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Handling Guidance for Semiconductor Devices

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1. Features and Types of Semiconductor Devices

1.1 Trends in Semiconductor Devices

As the downsizing, thinning, lightening, and functional sophistication further advance in the electronic equipment today, similar requirements are also directed to the electronic components. In the area of semiconductor chips, fine processing techniques and thin-film forming techniques are evolving, accompanied by higher integration, higher frequencies, and lower power consumptions of those chips, and packages for accommodating the chips are also moving toward further downsizing, thinning, and increase of lead pins.

In line with those latest trends, some unique developments have been achieved in the field of semiconductor chips, such as the development of products with submicron gate length based on an ultra-fine pattern processing technique, the evolution of bipolar-structure products toward MOS-structure products, and the improvement of speed attained by bipolar technology.

A great variety of packages have been conceived for surface-mounting type semiconductor devices, starting from the lead insertion or through-hole mounting type. In addition, new mounting methods of semiconductor chips have been worked out, including TCP (Tape Carrier Package), CSP (Chip Size Package), COB (Chip On Board), and MCM (Multi Chip Module) among others, which do not necessarily concur with the conventional shapes of package, representative of which are DIP, SOP, and QFP.

Opto-devices, GaAs devices, and semiconductor devices that are based on special technologies were excluded from this technical report, since they require special handling.

1.2 Types of Semiconductor Devices

1.2.1 Types of Semiconductor Chips[1.1]

The figure below represents a classification of silicon monolithic devices made from the structural standpoint:

Fig. 1. A Classification example of Semiconductor Chip Structures

- Monolithic Devices
  - Bipolar Devices
    - NPN Transistor
    - PNP Transistor
    - NPN, PNP mixed Transistor
  - Unipolar Devices
    - MOS FET
    - J-FET
    - SBD FET
    - SIT
  - Bipolar and Unipolar mixed Device

1.2.2 Types and Names of Packages[1.2][1.3][1.4]

Semiconductor devices are classified in the following manner, according to the shapes of their packages and the shapes of their leads:

(1) **Through-hole mounting package** (See Fig. 2)
Single Inline Type Package
-SIP(Single Inline Package)
-ZIP(Zigzag Inline Package)
Dual Inline Type Package
-DIP(Dual Inline Package)
Pin Grid Array Type Package
-PGA(Pin Grid Array)

(2) **Surface-mounting package**(See Fig. 2)
Small Outline Type Package
-SOP(Small outline L-Leaded Package of EIAJ)
-SOL(Small outline L-Leaded Package of JEDEC)
-SOI(Small outline I-Leaded Package)
-SOJ(Small outline J-Leaded Package)
-SON(Small outline Non-Leaded Package)
Quad Flat Type Package
-QFP(Quad Flat L-Leaded Package (Control dimension:mm)
-QFL(Quad Flat L-Leaded Package (Control dimension:inch)
-QFI(Quad Flat I-Leaded Package)
-QFJ(Quad Flat J-Leaded Package)
-QFN(Quad Flat Non-Leaded Package)
Ball Grid Array - BGA
Chip Size Package - CSP

(3) **Others**
Tape Carrier Package - TCP
Chip On Board - COB
Chip On Glass - COG
Multi Chip Module
-MCM-L(Multi Chip Module High Density Laminated PCB,COB)
-MCM-C(Multi Chip Module Co-Fired Ceramic)
-MCM-D(Multi Chip Module Deposited Thin Film on Si,Metal)
-MCM-D/C(Multi Chip Module Deposited Thin Film on Co-Fired Ceramic)

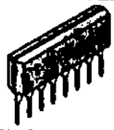
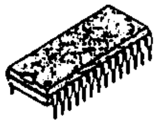
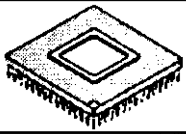
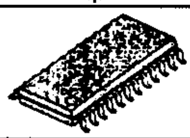
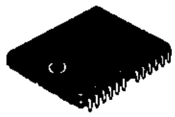
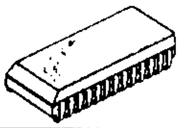
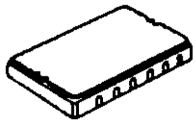
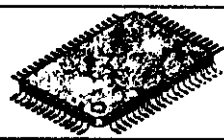
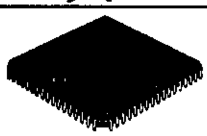
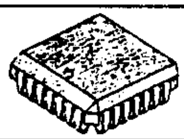
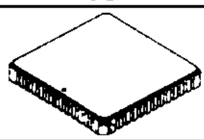
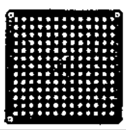
In the case where the basic structure conforms to the standard package, the codes listed below, which are classified according to the features in appearance and shape and the sizes of the packages, are prefixed to the classifications of packages:

