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STATIC ELIMINATION WORK STATIONS

By R. S. Hedges
and
J. L. Bellah

Published December 1978

Final Report
R. S. Hedges, Project Leader

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DP00613.

**Kansas City
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BDX-613-1953, Final Report, Published December 1978

Prepared by R. S. Hedges and J. L. Bellah

Electrostatic charges, if not properly controlled, can destroy or degrade certain semiconductor devices. Several techniques for controlling static charges were evaluated, using an electronic signal selector as the primary model for investigation. Included in the evaluation were air-ionizing equipment, encapsulant additives and materials, antistatic spray, and the use of X-rays.

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SUMMARY

Electrostatic-charge damage to CMOS, MOSFET, and JFET semiconductor devices, thick film resistors, and polycarbonate capacitors continues to cause production problems despite active attempts to control such damage. Four additional techniques for controlling charge buildup on production parts were evaluated. An economic alternative to the air-ionization fan now in use at Bendix was found.

Process procedures utilizing X-rays and new material additives also were tested. A search was made to find procedures which would remove part of the burden of static control from production operators. Methods of charge prevention, rather than elimination, were sought.

DISCUSSION

SCOPE AND PURPOSE

Several techniques for controlling electrostatic charge on electronic assemblies were studied in an attempt to shed light on a serious and costly problem. Air-ionization equipment, which uses externally produced ions to neutralize static voltage, and new encapsulation techniques to prevent or lessen the accumulation of charge were studied. Data were collected for analysis so that protective procedures might be developed to minimize the causes of electrostatic damage.

Five types of air-ionization devices were evaluated to determine their effectiveness and limitations in neutralizing electrostatic charge buildup. Polyurethane foam was monitored for static-charge buildup, and various techniques were studied in an effort to reduce or eliminate this buildup. Epoxy microbubbles and RTV 632 also were studied to determine if encapsulation systems using these materials posed a static-charge hazard.

An electronic signal selector was chosen as the primary model for investigation, since this unit has been found to be particularly sensitive to static voltages. The units are encapsulated with polyurethane foam and cured at 71°C for 8 hours. During the encapsulation and curing process, static voltages of more than 1500 V have been measured on the external foam surface. Several catastrophic failures attributed to charge buildup have occurred in the unit.

PRIOR WORK

In an earlier investigation, Bendix engineers used an energy-storage model of the human body to measure and collect static discharge data.^{1,2} This model was used to analyze electrostatic problems, and several modifications in facilities and process procedures to minimize these hazards were suggested. Several of those suggestions, such as the use of conductive wriststraps and footwear, currently are being used in sensitive device assembly areas.

ACTIVITY

Investigation was carried out in four areas.

- Several external air-ionization devices were tested for effectiveness in controlling charge buildup.

- Excapsulant additives and an antistatic spray were evaluated to see if charge buildup could be prevented.
- In the past, X-rays have been used to neutralize static voltage on bulk-stored materials. This technique was modified for use on production parts.
- Another encapsulation process was monitored for comparison with the data for polyurethane foam.

Air-Ionization Equipment

The 457- by 610-mm grounded ionization plate uses high voltage to cause air molecules to ionize. Ions are emitted on three sides near the perimeter of the plate, and they depend on the movement of air created by the working motions of a production operator to carry them to the work. Voltages were measured on a number of different materials; it was found that marginal charge reduction could be obtained only when an external air source (such as a laminar-flow clean bench) was used to direct the ions across the work.

An ionization grid, made of a framework of electrodes, mounts in a clean bench over the bench air exit. The electrodes are powered by a 7-kV source that causes the moving air to ionize. The grid was installed in a clean bench which was modified by the addition of a grounded stainless-steel surface over the top of the work surface. Air flow across the work area of the bench was 24.4 to 36.6 m/min.

After more than one minute in the ionized air, several materials (Teflon, cured polyurethane foam, and polyethylene bags and cups), which initially had been charged to several hundred volts positive, were tested for charge neutralization. Voltages of +50 to +100 V remained on the surfaces of the materials. When negatively charged and placed in the ionized air for 1 minute, the charges were reduced to nearly 0 V. These same materials, initially uncharged, also were placed in the ionized air and allowed to remain for a minimum of 10 minutes; this exposure to the ionized air built up charges as great as +100 V on the surfaces. The grid produces more positive than negative ions, which accounts for the positive residual voltages. The grid can be modified at the factory at extra cost to obtain a balanced charge output.

