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INTERNAL VISUAL WORKMANSHIP STANDARD FOR MICROELECTRONIC DEVICES (NASA STD XX-2) AND TRAINING MANUAL

VOLUME I

NASA STD XX–2

By

J. Gaffney, W. R. Rodrigues de Miranda, E. J. Rice, C. D. Root

September 1968

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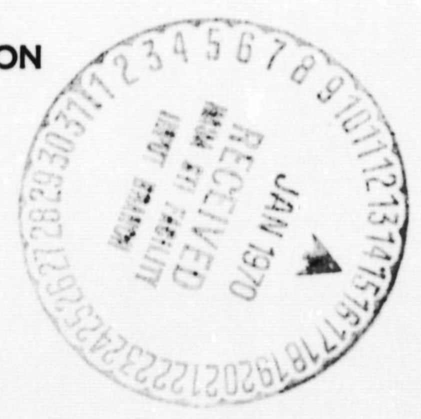

ELECTRONICS RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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INTERNAL VISUAL WORKMANSHIP STANDARD
FOR MICROELECTRONIC DEVICES
NASA STD XX-2

1. SCOPE

This standard defines the internal visual criteria covering die mounting requirements, surface imperfections, wire bonding and contamination on the die surface and on all internal areas as it applies to monolithic microelectronic devices for high reliability applications. In cases where reliability requirements are different, the criteria of this specification may be modified by the procuring agency through its purchasing documents.

2. PURPOSE

The purpose of this standard is to provide a set of reject criteria by which the acceptability of device construction and workmanship can be judged. The reject criteria listed herein are related to extended device performance. If properly executed, this standard will result in increasing the reliability of the devices to which it is applied. In order to aid the inspector in understanding and interpreting this specification, a training manual has been prepared as volume II of this specification.

3. APPARATUS

The apparatus for this test shall include optical equipment capable of the specified magnification, illumination and any visual standards (gauges, drawings, photographs, etc.) necessary to perform an effective examination and enable the operator to make objective decisions as to the acceptability of the device being examined.

4. PROCEDURE

The device shall be examined in a suitable sequence of observations and at the specified magnification to determine compliance with the requirements of the criteria as specified herein. If surface passivation is applied over interconnects and all criteria are not visible after passivation application, the appropriate defects must be inspected immediately prior to application of the passivation material. The order of examination may be varied at the discretion of the manufacturer.

5. DEFINITIONS

5.1 All references herein to silicon oxide or oxide shall also apply to any other passivation material used in fabricating monolithic silicon microcircuits.

5.2 For inspection purposes a "junction" is defined as the region bounded by the oxide step and an imaginary line running parallel to and at a distance of 1/4 mil (.00025 inch) from the oxide step external to the diffused region in question. (See Figure 1.)

5.3 The "active area" of the die is defined as all of those portions which are enclosed in an isolation region. (See Figure 2.)

5.4 A "diffusion window" is defined as the area enclosed by the oxide step which was formed prior to the diffusion. (See Figure 3.)

6. REQUIREMENTS

The semiconductor devices shall meet each of the following requirements. Failure to meet any one of these requirements shall be cause for rejection of the device.

6.1 Scribing

Microscopic examination for scribing defects on the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright or dark field illumination on the die surface. (See Figure 4.)

6.1.1 The die shall not contain any evidence of scribe marks across an active or metallized area of the die.

6.1.2 Portions of another adjacent die remaining attached to the die beyond the scribe lines, after imperfect die separation, shall not exceed 10% of the die area in size.

6.1.3 The die shall not contain chip-outs which have less than 1 mil (.001 inch) of oxide between the edge of the chip-out and the nearest diffused junction or metallization.

6.1.4 The die shall not contain semicircular cracks, which sever a chip of silicon from the remainder of the die, with the chip remaining in place.

6.2 Oxide Defects and Diffusion Faults

Microscopic examination for oxide defects and diffusion faults in the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright field light normal to the die surface. (See Figure 6.)

6.2.1 The oxide layers and passivation layers on the die, due to simultaneous processing, shall be of uniform thickness as demonstrated by uniform oxide colors.

6.2.2 The die shall not contain pinholes or areas which remain uncovered by oxide and which expose a junction or are present in active transistor/diode areas or touch metallization, except for contact windows. (See Figure 22.)

6.2.3 The oxide or glass layer shall not contain localized areas of discoloration or rainbow effects within the active areas.

6.2.4 Dielectric material such as thermally grown oxide or glass shall be free of flaking, lifting or crazing.

6.2.5 The die shall not contain oxide or diffusion faults which:

6.2.5.1 Are located completely or partly under metallization. (A surface depression in the metallization area is assumed to be a hidden oxide fault.)

6.2.5.2 Cause two diffused areas to be within 1/4 mil (.00025 inch) of shorting together.

6.2.5.3 Cause any diffusion area to be discontinuous or to be narrowed down to less than 1/4 of its design width.

6.3 Metallization Defects

Microscopic examination for metallization defects on the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright field light normal to the die surface.

6.3.1 All metallization at the edge of the die shall be separated from the edge by at least 1 mil (.001 inch) of oxide.

6.3.2 Metallization on the die shall not exhibit evidence of lifting or peeling from the die surface.

6.3.3 Metallization on the die shall not contain entrapped blisters.

6.3.4 Probe marks shall meet the following requirements:

6.3.4.1 They shall be present on bonding pads only.

6.3.4.2 They shall not be so deep as to expose the underlying surface.

6.3.4.3 They shall be no larger than 2 mils (.002 inch) in the largest dimension.

6.3.5 Metallization on the die shall not contain scratches or voids which:

6.3.5.1 Expose the underlying surface anywhere along the defect and, in addition, leave less than 50% of the minimum designed path width undisturbed. (See Figures 5 and 7.)

6.3.5.2 Occur at or over an oxide step and also leave less than 75% of the minimum designed path width undisturbed. (See Figure 5.)

6.3.5.3 Occur over a contact cut or window and also isolate more than 50% of the designed contact area from the interconnecting metallization.

6.3.5.4 Occur in a bonding pad or lead-away area between the bond and the connecting metallization; in addition, expose the underlying surface anywhere along the defect, and also leave a current carrying path the width of which is less than 50% of the narrowest design width of the connecting path.

6.3.5.5 Occur in a bonding pad; in addition, expose the underlying surface anywhere along the defect, and also isolate more than 50% of the bond from the connecting path. (See Figure 5.)

6.3.6 Metallization on the die shall not contain scratches or smears which cut completely across a path, regardless of the depth of the defect. (See Figure 5.)

6.3.7 The die shall not contain metallization smears or etching defects which reduce the distance between two adjacent metal areas or between metallization and the oxide boundary at the edge of the die to less than 50% of the designed separation. (See Figure 5.)

6.3.8 Metallization on the die shall not contain areas of small voids which cover more than 50% of the design path width at any point. (See Figure 7.)

6.3.9 Metallization on the die shall not contain areas of small voids over more than 25% of the path width for a length more than twice the design path width. (See Figure 7.)

6.3.10 Metallization shall not contain corrosion, or discoloration which may be evidence of corrosion, anywhere on the die.

6.3.11 Metallization shall not contain stains from processing residue or other contaminants anywhere on the die.

6.3.12 The following requirements apply to bimetallic molygold metallization systems only:

6.3.12.1 Metallization shall not contain evidence of a silver-gray gold/silicon eutectic formation anywhere on the die.

6.3.12.2 The top gold metallization layer (usually the design width) shall not extend more than 1/4 of the design width over the edge on either side of the molybdenum bottom layer (designated by the dimension "W" in the figure). (See Figure 8.)

6.3.12.3 The top metallization layer shall not contain scratches or voids which expose the lower metal layer anywhere along the defect and, in addition, leave less than 50% of the minimum designed path width undisturbed.

6.4 Die Mounting and Orientation

Microscopic examination of the die to header bond shall be performed at a minimum magnification of 30X utilizing a binocular microscope while the device is illuminated with side lighting and adjusted to yield an optimum light intensity with a minimum of shadowing.

6.4.1 The die shall be of the type as specified in the applicable assembly drawing.

6.4.2 The die shall be firmly attached to the package floor. (See Figure 23.)

6.4.3 The die shall not be rotated more than 10 degrees in either direction from the nominal design orientation. (See Figure 9.)

6.4.4 The die shall not be misplaced more than half its smaller dimension (width) in any direction from the nominal design location.

6.4.5 The die shall not be tilted such that it makes an angle of more than 5 degrees with the package floor.

6.4.6 There shall be no evidence of die mounting material on top of the die. (See Figure 10.)

6.4.7 The following requirements apply to devices the die of which is bonded with a non-conductive die mounting material such as glass or epoxy. (See Figure 10.)

6.4.7.1 Die mounting material shall not build up beyond the top surface of the die.

6.4.7.2 There shall be no cavities between the die and its mounting material.

6.4.8 The following requirements apply to devices the die of which is bonded with a <u>conductive</u> die mounting alloy such as gold/germanium. (See Figure 11.)

6.4.8.1 Where applicable a resolidified alloy fillet shall be visible along all of any three sides and along at least 90% of the fourth side around the die and shall extend upward against the side of the die.

6.4.8.2 The alloy fillet along the side of the die shall not extend upward more than 75% of the die height at any place.

6.4.8.3 The alloy fillet shall not exhibit any evidence of cracking or chipping.

6.4.8.4 There shall be no evidence of "balling" or flaking of the alloy material.

6.4.8.5 There shall be no sharp build-up or spikes of the alloy material which exceeds half the die thickness in height.

6.5 <u>Alignment</u> (See Figure 12.)

Microscopic examination for alignment defects on the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright field light normal to the die surface.

6.5.1 The die shall not contain contact windows which touch the edge of a diffusion window, or which extend across a junction into an undiffused area unless intentionally so designed.

6.5.2 Each contact window on the die shall have at least 90% of its area covered by metallization.

6.5.3 A diffusion window shall not approach another diffused area closer than 1/4 mil (.00025 inch) unless intentionally so designed.

6.5.4 Metallization not intended to cover a contact window shall not approach that window within 1/2 of the designed distance, or within 1/4 mil (.00025 inch), whichever is greater.

6.5.5 All junctions shall be covered by thermally grown oxide passivation.

6.6 Cracks (See Figure 13.)

Microscopic examination for cracks in the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright field light normal to the die surface.

6.6.1 The die shall not contain cracks which are longer than 1 mil and which point toward an active area or metallization.

6.6.2 The die shall not contain cracks in the active circuit area or in the metallization.

6.6.3 The die shall not contain cracks which cross a junction or isolation region.

6.7 Wire Bonding

Microscopic examination for wire bonding defects at the die bond shall be performed at a minimum magnification of 30X (except for the requirements of paragraphs 6.7.8 and 6.7.16.9 where 150X magnification shall be used) utilizing a binocular microscope while the device is illuminated with bright field light normal to the die surface.