Table 1. Features in Appearance and Shapes of Packages

Code	Description
*	Standard package
S	Standard package with reduced pin pitch
E	Standard package with extended pin pitch
T	Package with mounted height of 1.27 mm(0.050inch) or less
H	Package equipped with heat sink for heat dissipation
W	Package with translucent window
B	Package equipped with lead-protection bumper
M	Standard package with pins arranged in multiple rows
A	Piggyback package
G	Package with guard ring for protection of leads
X	Others

The materials of semiconductor device packages are classified into two large groups: plastic materials and ceramic materials, with the former becoming the mainstream today.

Fig. 2. Outlines of Semiconductor Devices (Integrated Circuits)

	Package	Outlines	Features
Through-Hole Mounting Type Semiconductor Devices	SIP		Package in which the leads are taken out of one side, and arranged in line.
	ZIP		Package in which the leads are taken out of one side, and folded alternately inside the package.
	DIP		Packages in which the leads are taken out of two sides.
	PGA		Package in which the leads are taken out of its top or bottom, and arranged in grid
SMD	SOP SOL		Package in which the leads are taken out of two sides and formed into gull-wing shape (L-shape).
	SOI		Package in which the leads are taken out of two sides and formed into I-shape.
	SOJ		Package in which the leads are taken out of two sides and formed into J-shape.
	SON		Package with pads on two sides, but with no lead.
	QFP QFL		Package in which the leads are taken out of four sides and formed into gull-wing shape (L-shape).
	QFI		Package in which the leads are taken out of four sides and formed into I-shape.
	QFJ		Package in which the leads are taken out of four sides and formed into J-shape.
	QFN		Package with pads on four sides, but with no lead.
	BGA		Package in which the pads are taken out of its top or bottom, and arranged in grid.

1.3 Features of Semiconductor Devices

The features of semiconductor devices are indicated below:

(1) The use of fine-structure semiconductor chips allows high integration in the mounting, with resultant reduction in the number of parts and the cost.

(2) SMDs allow to implement advanced automation through automatic supply and automatic assembling of parts.

(3) SMDs offer advantage when used in high-frequency circuits, since they can be mounted with short wiring lengths, which leads to a reduction in the floating capacity and inductance.

(4) Their ultraminiaturized sizes, light weights and thinness allow high-density mounting. Especially, the CSP and MCM types make it possible to cut back on the mounting area drastically, as compared to the conventional SMDs.

(5) The MCM, TCP and other types can be mounted in any way that best suits the shapes of the end products.

1.4 Points of Notice in Handling Semiconductor Devices

1.4.1 General Points of Notice in Handling Semiconductor Devices

(1) Semiconductor devices need to be used under the conditions that are specified in the relevant data sheets and other literature. Refer to Paragraph 2.1

(2) When a semiconductor device is going to be used for a special application, it is necessary to consult with the manufacturer, and good attention should be paid to the safe design. Refer to Paragraph 2.2

(3) When designing an equipment using semiconductors, due consideration must be given to preventing them from being adversely affected by external factors. Refer to Paragraph 2.3

1.4.2 Points of Notice in Handling Semiconductor Chips

(1) Since it is hard to incorporate internal element protection in fine-structure semiconductor chips, especially, high-frequency devices, they need to be the object of special control.