A protective screen over the grid is required for complete safety. Data have not been compiled as to its effect on the ionizing ability of the grid.

A radioactive isotope (Po_{210}) is used as an ionizing source in the ionization fan. Alpha particles, emitted by the isotope, create ions that are directed across the work by a small fan. Exposure of some uncharged materials (Teflon, cured polyurethane foam, polyethylene bags and cups, silicon rubber, nylon, polyolefin shrink sleeving, and epoxy-laminate printed circuit board material) for more than 10 minutes at a distance of less than 610 mm always left zero-voltage charges on the materials. Attempts then were made to charge the materials positively and negatively (some would charge only positively and others only negatively). The materials then were placed in the air stream and the charge always was reduced to nearly 0 V after 1 minute of exposure.

The fan can only be leased from the manufacturer, and it must be returned annually to the factory for replacement of the isotope. It currently is the prime ionization fan in use at Bendix.

Another ionizing fan is described as a nonnuclear replacement for the radioactive-isotope ionizing fan. A grid powered by a high-voltage supply produces ions which are blown across the work by a small fan.

The nonnuclear fan left voltages of -50 to -150 V on Teflon, cured polyurethane foam, and polyethylene bags and cups after exposure to the air stream for more than 5 minutes at a distance of less than 610 mm. This occurred regardless of whether the materials initially were charged to several hundred volts negative or were uncharged. When initially positively charged, however, the charge on these materials was reduced to nearly 0 V after exposure to air for 1 minute. However, the charges on other materials (silicon rubber, nylon, polyolefin shrink sleeving, and epoxy-laminate printed circuit board material) always was nearly 0 V after exposure to the air stream for more than 10 minutes. This always occurred, regardless of whether the materials were uncharged or were charged positively or negatively.

A third ionization fan also uses a high-voltage source for the generation of positive and negative ions, but apparently solves the problem of residual charge, since prolonged exposure of Teflon, cured polyurethane foam, and polyethylene bags and cups for more than 10 minutes at a distance of less than 610 mm always left a 0-V charge. This occurred if the materials were positively or negatively charged or were uncharged. This fan also left a zero-voltage charge on silicon rubber, nylon, polyolefin shrink sleeving, and epoxy-laminate printed circuit board material after exposure to the air stream for more than 10 minutes at a distance of less than 610 mm.

As received, the fan has semiexposed high-voltage electrodes on the front panel. A protective screen was fabricated and installed over the electrode area. The voltage-neutralization property of the fan was not affected by the addition of the screen. This fan is slightly larger and heavier than either of the other two fans, but it has greater air output, which enhances its neutralizing ability.

Encapsulation Investigations

In addition to the investigation of ionizing air blowers and grids, other techniques were tried in an attempt to control static-charge buildup. The blowers and grids have the disadvantage of being expensive to buy or lease, and they require careful use to be effective in controlling static charge.

A screening test was run to determine whether the physical characteristics of polyurethane foam encapsulation material could be changed to reduce or eliminate static voltages. To be useful in a static-reduction program, the volume resistivity of polyurethane foam must be reduced from about 10^{16} to 10^{10} Ω -cm.

Specimens were molded from polyurethane foam, with each of the two antistatics being evaluated in concentrations of 0.5, 1.0, and 2.0 percent by weight. Electrical tests--volume resistivity and capacitance--were conducted on specimens approximately 6.3 mm thick. At a concentration of 2 percent, both additives showed only a slight reduction in volume resistivity from 10^{16} to 10^{15} Ω -cm. Capacitance was unaffected. Other concentrations did not significantly affect either resistivity or capacitance.

Most antistatic additives utilize a mechanism of moisture attraction and retention to bleed off static charges. Thus, they are chemically reactive and do not lend themselves to polyurethane foam systems. The slight change in volume resistivity caused by the addition of the antistatic agent suggests that additional work with this additive would not be beneficial.