Microscopic examination for wire bonding defects at the post bond shall be performed at a minimum magnification of 30X utilizing a binocular microscope while the device is illuminated with side lighting.

6.7.1 All wires shall be connected in accordance with the applicable assembly drawing. There shall be no missing, broken or incorrectly connected wires.

6.7.2 All bonds shall be complete and in intimate contact with the bonding surface and shall not exhibit evidence of lifting or partial separation. (A complete stitch or wedge bond is one in which the complete portion of the wire remains which was in contact with the tool.)

6.7.3 The bonding process shall not produce intermetallic compounds (such as "purple plague") which extend beyond the bond periphery when viewed from above.

6.7.4 Bonds shall be placed such that the bond exit wire does not pass over another bond or wire.

6.7.5 At least 75% of the compressed bond area shall be within the boundaries of the bonding pad. (See Figure 14.)

6.7.6 Bonds shall not be placed in the fillet area such that the major distance between the bond periphery and the edge of the fillet is reduced to less than 50% of the narrowest design width of the connecting metallization path. (See Figure 14.)

6.7.7 Separation between bonds, or between a bond and metallization other than that to which it is bonded, shall be at least 1/2 mil (.0005 inch). (See Figure 14.)

6.7.8 The bond periphery shall be separated from the die edge by at least 1 mil (.001 inch) width of passivating oxide. (Inspection at 150X magnification is required.) (See Figure 14.)

6.7.9 At least one complete bond shall terminate each wire run on the terminal post. This bond shall be fully on top or fully on the side of the post.

6.7.10 Bonding pads shall not contain evidence of the bond having been pulled laterally across the pad.

6.7.11 The die bonding pads shall not exhibit any evidence of rebonding (placing a second bond after the first attempt has failed).

6.7.12 No more than two (2) rebonds shall be made on the terminal post.

6.7.13 The rebond (second bond) shall be completely separated from remaining material left by earlier bond attempts.

6.7.14 The device shall not contain stacked (double) bonds of any type.

6.7.15 The following requirements apply to <u>ball bonds</u> only:

6.7.15.1 The diameter of the finished bond shall be at least twice and no larger than five times the wire diameter.

6.7.15.2 The location of the wire exit from the ball bond shall be within, and no closer than 1/2 wire diameter from the bond periphery and, in addition, shall be completely within the boundaries of the bonding pad, when viewed from above. (See Figure 14.)

6.7.15.3 The bond exit wire shall be perpendicular to the surface of the die chip for a distance of at least 1 wire diameter before bending toward the other terminal point. (See Figure 15.)

6.7.16 The following requirements apply to <u>ultrasonic bonds</u> only. (See Figure 16.)

6.7.16.1 The spread width of the finished bond shall be at least 1.5 but not more than 2.5 wire diameters.

6.7.16.2 Bonds shall have a uniform spread length of at least 3 but not more than 5 wire diameters.

6.7.16.3 The difference in spread width from bond toe to bond heel shall not exceed 1/2 wire diameter.

6.7.16.4 Bonds shall not show evidence of being incomplete due to nicks in the side of the bond impression.

6.7.16.5 The bond tail on the die shall not exceed 1½ wire diameter in length.

6.7.16.6 The bond tail on the terminal post shall not exceed 3 wire diameters in length.

6.7.16.7 The bond tail shall not make an angle of more than 10 degrees with the surface to which the bond is made.

6.7.16.8 The angle in the vertical plane between the wire near the bond and the die surface to which it is bonded shall be at least 10 degrees but not more than 30 degrees. (See Figure 17.)

6.7.16.9 Bonds shall not exhibit evidence of tears, or micro-cracks in the bond heel, or any other damage. (Inspection at 150X magnification is required.)

6.7.17 The following requirements shall apply to stitch and wedge bonds as well as resistance welds to the terminal post:

6.7.17.1 The spread width of the finished bond is at least 1.2 but not more than 2.5 wire diameters.

6.7.17.2 The bond impression shall not be completely pushed through the wire to the underlying surface.

6.7.17.3 Bonds shall not show evidence of being incomplete due to a missing tail, nicks in the side of the bond impression, or as a result of being damaged.

6.7.17.4 The bond tail shall not exceed 2 wire diameters in length.

6.7.17.5 The angle in the vertical plane between the wire near the die bond and the die surface shall be at least 10 degrees but not more than 30 degrees. (See Figure 17.)

6.8 <u>Wire Routing</u>

Microscopic examination for wire routing defects shall be performed at a minimum magnification of 30X utilizing a binocular microscope while the device is illuminated with side lighting.

6.8.1 The separation between two wires or between a wire and any other conductive surface anywhere in the device package shall be at least 2 wire diameters. (See Figure 18.)

6.8.2 Lead wires shall not cross other wires, metallization, bonding pads or terminal leads. (See Figure 18.)

6.8.3 The angle in the horizontal plane between the center-line of an ultrasonic or wedge bond and the connecting wire shall not exceed 15 degrees. (See Figure 16.)

6.8.4 The horizontal displacement (viewed from above) of a wire run shall not exceed 3 wire diameters from the imaginary straight line between its terminal points (pad and post bond). (See Figure 18.)

6.8.5 The vertical displacement of a wire run shall be at least one (1) wire diameter from the imaginary straight line between its terminal points, but not so much as to approach the package cover (when in place) or the die surface within 2 wire diameters. (See Figure 19.)

6.8.6 Lead wires shall not sag below the top surface of the die to which it is bonded. (See Figure 19.)

6.8.7 Lead wires shall not be nicked, cut, crimped, scored or otherwise damaged so that the effective diameter is reduced by more than 10%. (See Figure 20.)

6.8.8 Lead wires shall not be necked down due to excessive tension so that the effective diameter is reduced by more than 25% of the nominal wire diameter.

6.8.9 Lead wires shall not be twisted more than 90 degrees in its span between bonds.

6.8.10 Lead wires shall not be bent or kinked such that the bend radius is less than twice the wire diameter. (See Figure 20.)

6.8.11 The device shall not contain lead wires other than those specified in the applicable assembly drawing.

6.8.12 Terminal posts shall not contain extra lead wires or remaining portions of bonds which are more than 3 wire diameters in length.

6.9 Contamination

Microscopic examination for contamination on the die shall be performed at a minimum magnification of 150X with a binocular microscope while the device is illuminated with bright field light normal to the die surface.

Microscopic examination for contamination in the package and on its internal surfaces shall be performed at a minimum magnification of 30X utilizing a binocular microscope while the device is illuminated with side lighting.

6.9.1 The device package and die surface shall not contain any unattached particles, silicon chips, or other foreign matter. "Unattached" is defined as particles which can be removed by blowing a jet of nitrogen of not more than 20 PSI. Such particles may be removed by this method to avoid rejection of the device. Foreign material shall not be removed by tweezers or other mechanical instruments.

6.9.2 The surface of the die shall be free of attached particles, silicon chips or other foreign matter which are larger than 1 mil in major dimension or which are larger than half the narrowest metallization separation on the die whichever is smaller. (See Figure 21.)

6.9.3 The surface of the die shall be free of attached particles, silicon chips or other foreign matter, or groups of such particles which bridge more than half the space between two metallization areas or paths, or which bridge more than half the space between metallization and the boundary of the passivating oxide at the edge of the die. (See Figure 21.)

6.9.4 The die surface shall be free of residue from photo resist or other processing chemicals.

6.9.5 The oxide or glass layer shall not contain corrosion, or discoloration which may be evidence of corrosion, anywhere on the die.

6.10 Package Condition

Microscopic examination of the package condition shall be performed at a minimum magnification of 30X utilizing a binocular microscope while the device is illuminated with side lighting.

6.10.1 The die surface and internal cavity of the package shall not contain lacquer, grease, paste, desiccant nor any other materials which are not required, nor specified.

6.10.2 Lead-in terminal to case clearance at any point shall be at least 1 mil (.001 inch) (metal package only).

6.10.3 The internal surfaces of the package and lid shall be clean and free of any material which could possibly become detached when used in the specified environment.

6.10.4 The internal surfaces of the package and lid shall be free of pinholes, cracks, dents, or other evidence of damage or poor workmanship.

6.10.5 The internal surfaces and seal of the package and lid shall be free of any evidence of corrosion, residue, or other contaminants.

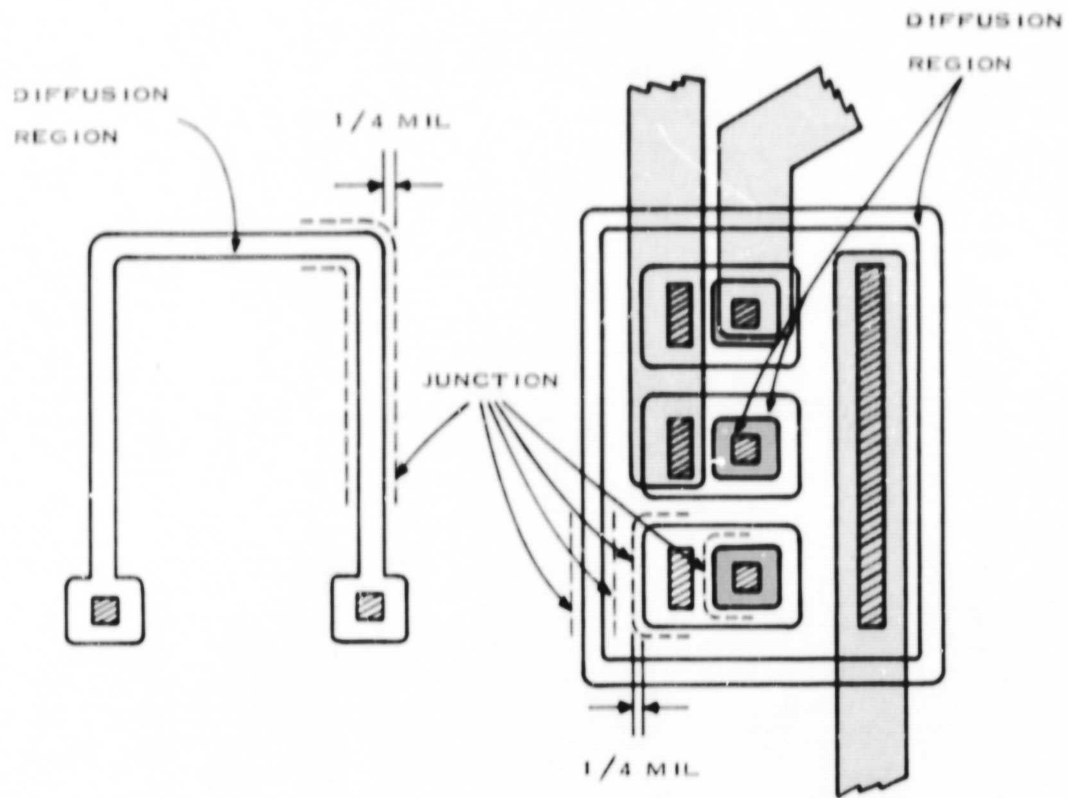

Figure 1 - Definition of a junction.

