Electrostatic Discharge Damage and Control

Application Note A004R

Introduction

Electrostatic discharge (ESD) is a natural phenomenon that affects virtually every production facility in one way or another. As semiconductor devices become smaller and more sensitive, the list of devices susceptible to damage by electrostatic discharge continues to grow. Many companies accept static damage as inevitable, writing off these losses in rework, customer returns, field service, warranty costs and ultimately in higher prices to their customers.

Static, however, can be predicted, measured, generated in a controlled fashion, suppressed, channeled, shielded against and, most important, prevented. In the following, a discharge circuit is formulated from empirical test data and pertinent literature. It will be shown that stored charges sufficient to produce device damage are present at all levels of production flow and recommendations are presented for reducing ESD damage. Mistakes often made in ESD control procedures are also given.

Description

Parametric or functional failure of Si bipolar, MMIC and GaAs FET transistors can occur as a result of electrostatic discharge. Failures in bipolar transistors are characterized by low breakdown voltage or high leakage current. FET failures are characterized by resistive shorts. In some cases, leakage current would increase with applied voltage and reduced reverse breakdown voltage.

Diagnosis

Diagnosis of failure in bipolar devices shows the area affected to be predominantly in the emitter base region of the NPN transistor (Figure 1). This region is selectively affected because the emitter-base junction is normally smaller than any other element in the circuit. Damage in this area actually results from silicon melting and is caused by localized overheating in the depletion region of the P-N junction. The dominant failure mode of field effect transistors is a rupture in the gate channel between the source and drain (Figures 2 – 4). This effect may be aggravated by a non-homogeneous GaAs active area, GaAs hillocks or clusters, all of which could cause reduction in dielectric strength of the GaAs.

Discussion

Semiconductor electrostastic discharge susceptibility can be determined through sample testing; however, one quickly realizes that this approach is impractical. A better approach might be to consider all semiconductors as being susceptible, though this is unreasonable for some devices. Also, other parts families such as thin-film resistors and capacitors are also susceptible to ESD. The need for ESD control within a company increases along with the use of such susceptible products.

The potential energy of electrostatic charges can only be quantified by measurement of body capacitance and charge potentials and the absence of electrostatic charges can only be verified by potential measurement. Survey instrumentation basically consists of a capacitance bridge for measuring body capacitance and a non-conducting static voltmeter or gun.

Because the damage to a semiconductor is a function of the energy of the discharge ($1/2CV^2$), the capacitance of the discharging body is an important parameter. This will determine the tolerable voltage level before damaging thresholds are reached. The procedure for measuring body capacitance is much the same as measuring a component capacitor. The person to be measured is connected to the high side of the bridge while the low side of the bridge is connected to ground (normally the safety ground in the 110 VAC supply). Normally the connection to the person is by the hand or fingertips. In this case, the person's skin is one electrode of the capacitor; the soles of the shoes, the flooring and other non-conductors are the dielectric; and the earth is the other electrode. Typical capacitance values that have been measured are in the range of 80 to 140 pF.

Electrostatic voltage measurements are made on personnel and fixturing in a normally operating environment with sufficient frequency during the survey period to determine the worst case conditions. It is imperative that the measurements be made without contacting the charged source to prevent bleed-off of the stored charge. The highest impedance contact type of voltmeters provide sufficient leakage current paths to bleed off the stored charge. It is also necessary that the voltmeter be grounded because the non-contacting voltmeter will give a differential voltage reading between the operator of the meter and the body being measured. Electrostatic potentials between 2,000 and 40,000 Volts were measured in areas where no controls were in effect.

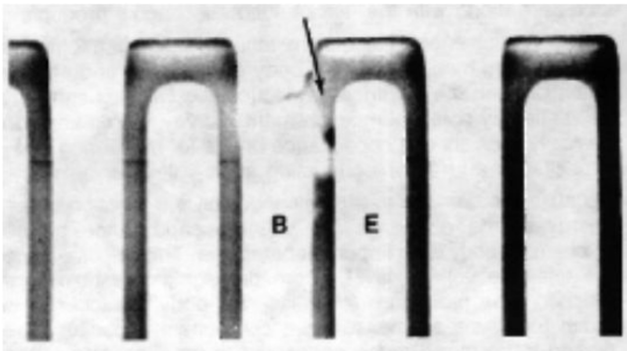


Figure 1. Bipolar Transistor with electrostatic discharge damage (2.5KX)

Since the source and magnitude of electrostatic charge is now understood and quantified, it is now possible to evaluate some semiconductor susceptability using a test circuit which simulates the body discharge. Schematically, the basic test circuit is a 150 to 200 pF capacitor with a series 1.5 to 2.0 kΩ resistor as shown in Figure 5. These circuit values were selected on the basis of measured body charge potentials, emperical damage correlation and related literature.

The device under test is subjected to increasing values of charge potential from the charged capacitor until it either fails or is determined to pass worst case test conditions.

Possible Causes

Static discharge is almost always associated with people, the type of material/clothes that people wear and/or handling equipment.

Analytical Techniques

1. Electrical characterization – Curve tracer.
2. Optical detection – Optical microscopy equipped with a Nomarski interference contrast.
3. Physical identification – Scanning electron microscope.