(2) Because bare chips are not subjected to high temperature tests and screening, appropriate screening should be done after they are mounted, in order to secure a non-defective quality assurance level equal to that of end products. Refer to Paragraph 6.1

(3) In handling and storing semiconductor chips, appropriate precautions must be taken so that they will not be adversely affected by external environment. Refer to Paragraphs 3.1, 4.2, and 6.2

1.4.3 Points of Notice in Handling SMDs

(1) Some devices may impose restrictions on the mounting method (soldering) to be employed. Refer to Paragraph 5.2

(2) Devices in themselves and the materials of the associated printed-circuit boards need to have mutually approximate coefficients of thermal expansion; otherwise, heat may produce cracks in the joint between the device and the printed-circuited board.

(3) Flux left out after the soldering process could originate leakage problem between pins or corrosion of the pins, as it gradually absorbs moisture along time. Refer to Paragraph 5.2.7

(4) The narrow lead pitch of this type of devices calls for closer attention to be paid to the bridges that may be formed in the soldering process, as compared to the through-hole mounting type semiconductor devices. Refer to Paragraph 5.5.8

(5) Likewise, the higher mounting density of this type of devices requires stricter consideration to be given to the possibility of occurrence of flexures and deformations of the leads from their flatness, as compared to the through-hole mounting type semiconductor devices. Refer to Paragraph 5.2.1

(6) Since SMDs have small conductive patterns (lands), they require higher geometrical positional accuracy than ever. Refer to Paragraph 5.5.2

(7) The epoxy resin used in making plastic packages for semiconductor devices basically absorbs moisture when stored in highly humid places. Especially, when SMDs containing large amount of absorbed moisture are subjected to a soldering process (total heating method), the absorbed moisture quickly evaporates giving rise to delamination between the epoxy resin and the lead frame, or cracks in the package.
Devices with such damages are likely to decrease their moisture resistance (surface leakage, corrosion, etc.) afterward, with adverse effects on their reliability.
Refer to Paragraph 5.5.3

Bibliography

[1.1] Kazuo Maeda: Latest LSI Processing Techniques (1983), Industrial Investigation Association, p. 18

[1.2] Monthly Semiconductor World (Nov. 1993), p. 128, 129

[1.3] EIAJ ED-7411 "General Rules on Integrated Circuit External Shapes/Designations and Codes of Packages" (1989), Japan Electronic Industries Association

[1.4] Kaori Fujita: Nikkei Electronics (Jan. 16, 1995), Nikkei BP, p. 79

2. Points of Notice in Design Works Using Semiconductor Devices

2.1 Recommended Operating Conditions and Absolute Maximum Ratings

Semiconductors need to be used under the recommended operating conditions, absolute maximum ratings, and other conditions that are specified in the related catalogs and data sheets, as described below.

2.1.1 Recommended Operating Conditions

Recommenced operating conditions prescribed in semiconductor catalogs and other literature are expressed in ranges of supply voltages and input/output voltages, and the applied electronic equipment have to be so designed that their semiconductors will operate within those ranges.

If even a noise or surge surpasses their permissible ranges just momentarily, the semiconductors will no longer be able to operate normally. In the cases where semiconductors are used outside their permissible ranges, due care should be taken, since the reliability inherent to those semiconductors can no longer be maintained.

2.1.2 Absolute Maximum Ratings

The absolute maximum ratings specified in semiconductor brochures and catalogs represent permissible values that must not be surpassed even for an instant. Once that value is exceeded, the semiconductor in question is likely to failure. Therefore, electronic equipment in which semiconductors are applied need to be so designed that no stress in excess of their permissible values will act on the semiconductors at any moment.

Meanwhile, absolute maximum ratings are not meant to guarantee reliability. Even when semiconductors are operated within the ranges of absolute maximum ratings, their durability may diminish if the actual operating conditions exceed the recommended ones, making it hard to use them for long time.

The major items of absolute maximum ratings consist of such electrical items as operating voltages and currents, permissible losses (permissible power consumption), items relating to heat generation, including operating temperatures, storage temperatures, and so forth.

(1) Electrical items

These items are defined from the viewpoint of the distribution of physical limit values, etc., of semiconductors. Even a momentary excess of those values could result in failure of the semiconductor. Even a noise or surge surpassing their limit values are likely to lead to a failure. Absolute maximum rated values do not represent the permissible operating ranges of semiconductors.

(2) **Items relating to heat generation**

If those values are exceeded even momentarily, failures may occur in the semiconductors due to thermorunaway or other cause. The devices have to be used under conditions that do not reach those values.