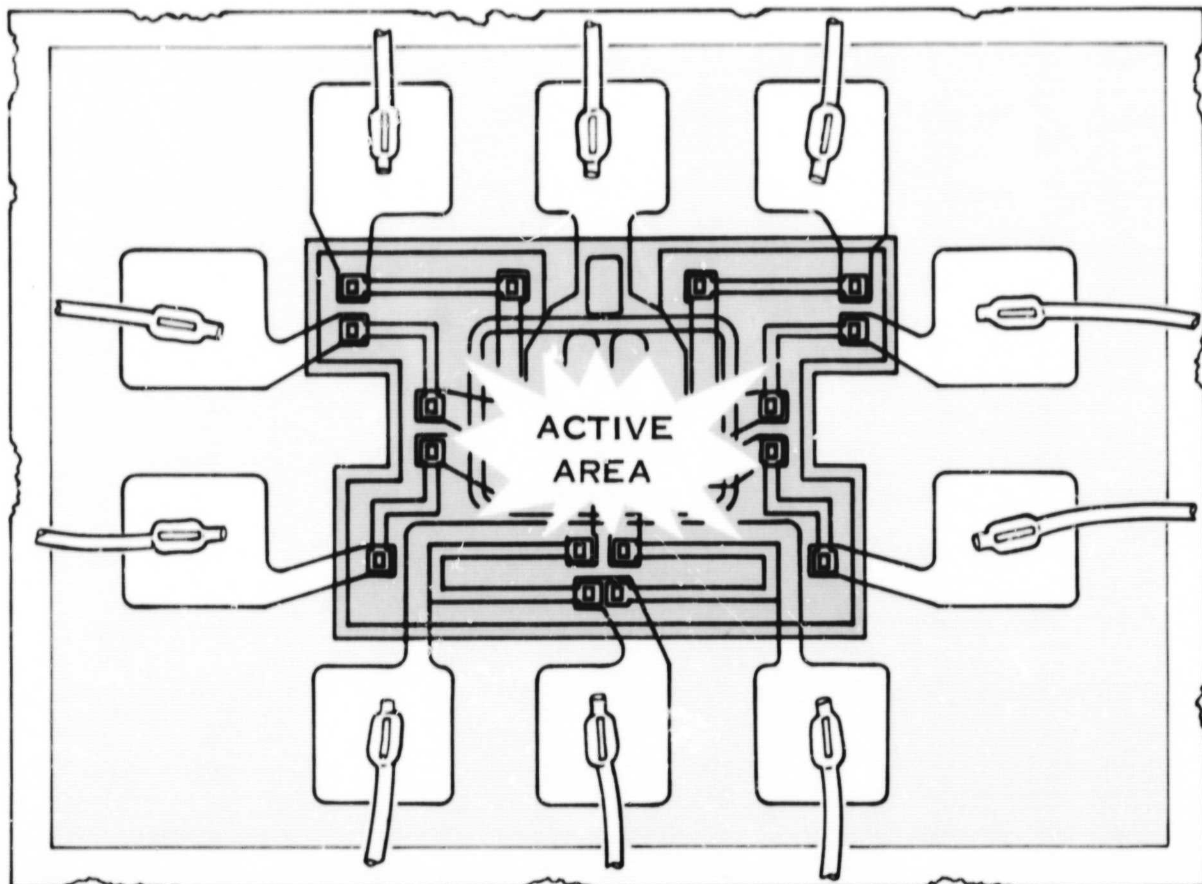

Figure 2 - Definition of the active area.

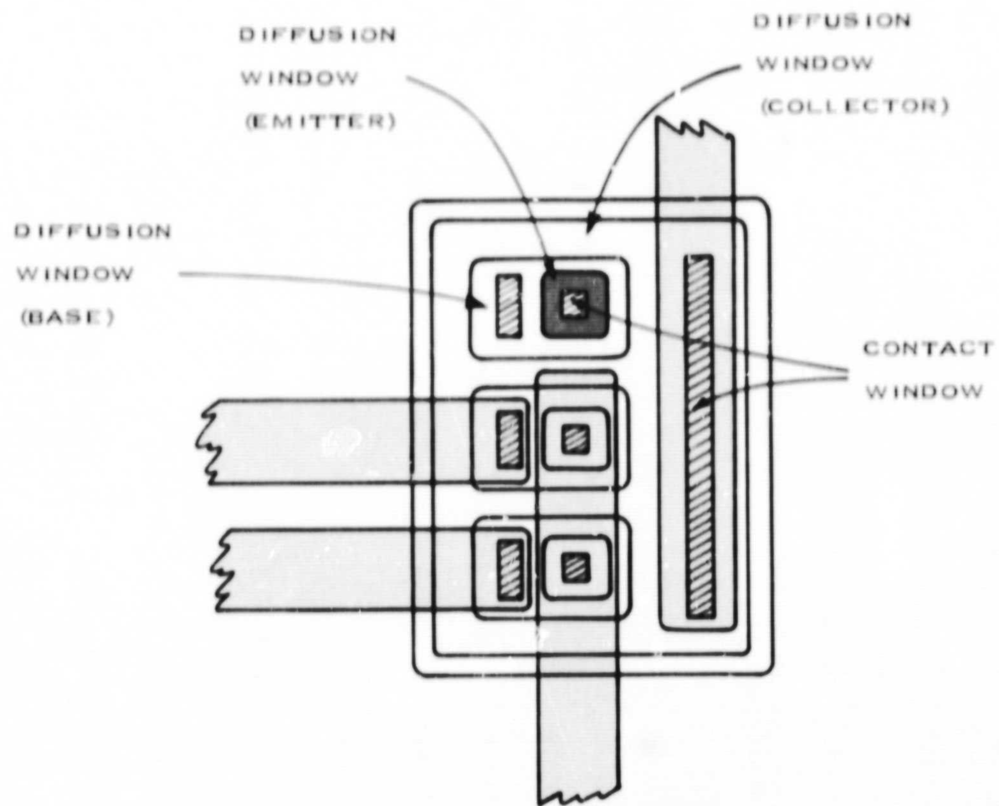

Figure 3 - Definition of diffusion and contact windows.

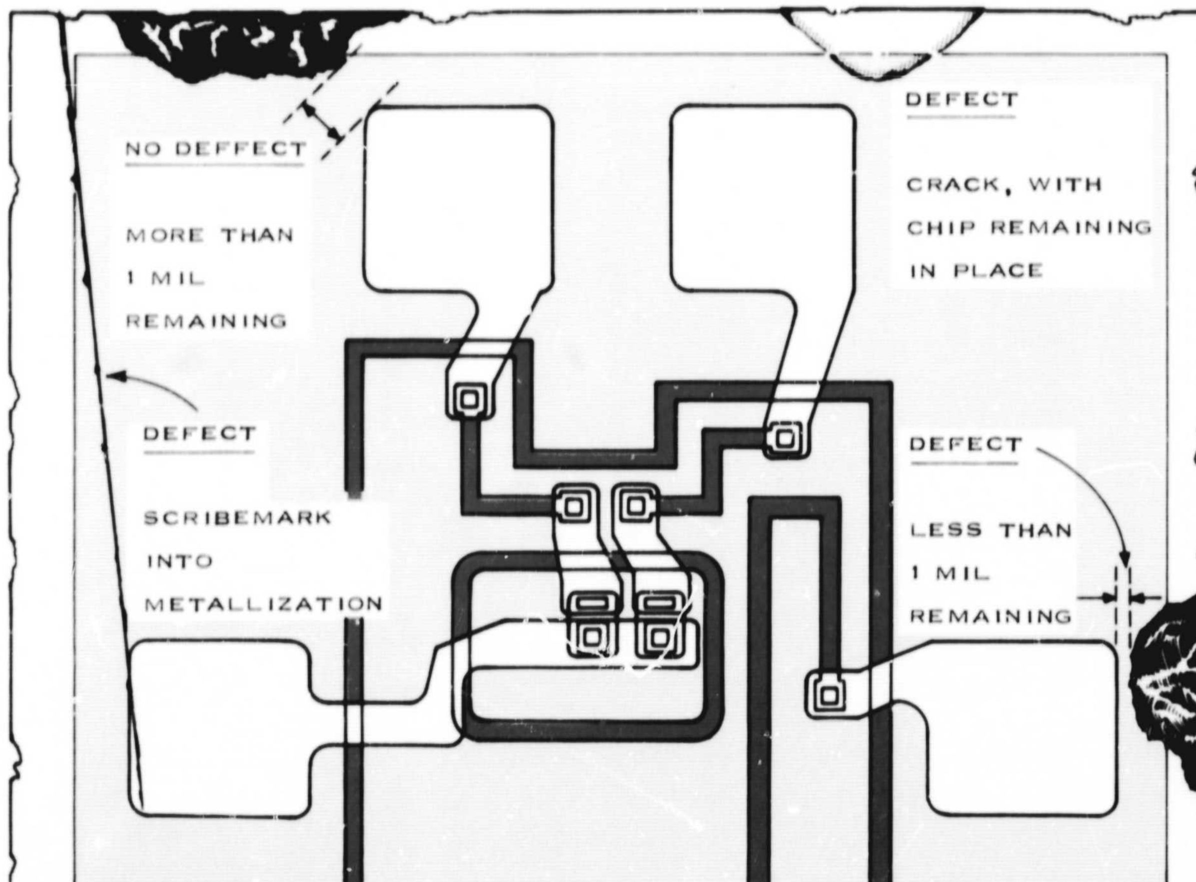

Figure 4 - Typical scribing defects.

