, N. G., and F. A. Barton
APPLICATION OF OVERLAY TRANSISTORS TO SOLID STATE MOBILE EQUIPMENT
IEEE Wescon Conv. Record, vol. 10, pt. 8.2, 1966, pp. 1-6. (-)
PRECAUTIONS

66R4 Rogers, J. D., and J. J. Wormser
SOLID-STATE HIGH-POWER LOW-FREQUENCY TELEMETRY TRANSMITTERS
Proc. Nat. Electronics Conf., vol. 22, pp. 171-176, 1966. (-)
PRECAUTIONS

66S Schafft, H. A.
AVOIDING SECOND BREAKDOWN
Presented at the XIIIth International Scientific Congress on Electronics, sponsored by Rassegna Internazionale Elettronica, Nucleare E Teleradiocinematografica, Rome, June 1966.
PRECAUTIONS
SPECIFICATIONS
SURVEY: characteristics, specifications.

66S1 Schafft, H. A., G. H. Schwuttke, and R. L. Ruggles, Jr.,
SECOND BREAKDOWN AND CRYSTALLOGRAPHIC DEFECTS IN TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 738-742, November 1966.
CHARACTERISTICS: transistor, pulsed, SB, design, current distribution, defect.
DAMAGE

66S2 Schafft, H. A., and J. C. French
SECOND BREAKDOWN AND CURRENT DISTRIBUTIONS IN TRANSISTORS
Solid-State Electronics, vol. 9, pp. 681-688, July 1966.
THEORY: interaction, SB state.
CHARACTERISTICS: transistor, pulsed, SB, multiple levels, design, current distribution, defect.
OBSERVATION: current distribution.

66S3 Schafft, H. A., and J. C. French
A SURVEY OF SECOND BREAKDOWN
IEEE Trans. Electron Devices, vol. ED-13, pp. 613-618, August/September 1966.
SURVEY

66S4 Schiff, P., and R. L. Wilson
DETECTION TECHNIQUES FOR NONDESTRUCTIVE SECOND BREAKDOWN TESTING
IEEE Trans. Electron Devices, vol. ED-13, pp. 770-776, November 1966.
CHARACTERISTICS: transistor, measurement, oscillations, indicator.
OBSERVATION: temperature.
SPECIFICATIONS: F, O, R, test.

66S5 Schneer, G. H., and L. H. Holschwandner
SECOND BREAKDOWN AND DEGRADATION IN GERMANIUM ALLOY JUNCTIONS
IEEE Trans. Electron Devices, vol. ED-13, pp. 806-810, November 1966.
THEORY: thermal, non-thermal.
CHARACTERISTICS: transistor, swept, measurement, design.
DAMAGE

66S6 Schroen, W., and R. M. Scarlett
SECOND BREAKDOWN IN SIMPLIFIED TRANSISTOR STRUCTURES AND DIODES
IEEE Trans. Electron Devices, vol. ED-13, pp. 619-626, August/ September 1966.
THEORY: instability, SB state.
CHARACTERISTICS: transistor, diode, pulse, measurement, indicator, ballast, design, current distribution, defect.
OBSERVATION
DAMAGE

66S7 Steffe, W., and J. LeGall
THERMAL SWITCHBACK IN HIGH F_t EPITAXIAL TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 635-638, August/ September, 1966.
CHARACTERISTICS: transistor, ballast, design, current distribution.

66S8 Stolnitz, D.
EXPERIMENTAL DEMONSTRATION AND THEORY OF A CORRECTIVE TO SECOND BREAKDOWN IN SI POWER TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 643-648, August/ September 1966.
CHARACTERISTICS: transistor, swept, indicator, ballast.
OBSERVATION: current distribution.

66T Takagi, K., and K. Mano
TRANSIENT TEMPERATURE RISE OF P-N JUNCTION AND ITS APPLICATION FOR THE DETERMINATION OF THE ALLOWABLE POWER OF TRANSISTORS
Scientific Reports of the Research Institute of Tôhoku University, B - (Electrical Communication), vol. 18, pp. 29-47, January 1966.
THEORY: thermal.
CHARACTERISTICS: transistor, pulsed, measurement.
OBSERVATION: temperature.

66T1 Takagi, K., and K. Mano
TRANSIENT JUNCTION TEMPERATURE RISE AND SECOND BREAKDOWN IN TRANSISTORS
IEEE Trans. Electron Devices, vol. ED-13, pp. 759-763, November 1966.
THEORY: thermal, pinch.
CHARACTERISTICS: transistor, pulsed, SB, measurement, design.
OBSERVATION: temperature.

66V Vahle, R. W.
GERMANIUM TRANSISTOR RATINGS FOR SECOND BREAKDOWN RELIABILITY
Proc. Nat. Electronics Conf., vol. 22, pp. 144-149, 1966.
CHARACTERISTICS: transistor, indicator, current distribution.
SPECIFICATIONS

66W Weitzsch, F.
A DISCUSSION OF SOME KNOWN PHYSICAL MODELS FOR SECOND BREAKDOWN
IEEE Trans. Electron Devices, vol. ED-13, pp. 731-734, November 1966.
THEORY: trigger temperature, thermal, pinch, non-thermal, SB state.

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67E Electro-Technology
POWER TRANSISTORS
Electro-Technology (New York), vol. 80, pp. 83-86, August 1967.
(pp. 85-86)
CHARACTERISTICS: transistor, design.
SPECIFICATIONS: F, use, test.

67G Gerstner, D.
SCHUTZMASSNAHEM GEGEN DEN 2. DURCHBRUCH IN LEISTUNGTRANSISTOREN
Europäische Tagung. Forschung auf dem Gebiet der Halpleiter - Bauelemente, Bad Nauheim, April 1967.
CHARACTERISTICS: transistor, swept, measurement.
PRECAUTIONS

67H Hakim, E. B.
SECOND BREAKDOWN GIVES FAST PULSES
EEE - The Magazine of Circuit Design Engineering, vol. 15, pp. 166-167, March 1967. (Title interchanged with one for a paper on page 162.)
APPLICATION

67H1 Hamiter, L.
INFRARED TECHNIQUES FOR THE RELIABILITY ENHANCEMENT OF MICROELECTRONICS
Semiconductor Prod. Solid State Technol., vol. 10, pp. 41-49, March 1967. (-)
OBSERVATION: temperature, current distribution.

67H2 Hower, P. L., and V. G. K. Reddi
AVALANCHE SECOND BREAKDOWN IN TRANSISTORS
Physics of Failure in Electronics, vol. 5, RADC Series in Reliability, T. S. Shilliday and J. Vaccaro, Ed., 1967, p. 557.
AD 655 397 [2]
THEORY: charge carriers, non-thermal.
CHARACTERISTICS: transistor, n^+-n-n^+, design.

67K Kannam, P. J., F. G. Ernick, and J. Marino
SECONDARY BREAKDOWN CAPABILITY OF EPITAXIAL TRANSISTORS
J. Electrochem. Soc., vol. 114, p. 63C, March 1967.
CHARACTERISTICS: transistor, design.

67M Minton, R.
DESIGN TRADE-OFFS FOR R-F TRANSISTOR POWER AMPLIFIERS
EE The Electronic Engineer, vol. 26, March, 1967. (-)
CHARACTERISTICS: transistor, swept.
PRECAUTIONS

67M1 Marshall, S. L.
SECOND BREAKDOWN IN TRANSISTORS
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