A surface-spray antistatic agent was evaluated during foaming. The Teflon-covered lid of a potting fixture was treated with spray before the unit was foamed. Another unit, left untreated, was used as a control for comparison. When both units were disassembled from their molds, the voltages on both units and both fixture lids were measured. There was no difference between the two units. A slight yellowing of the foam was noticed in the treated unit, however, indicating an increase in exothermic-reaction temperature.

X-Ray Exposure

In the past, X-rays have been used successfully to reduce the static voltage on polystyrene plastic beads contained in drums. The X-rays temporarily lower the volume resistivity of the beads, causing the charges to bleed off. Dummy units were foamed, cured, and X-rayed to see if this treatment could be used as a substitute for external static-control measures, such as air-ionizing devices. One control unit was not X-rayed. A blank printed circuit board with paths wired together was formed inside each dummy unit, and it was used as a probe for measuring internal voltages. Units were irradiated with 50-kV X-rays for either 30 minutes at film-to-focal-spot distances of 457 or 914 mm, or for 60 minutes at 914 mm. Radiation is approximately 0.155 C/kg/min (150 roentgens/minute) at 914 mm and 0.039 C/kg/min (600 roentgens/minute) at 457 mm.

All units, including the control unit, showed zero internal voltage after being treated. As the potting-fixture lid was removed, internal voltages increased to approximately +150 to +200 V on all units. The surface charge on the foam of all units ranged from +1500 to +2000 V at that time. Thus, the results indicate that X-ray treatment offers no real benefit for static control in this application. Difficulties with electrostatic-charge buildup may be more dependent on differences in triboelectric voltage potentials (as between polyurethane foam and Teflon) than on chemical reactions.

Another Encapsulation Process

The encapsulation of epoxy microbubbles over RTV 632 slush coat was monitored so that static-voltage data could be collected for comparison with data for polyurethane foam. A pickup element was installed in, but insulated from, two aluminum cups before the interiors of the cups were slush-coated. The RTV was poured over the element in the cups and evacuated for 2 to 3 minutes. The cups then were turned over for the RTV to drain. The internal and the surface voltages remained at 0 V during all steps. The RTV in the two cups then was oven-cured. One cup was covered while in the oven to prevent contact of the RTV with moving air.

After the RTV had cured, the two cups were removed from the oven and filled with epoxy microbubbles. A third cup, also containing a pickup element, was not slush-coated and was at room temperature. It was poured with microbubbles at the same time. Voltages were monitored during the following operations:

- Slush-coated cup, evacuated 2 to 3 minutes at 66.7 Pa;

- Slush-coated cup, standing in free air for 2 to 3 minutes; and
- Untreated cup, evacuated 2 to 3 minutes at 66.7 Pa.

The internal voltages on all three cups remained at 0 V during and after pouring and during evacuation. After curing, the voltages again were measured and found to be 0 V.

ACCOMPLISHMENTS

One ionization fan currently in use and four new air-ionization devices were studied and compared. Three of the four new devices left a residual static voltage on a number of materials after several minutes' use. One fan, however, effectively neutralized both positive and negative charges and did not induce a voltage of its own on the materials. When the fan is modified to protect operators against electrical shock, it proves to be equal to the nuclear fan in static-protection ability. The fan can be purchased from the manufacturer for slightly more than the cost of a one-year lease on the nuclear fan.

Two antistatic additives for polyurethane foam did not prove beneficial for electrostatic control. The additives were tested in polyurethane in three concentrations. Volume resistivity, a measure of static-suppression ability, decreased one order of magnitude, from 10^{16} to 10^{15} Ω -cm. An antistatic surface spray did not prevent static voltages on polyurethane foam.

Exposure of foam to X-rays was tested at three intensity levels. Although this technique has been used successfully on another material in the past, it did not reduce internal or surface charges in this application.

FUTURE WORK

The air-ionization grid installed in the clean bench will be modified so that it can be used safely. A static-free work station will be established, and additional data will be taken so that manufacturing procedures and processes can be refined. Other encapsulant additives may be tested in an attempt to prevent charge buildup before it can present a hazard.

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¹W. J. Kirk, Jr., and others, Control of Electrostatic Damage to Solid State Devices. Bendix Kansas City: BDX-613-1080, March, 1974 (available from NTIS).

²W. J. Kirk, Jr., and others, "Eliminate Static Damage to Circuits," Electronic Design, Volume 24, Number 7, March 29, 1976, p. 80.

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