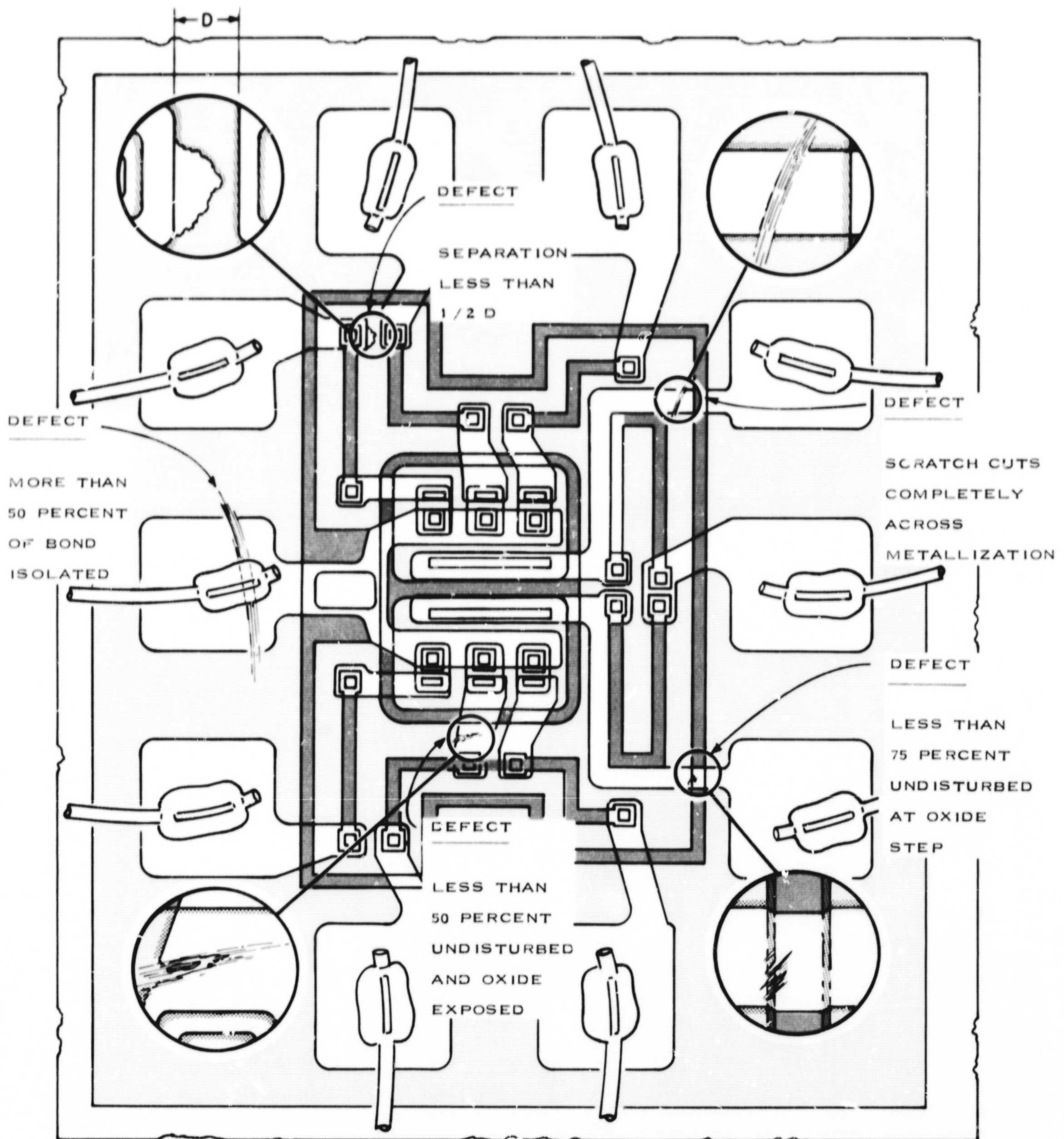

Figure 5 - Typical metallization defects.

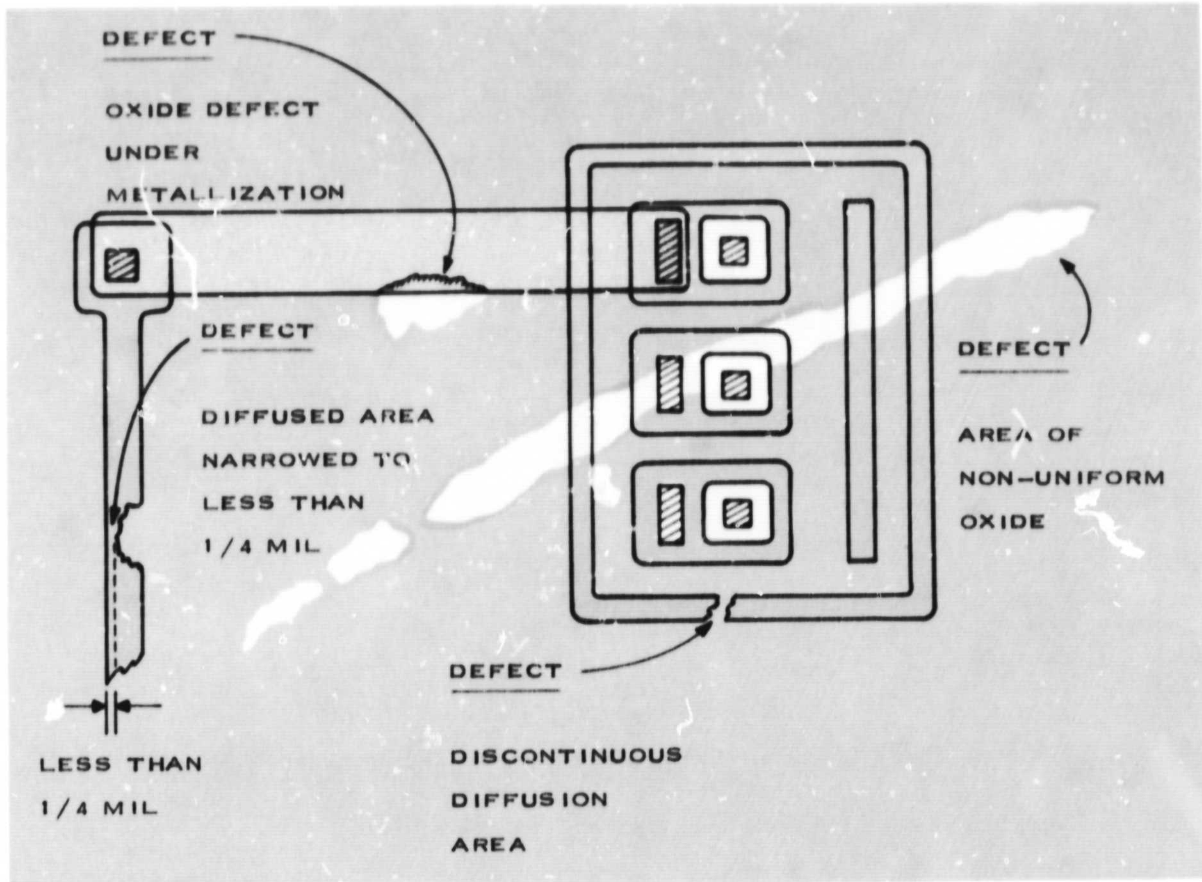

Figure 6 - Typical oxide defects.

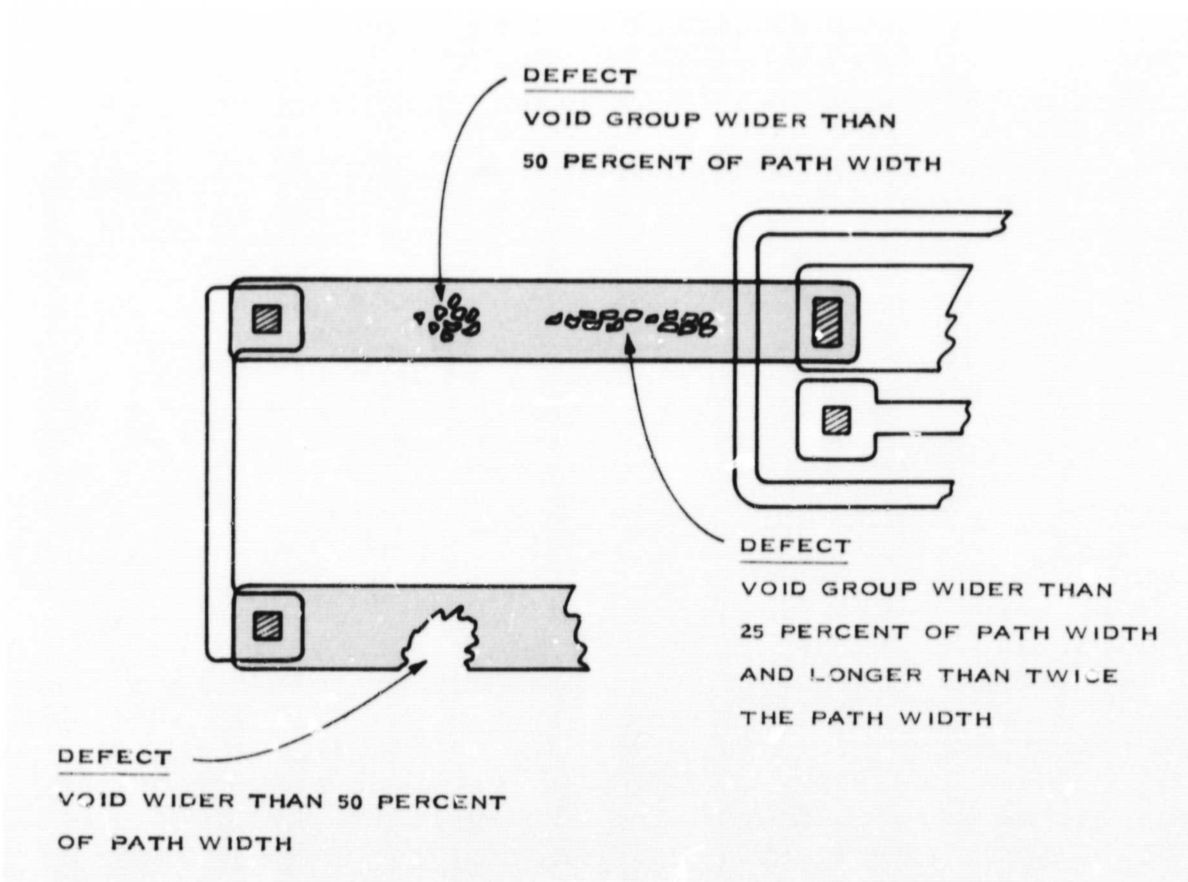

Figure 7 - Typical defective voids
in metallization.

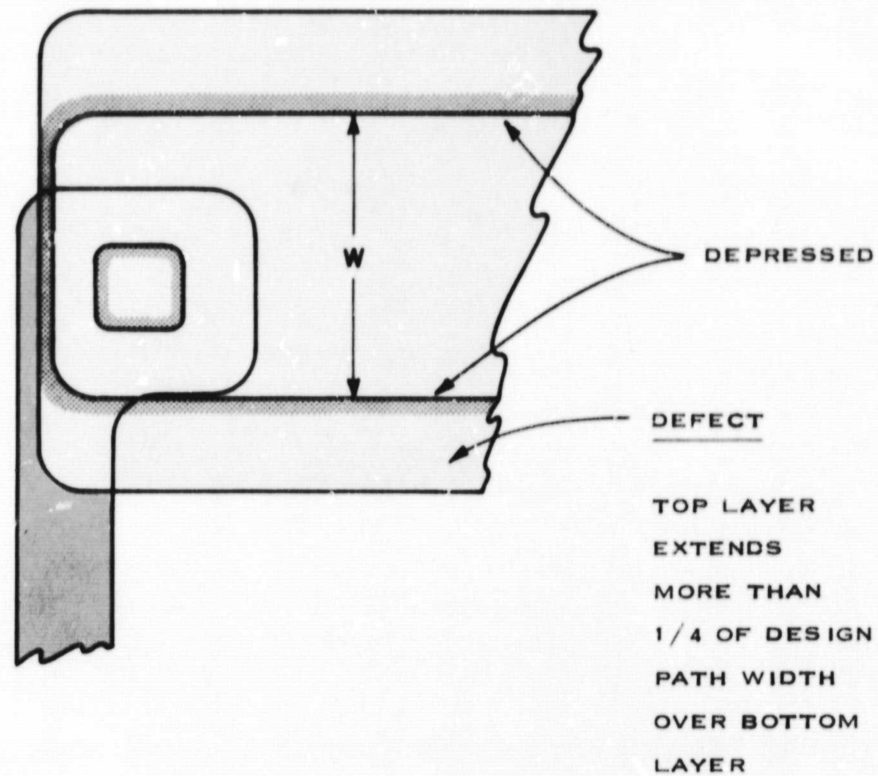

Figure 8 - Typical defective bi-metallic system metallization.