(3) **Storage temperature**

This represents a tolerance in case a semiconductor is exposed to high or low temperature environment for relatively short time during transportation or assembling of electronic equipment. But, it does not allow prolonged storage under the temperature conditions specified in the catalogs. Moreover, the specified storage temperature may be exceeded during mounting by soldering. In such case, the mounting by soldering should be conducted within the mounting conditions that are established separately. Likewise, in operating semiconductors or applying heat treatment to them, the recommended operating temperature must be observed.

2.2 Points of Notice for Special Applications

Semiconductor devices presuppose their use in industrial applications, and in consumer electronic equipment and appliances (office machines, telecommunications equipment, home appliances, game machines, etc.). In special applications where malfunction or false operation of a semiconductor device could threaten human life or damage to human body, or where the system or equipment (large plants, aviation equipment, passenger and cargo transportation equipment, medical equipment, etc.) requires particularly high reliability, it is necessary to consult with the manufacturer of the semiconductor in question, and at the same time, to take utmost precautions in such safety aspects as fail-safe design, redundancy, prevention of fire propagation, prevention of false operation, and so forth.

2.3 Points of Notice in the Design

Under the influences of EOS (Electrical Overstress), which includes external noise, power source surges, etc., semiconductor devices are likely to register abnormally high temperature rise because of latch-up, short-circuit, or other malfunctions, leading to breakages of their package, red heat, or smoke emissions. In designing equipment using semiconductor devices, non-flammable or flame-retardant materials should be used in the peripheral parts, and fuses need to be arranged in strategic locations where the power supply can be cut off for sure, in case overcurrents flow to the individual devices. Furthermore, printed circuit boards and their associated SMDs must have mutually approximate coefficients of thermal expansion, lest cracks be produced in the soldered joints from heat. This requires to exert special care also in selecting materials for the printed-circuit boards.

The points of notice in the design are summarized as follows:

(1) External noise and power source surge must not be imposed on the semiconductor devices.

(2) Fuses must be arranged in locations such that they can cut off power supply without fail in case overcurrent flows to each individual device.

(3) Nonflammable or flame-retardant materials must be employed for peripheral parts of semiconductor devices.

(4) The coefficients of thermal expansions of semiconductor devices and their mounting printed-circuit boards be approximated.

2.3.1 False Operation Caused by Noise

(1) **What is the noise?**

While noise could be defined in a variety of ways, let us interpret it here as "something that interferes with the input/output signals of an IC, including its power supply part, thereby hampering the transfer of information, or as an external disturbance that destroys or degrades an IC."

The electromagnetic troubles, disturbances and interferences originated by noise are collectively called EMI. Discussions are presently under way on the false operation of computers, interferences with TV, radio, telephone, navigation systems, etc., that are caused by these EMI, and more recently, on their adverse effects on the ecological systems, including human body and animals. The term EMI particularly notices the side of electromagnetic generation, as opposed to the resisting capability of the side subjected to the EMI, which capability is called EMS, and both of them are generically referred to as EMC.

EMC (Electromagnetic Compatibility)
- EMI (Electromagnetic interferences: Electromagnetic trouble, disturbance, and interference)
- EMS (Electromagnetic Susceptibility: Electromagnetic sensibility and immunity)

The EMI problems in early days generally used to be originated by switching noise propagated from power lines, and noise produced by automotive ignition systems. Recently, however, the generation of noise by high frequencies is posing problems, as more and more radio waves are used these days along with the evolution of radio communication equipment, spread of computers and control microcomputers in electronic/electric equipment, and use of higher frequencies for clocks. Also the EMS is beginning to raise problems of fine noise, generated by digitalized electronic/electrical equipment working at low voltages and high frequencies.

(2) **Generating mechanism of noise**

Noises can be categorized into two large groups from their sources: factitious mode noise and natural noise.

(2.1) **Factitious mode noise**

(a) Discharge noise by fluorescent and mercury lamps, and static discharge noise caused by static electricity accumulated in moving parts of electronic and electrical equipment.

(b) Relayswitching noise and motor noise emitted by on-off operations of electronic and electrical equipment.

(c) Switching noise of digital circuits and interference noise deriving from high-frequency circuits.