Recommendations on ESD Control

Apartial list of the most common generators of electrostatic charge is as follows:

1. Work stations and areas
   a. Work benches and surface coverings (non-conductive)
   b. Floors (vinyl and all waxed surfaces)
   c. Chairs (ungrounded)
2. Operator clothing
   a. Clean-room garments (synthetics)
   b. Personal clothing (synthetics, silk and wool)

Figure 2. Typical Location of ESD damage in FETs

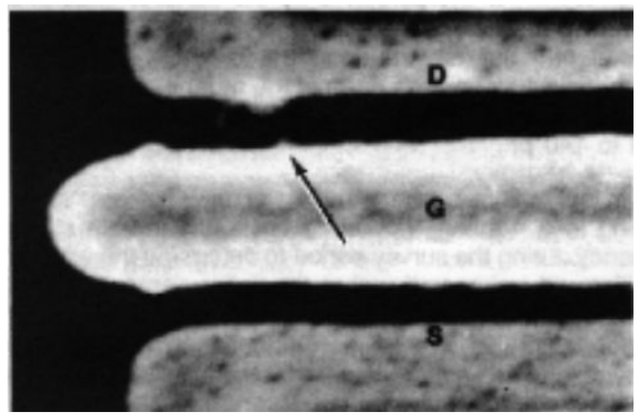


Figure 3. T-Gate Channel with Electrostatic Damage (5.8KX)

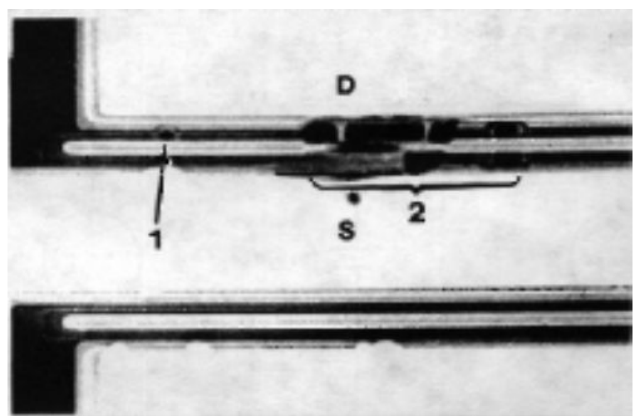


Figure 4. An example of interdigitated metallization with electrostatic damage. (1) Initial static damage.
(2) Side effect of discharge resulting from damage shown in (a)

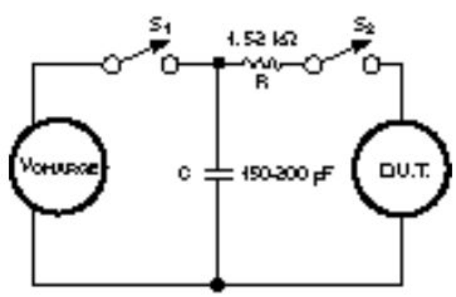
3. Part and assembly packaging materials
    a. Polyethylene bags and films
    b. Polyethylene bubble pack and foam
    c. Plastic boxes, trays and cabinets
4. Cleaning and test areas
    a. High velocity gas flow temperature chambers for drying

    A partial list of corrective measures for use in neutralizing these generators of electrostatic charge is as follows:

    1. Work stations and areas
        a. Use grounded conductive mats and plates over non-conducting surfaces
        b. Ground conductive surfaces
        c. Use grounded floor mats
        d. Apply grounded conductive grids or nets to chairs
        e. Use electrostatic precipitators in the immediate work area
    2. Operator clothing
        a. Use wrist grounding strap (10 MW ground)
        b. Use static-free smocks
        c. Use foot-grounded straps on leather soles
        d. Control of personal clothing may be necessary
    3. Part and assembly packaging materials
        a. Use conductive bags and wrappings
        b. Eliminate the use of bubble pack
        c. Use shorting collars, rings, or wrappers on individual parts prior to installation
    4. Cleaning and test areas
        a. Eliminate high-velocity gas flow over assemblies and parts.

    Last, but definitely not least, are some common mistakes and problems often associated with operator grounding. Some of these problems may be difficult to prevent if not carefully looked into.

    1. Remember to place ground straps back on after breaks and lunch before handling any susceptible parts.
    2. Be sure that the wrist strap is securely attached to the ***wrist*** touching the skin snugly for adequate connection. Wrist straps do not work when attached over clothing.
    3. Do not wear smocks or clothing made of materials which tend to generate high electrostatic potentials such as synthetics, wool or silk.
    4. Do not use any type of quick disconnect fasteners, such as alligator clips, to ground the operator to the mat, as they tend to fall off easily.
    5. Do not use tangled or knotted ground cords.
    6. Do not allow wrist straps to become corroded or dirty from excessive usage. They must be cleaned or replaced regularly.



Test Procedures:
1. S_1 closed S_2 open to charge C.
2. S_1 opens.
3. S_2 closes to stress the device under test.

Figure 5. Destructive Test Circuit to Simulate the Static Charge/Discharge Characteristics of the Human Body

Static Control Vendors

The following companies can supply static control equipment and/or supplies and may be of assistance in solving static control problems. These vendors are listed for reference only and their listing here does not constitute an endorsement or recommendation by Avago Technologies.

Teno Stat, Division of Teno A B
Box 297, S-601 04 Norrkoping, Sweden
Telephone: 46 11 19 75 00
Telex: 64329

Wescorp, 144 South Whisman Road
Mountain View, CA 94041
Telephone: (415) 969-7717
Telex: 345507

3M, San Francisco Sales Center
1241 E. Hillsdale Boulevard
Foster City, CA 94404
Telephone: (415) 571-6700

Charleswater/West
6731 San Fernando Road
Glendale, CA 91201
Telephone: (818) 502-1453
Telex: 910 498-2214

Startex Corporation
8235 220th Street West
Lakeville, MN 55044
Telephone: (612) 469-5461
Toll Free: (800) 328-4080

Typical equipment for the control of static charges includes the Simco model SS-2X Electrostatic Locator available from:

Dryden Engineering Company
3350 Scott Boulevard
Santa Clara, CA 95054
Telephone:(408) 727-7321

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