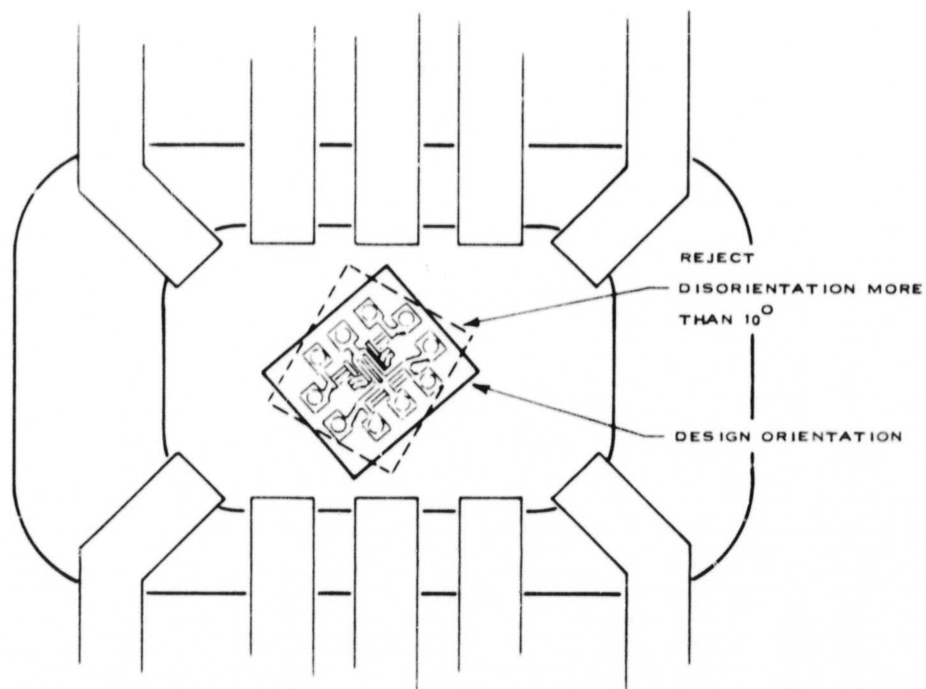

Figure 9 - Typical defective die orientation.