Of the different noises listed above, the switching noise will be discussed below a little more in depth:

Since CMOS charges and discharges the load on switching, a high spike current flows out onto the power line. This spike current reaches the pattern of the mounted printed-circuit board, after going through the bonding wires, lead frame inductance and resistance. The resistance and inductance of the socket and printed pattern also have an influence on the spike current. (Fig. 3)

When the switching noise rises to exceed the rating of an IC or to such a level that current flows in forward direction across a parasitic diode, it needs to be heeded to. It must be contemplated to provide enough decoupling of power supply, since such noise could cause glitches in the transition of signals and a resultant false operation, even when the noise falls short of originating latch-up.

(2.2) **Natural noise**

(a) Discharge noise by lightnings and electrostatic generation

(b) Electromagnetic noise arriving from outer space

When these noises inject into digital signals, they sometimes change the logic level of the digital signals, leading to a false operation of the related equipment. (Fig. 4)

Fig. 3 Switching Noise in Digital Circuit

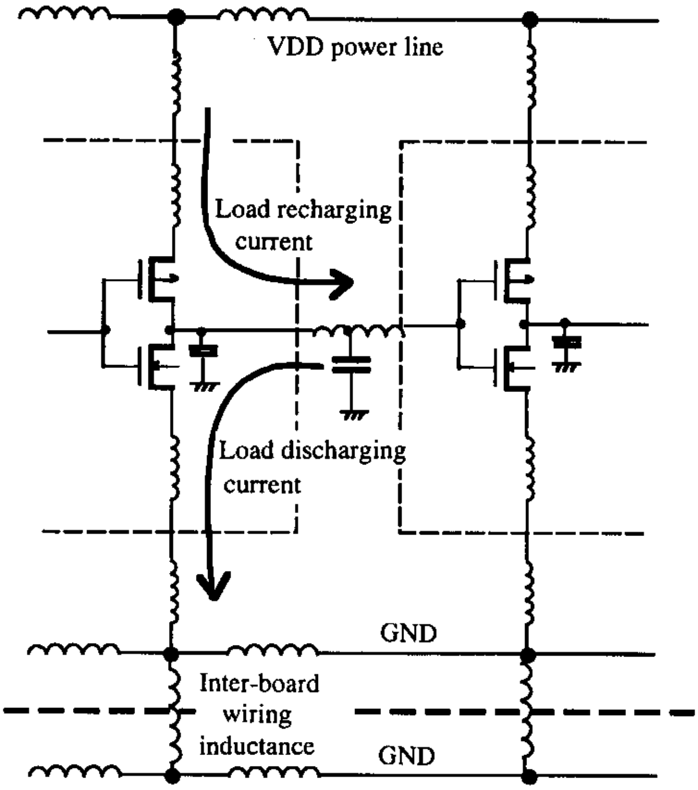
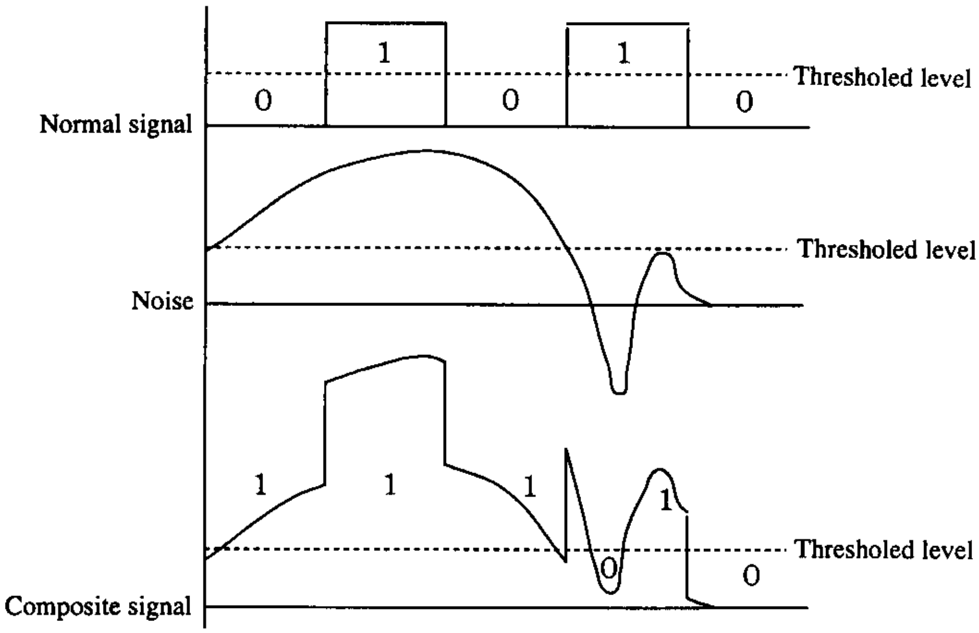