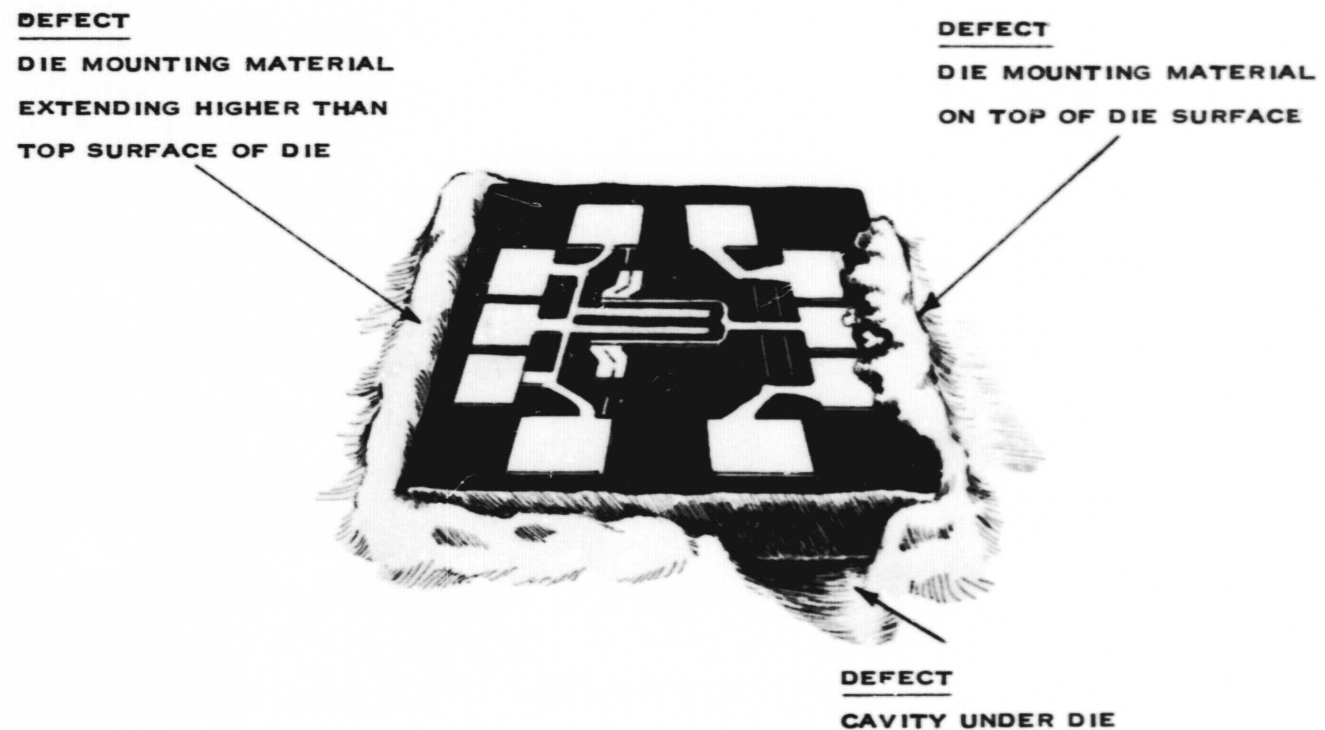

Figure 10 - Typical defective die mounting with non-conductive material

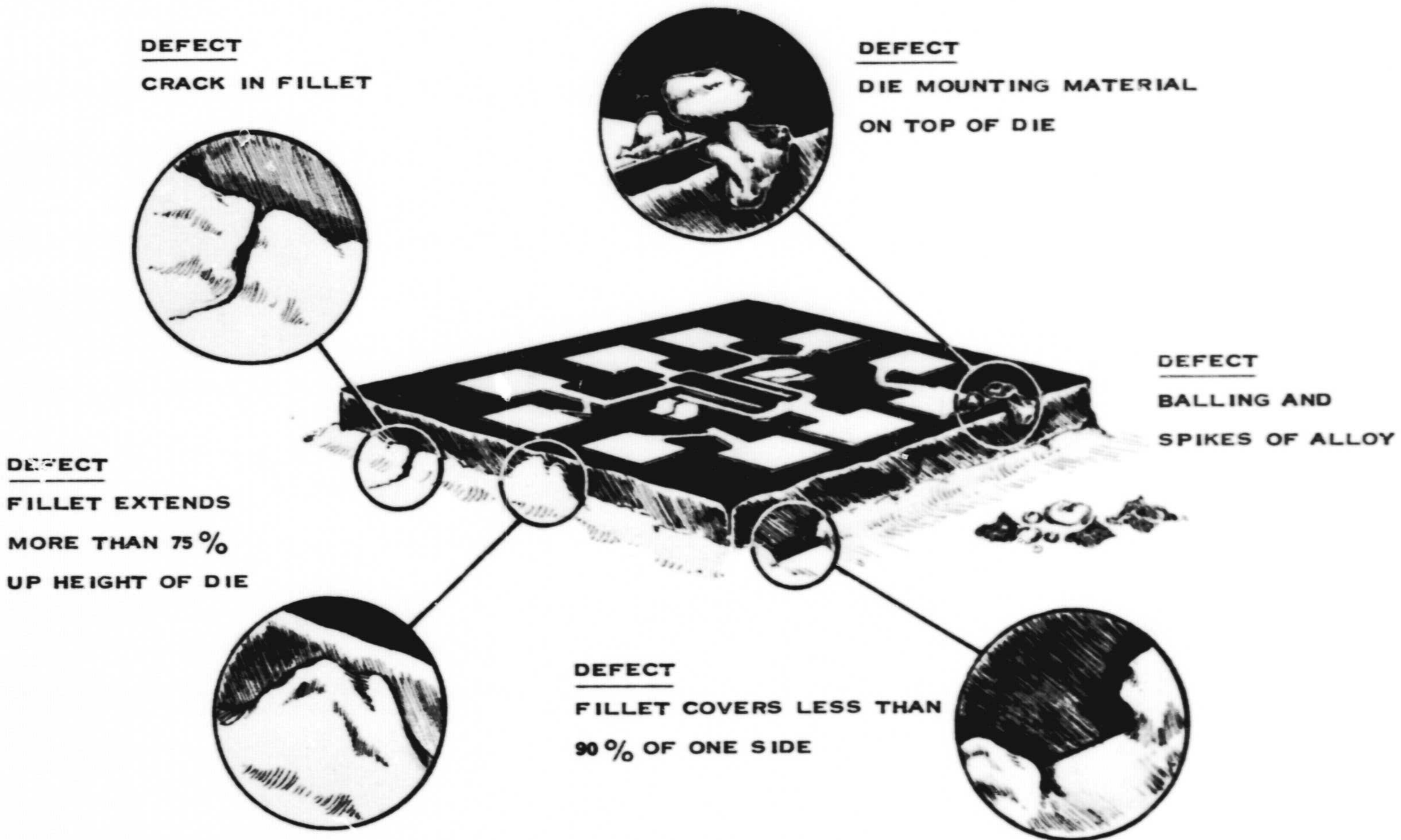

Figure 11 - Typical defective die mounting with conductive material

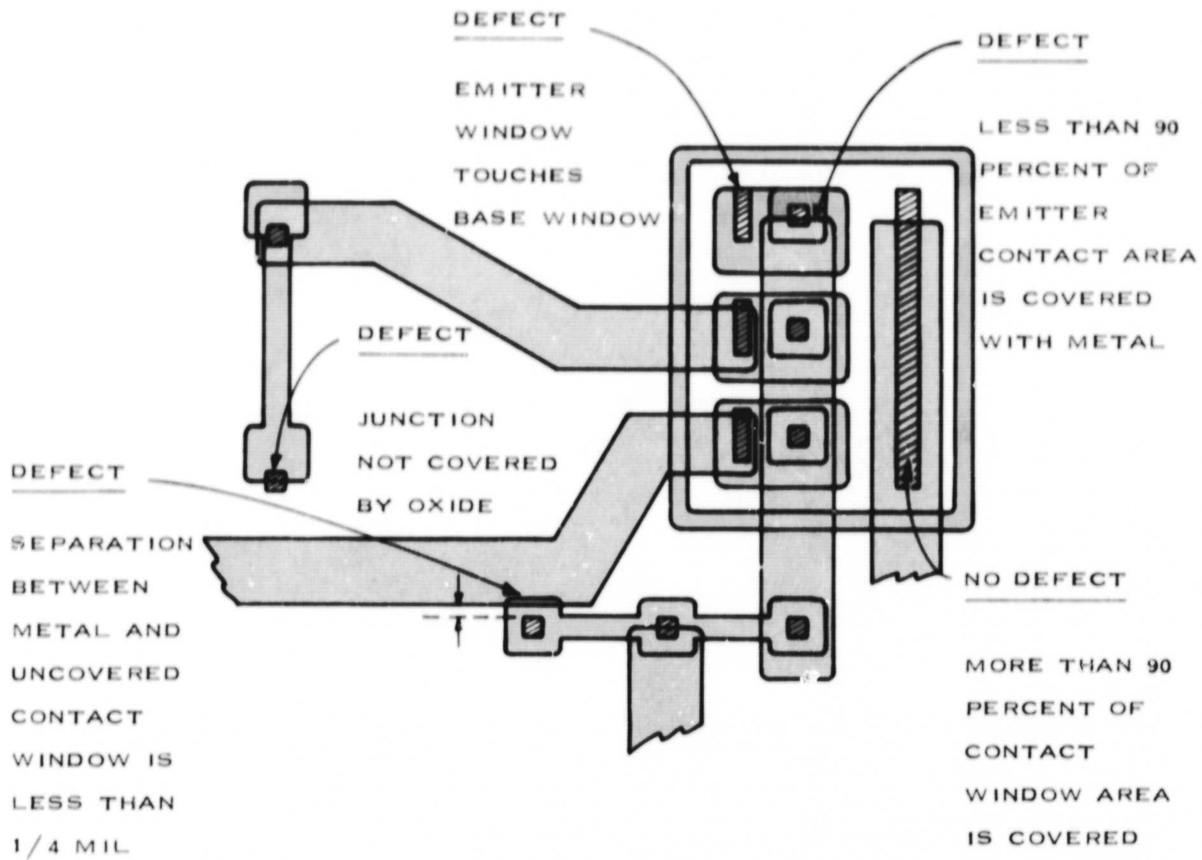

Figure 12 - Typical alignment defects.

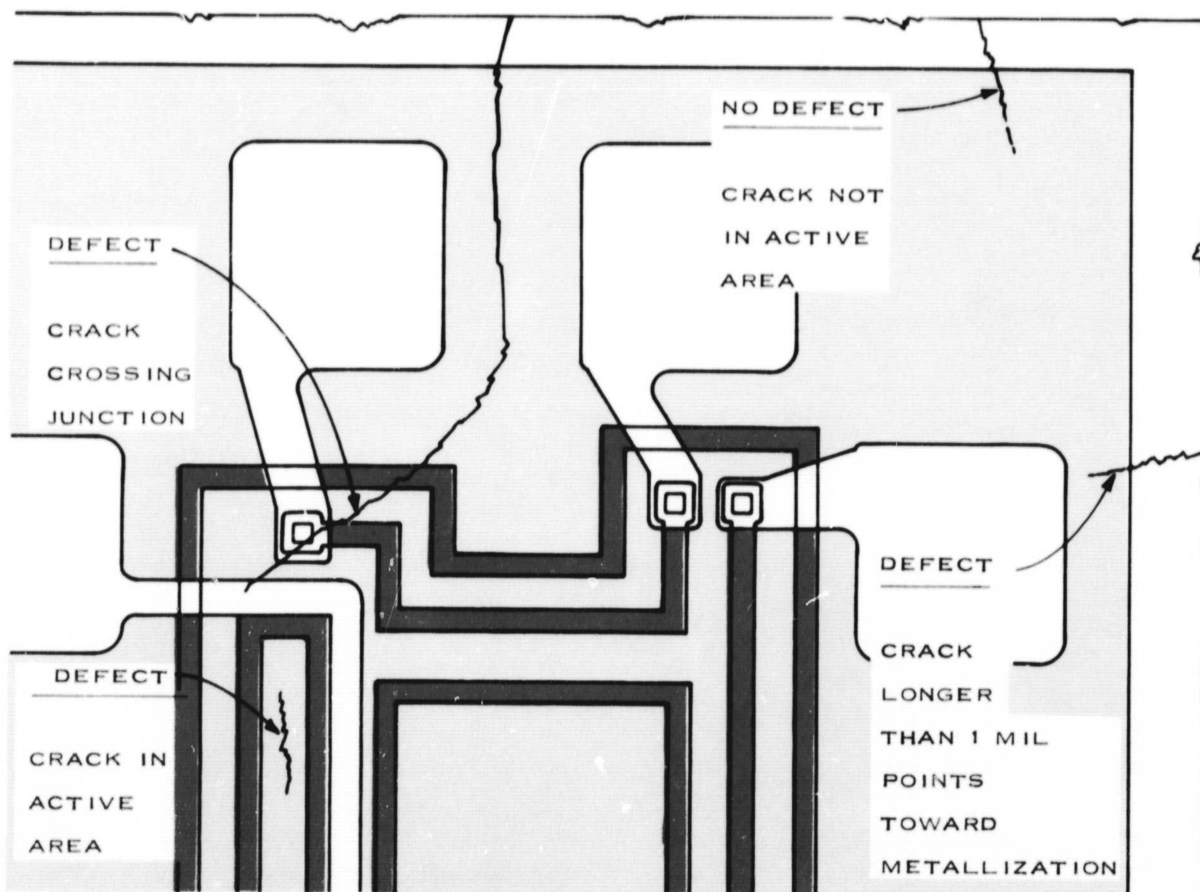

Figure 13 - Typical defective cracks.

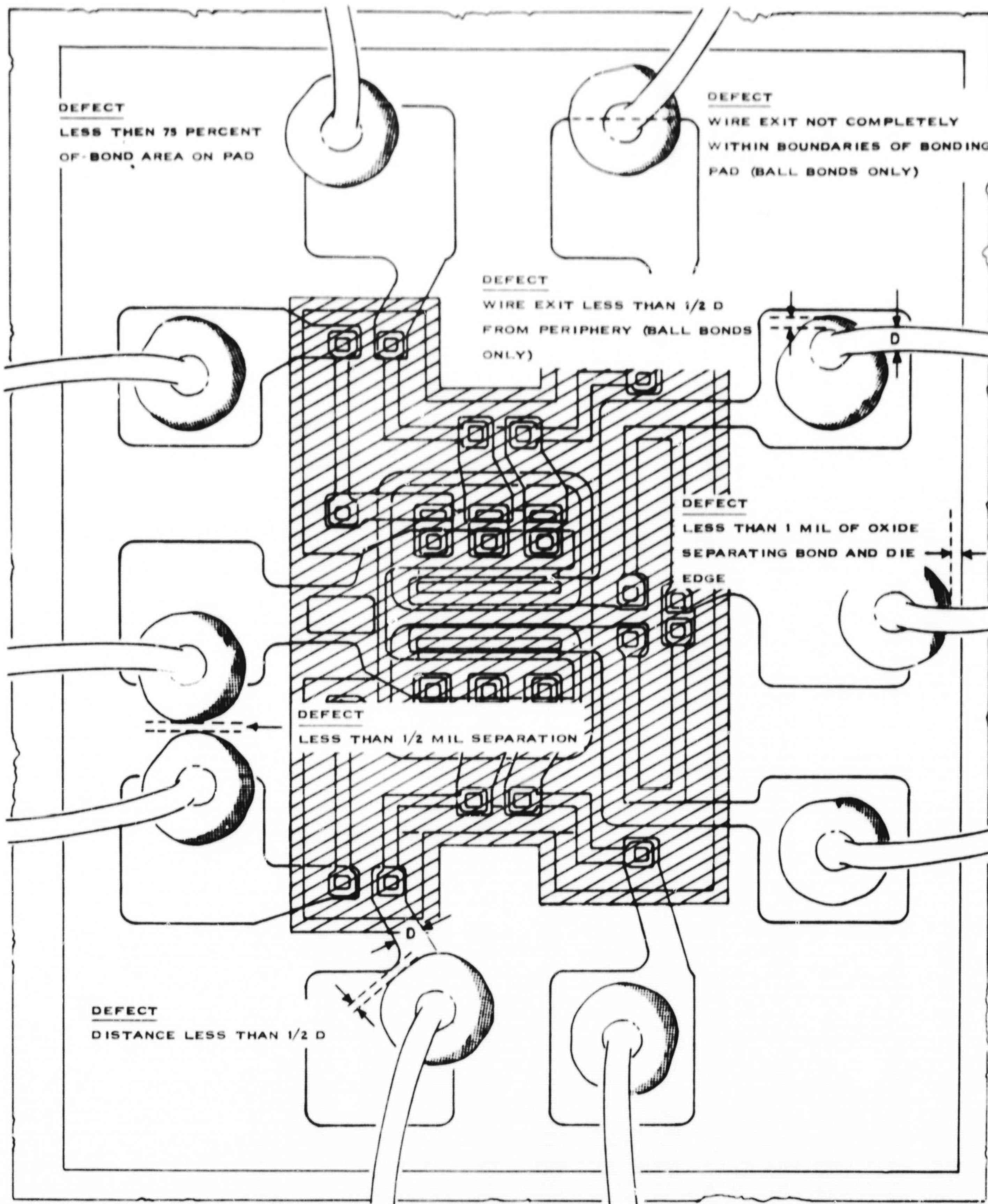

Figure 14 - Typical defective bo[illegible] placement.

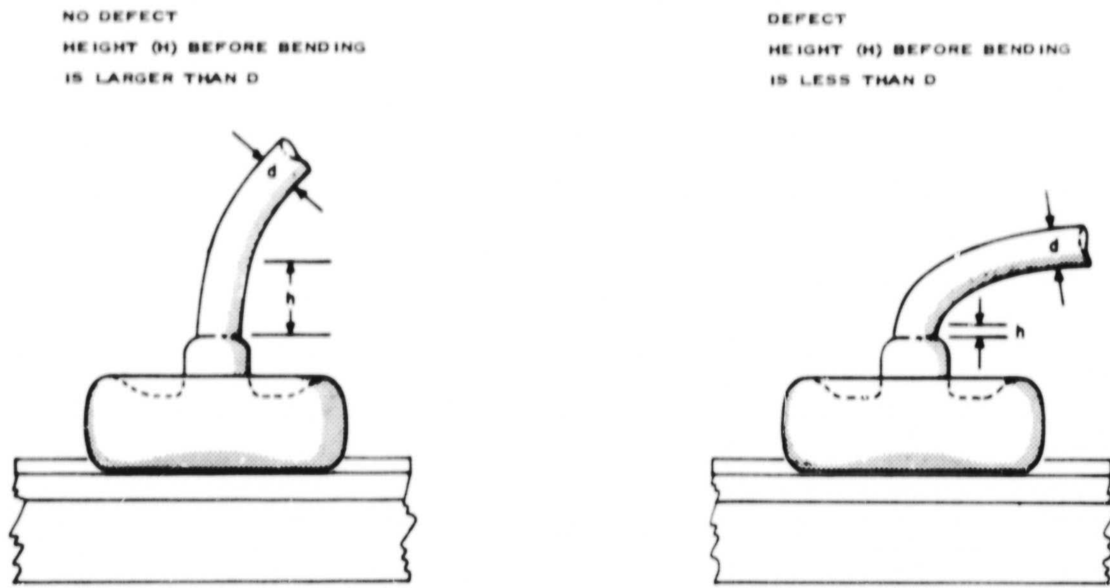

Figure 15. Defective wire exit at ball bonds.

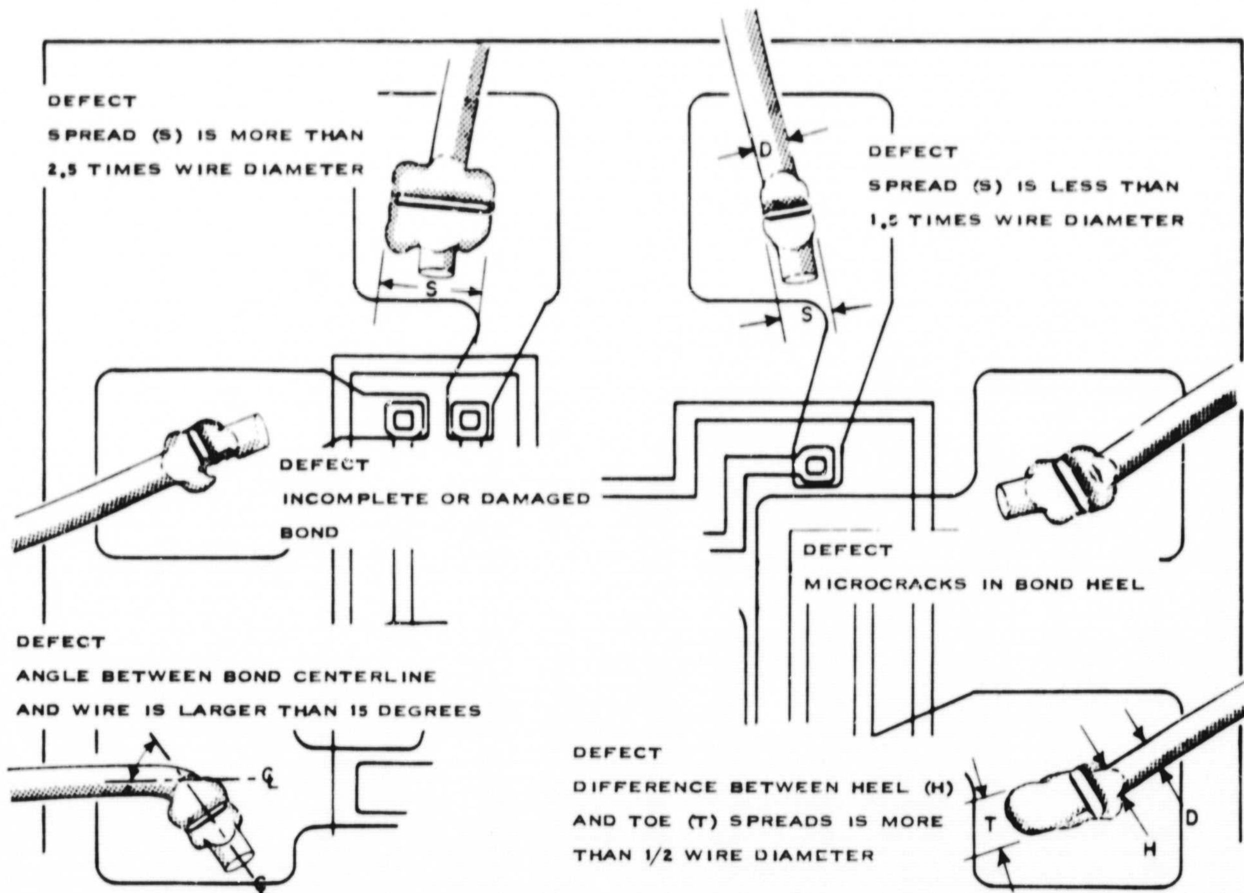

Figure 16. Typical defective ultrasonic bonds.

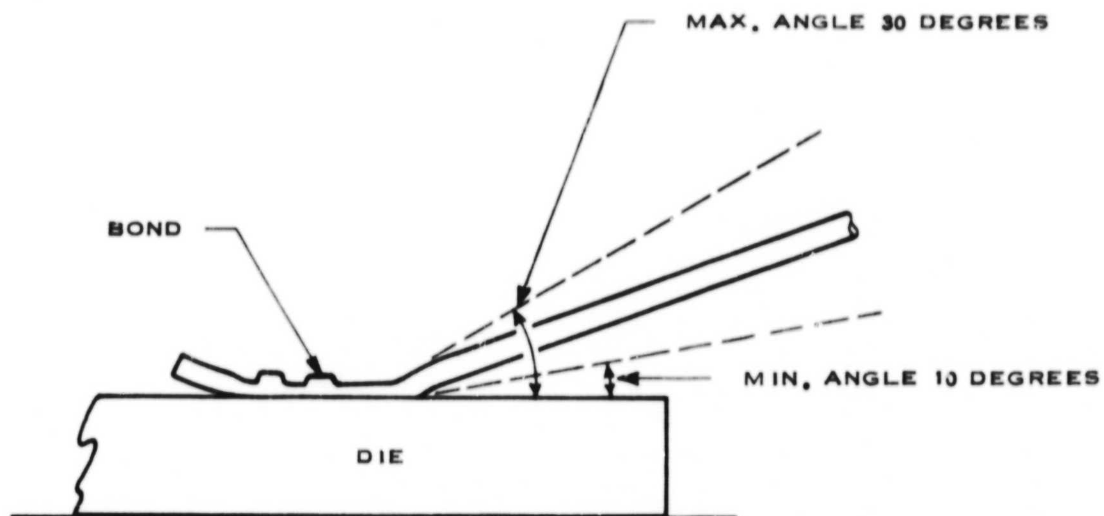

Figure 17 - Allowable range of angles for exit wire of ultrasonic and wedge bonds.

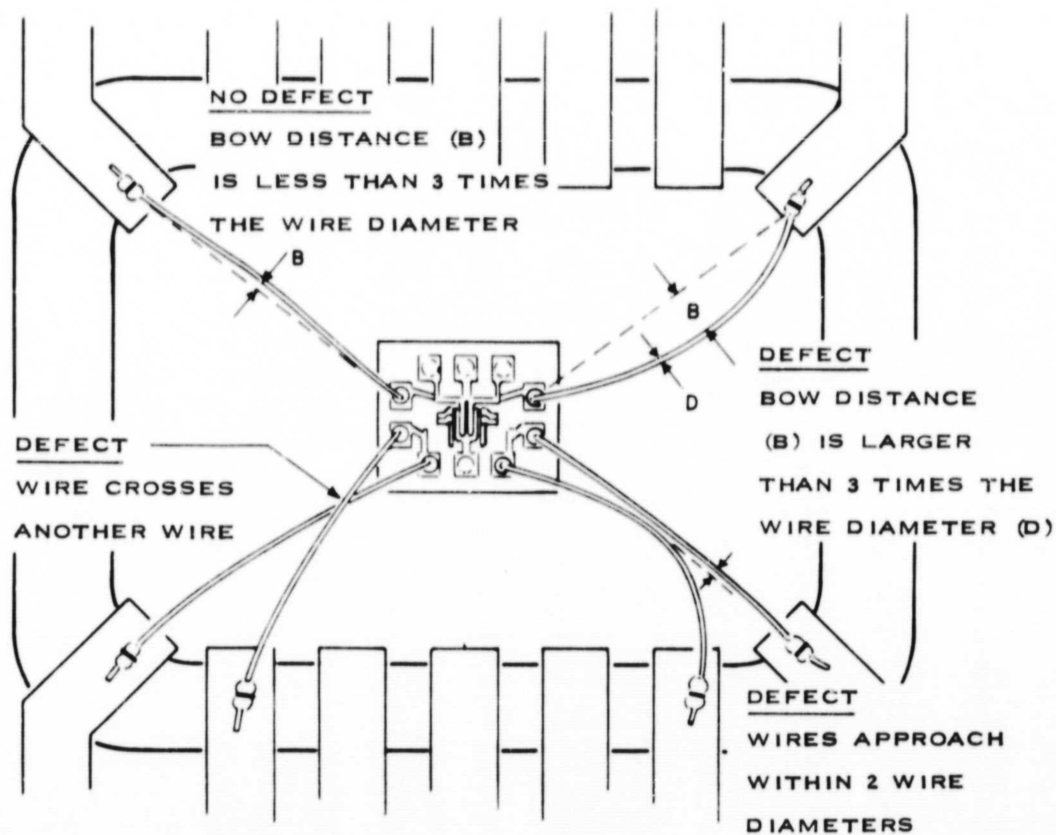

Figure 18 - Typical defective wire routing.

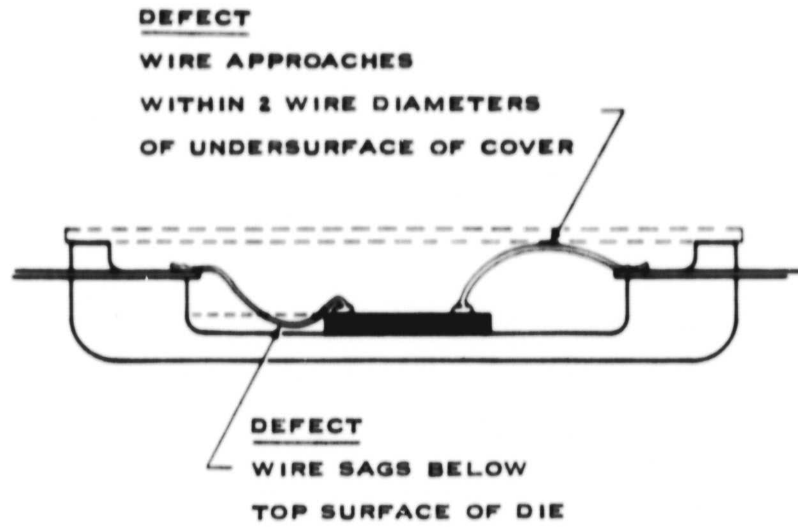

Figure 19. Typical defective wire routing.