Fig. 4 Example of False Operation due to Noise Ingress



(3) **Noise injection route**

(3.1) **Noise injection from AC power line**

Noise entering from power lines largely depends on the environment in which equipment are installed, and other sources of noise working at the same time. This noise penetrates into the interior of the equipment from the power lines through power transformers, and so on.

(3.2) **Noise originating from ground lines:**

Noise arriving through impedance Z between the grounding terminal of a printed-circuit board or and ground.

Impedance Z consists of inductance and resistance to the ground reference, and earth electrostatic capacity of the circuit or printed-circuit board. When current flows across that impedance, a noise voltage is generated, giving rise to an apparent change in the ground potential of the circuit.

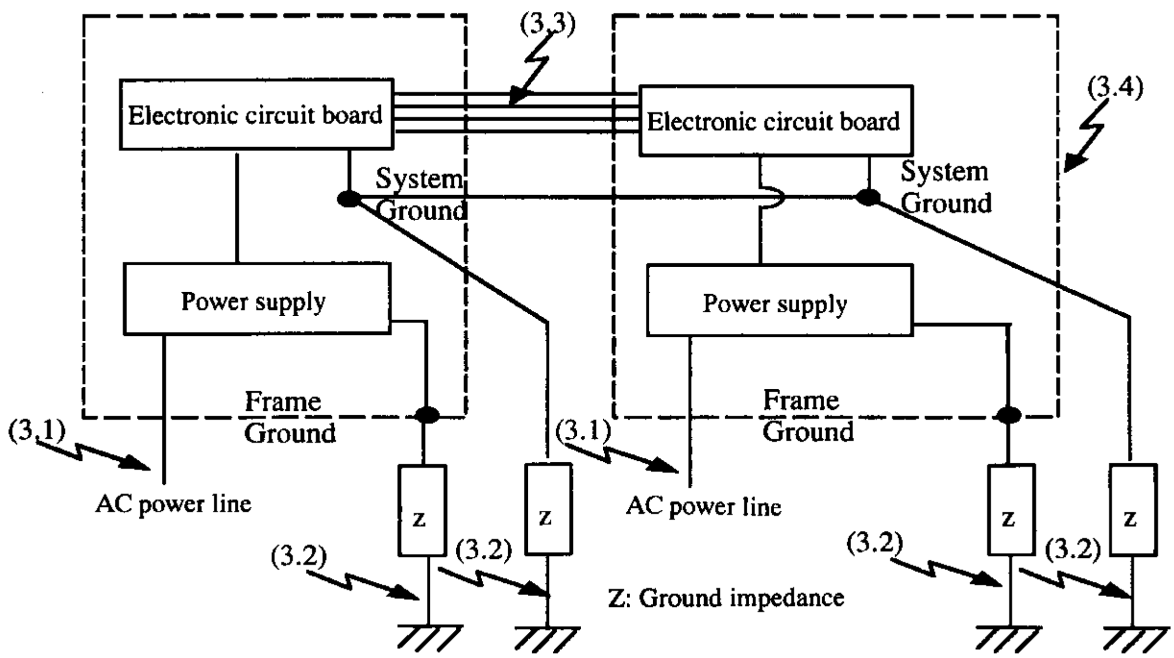
(3.3) **Noise generated by electromagnetic induction or static induction that penetrates into interconnection cables of units and subsystems comprising a system**

When a noise current flows in the proximities of a cable, noise is induced inside the system through the cable.

(3.4) **Electrostatic discharge**

When a human body or a metal object bearing electrostatic charge comes into contact with an equipment, discharge occurs, producing a heavy variation of potential momentarily through the resistance (impedance) of the frame ground.