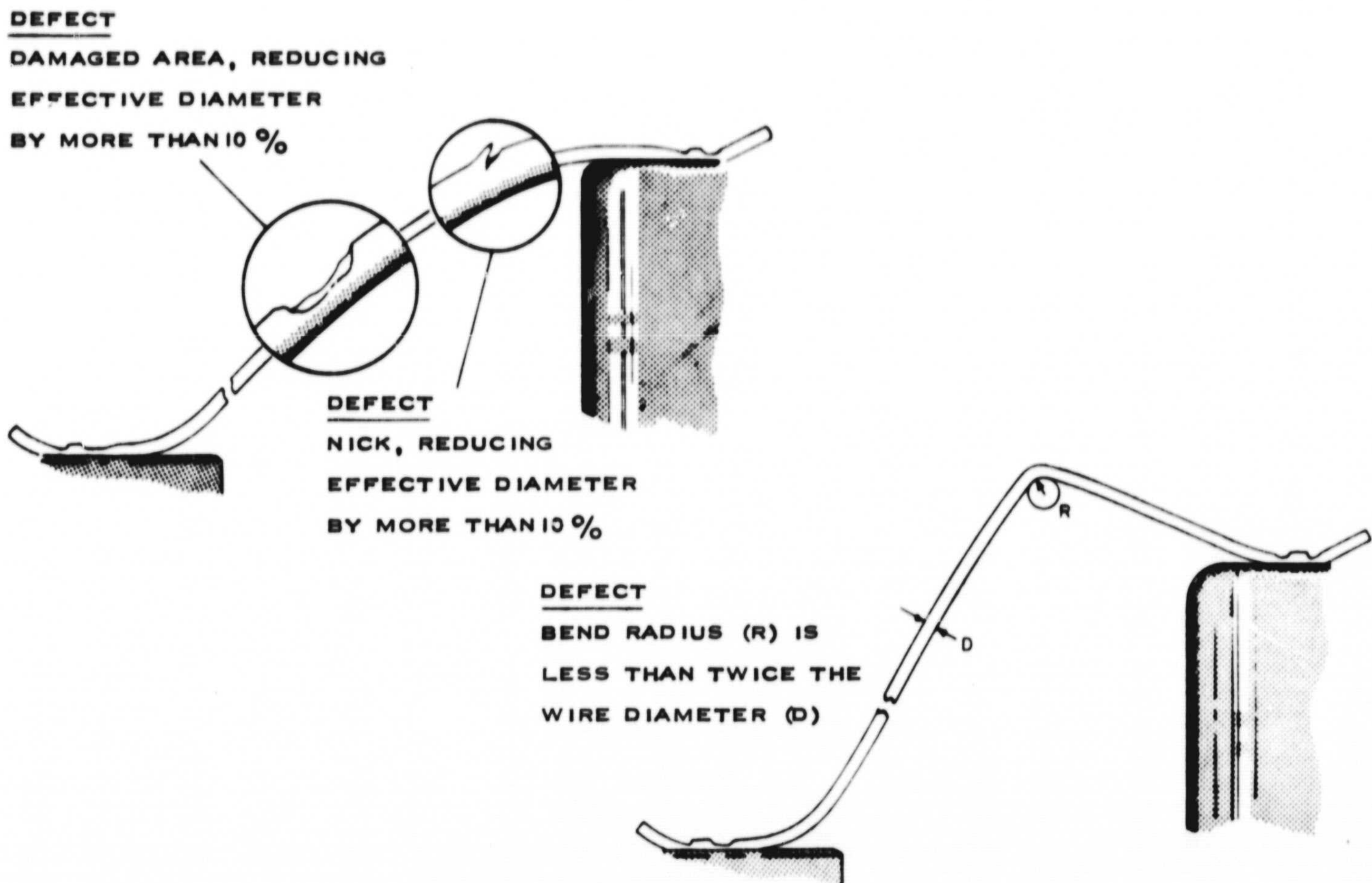

Figure 20. Typical defective lead wires.

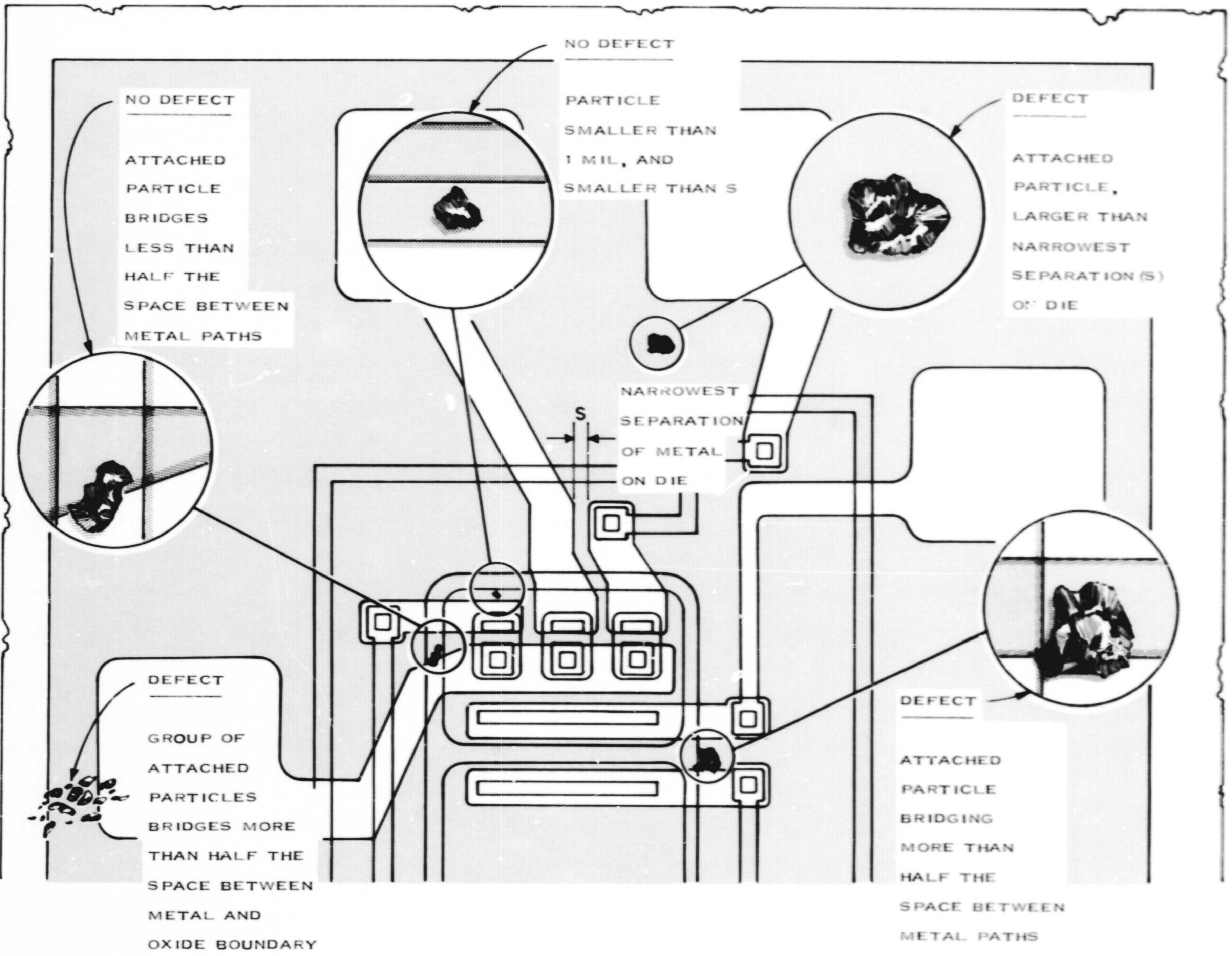

Figure 21 - Typical defective particles.

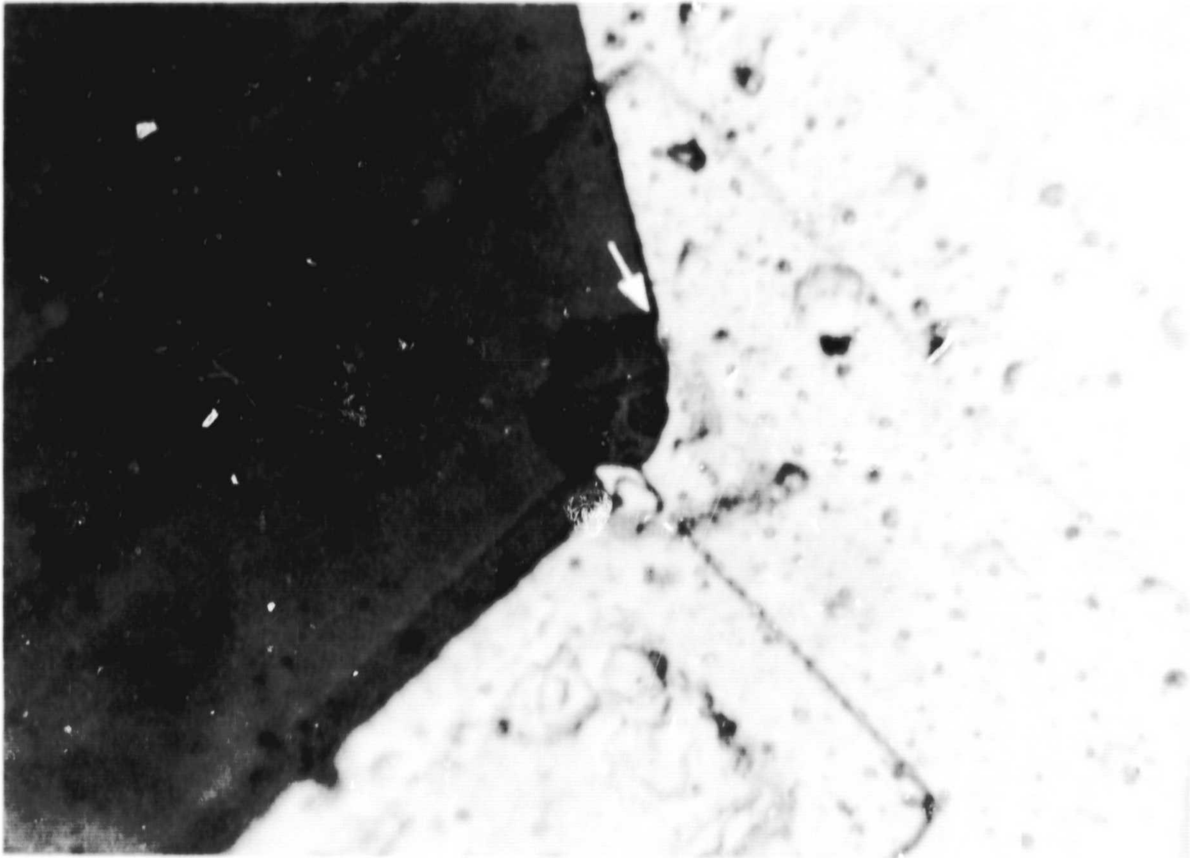

Figure 22 - Oxide flaw (large pinhole) extending under metallization and in active area.

Figure 23 - Die not firmly attached to package floor.