Fig. 5 Penetrating Route of Noise



2.3.2 Electrical Overstress Failures of Semiconductor Devices

An electrical stress represented by a noise that causes element failure or element degradation as it exceeds absolute the maximum rating is called EOS (Electrical Overstress). In designing an equipment, due care must be taken to prevent this EOS from being imposed on the semiconductors.

2.3.3 Latch-Up

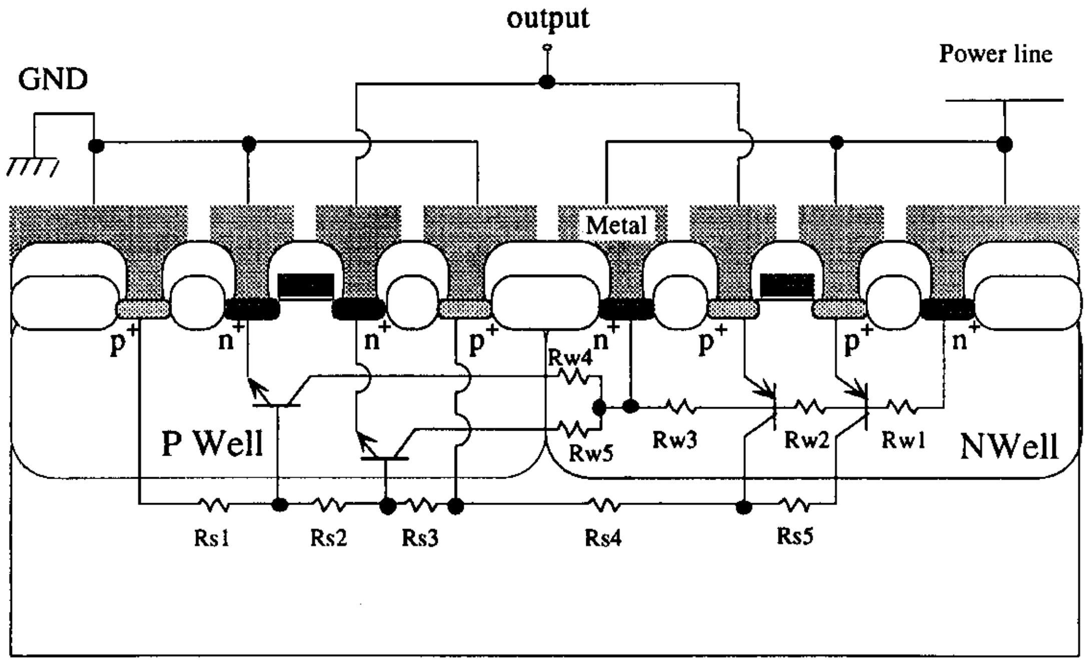
(1) What is the latch-up?

The integration density of ICs is rising year after year, but the permissible power consumption for a given system as a whole is not necessarily increasing. This has prompted the generalized use of CMOS in ICs, since CMOS is characterized by low power consumption. Latch-up is what is believed to be a weak point of this CMOS.

CMOS consists of a pair of PMOS and NMOS. Therefore, numerous parasitic bipolar transistors are formed inside the device (Fig. 6). Thyristors are made up of the parasitic vertical bipolar transistors and horizontal bipolar transistors, and they sometimes turn on when applied a large energy from the outside. This is the phenomenon called latch-up.

Once the thyristor turns on, a high current keeps on flowing between the power supply and ground, till the power supply is cut off, causing smoke emissions in some cases, even with the remote possibility that fires may break out.

Fig. 6 Cross-Sectional Structure of CMOS



Rsx --- Resistance of substrate
Rwx --- Resistance of well

Table 2 Causes of Latch-Up

Noise injection terminal	Cause of Latch-Up
Input/Output Terminal	When the high voltage level at input/output terminal (VIH) surpasses the VDD voltage.
	When the low voltage level at input/output terminal (VIL) falls below the GND voltage.
Power Supply	When an energy exceeding the absolute maximum rating comes in through power supply terminal.
	When the rise time of supply voltage is too fast, latch-up is induced by charging/discharging currents against the junction parasitic capacitance.
Others	Radiation of radioactive rays

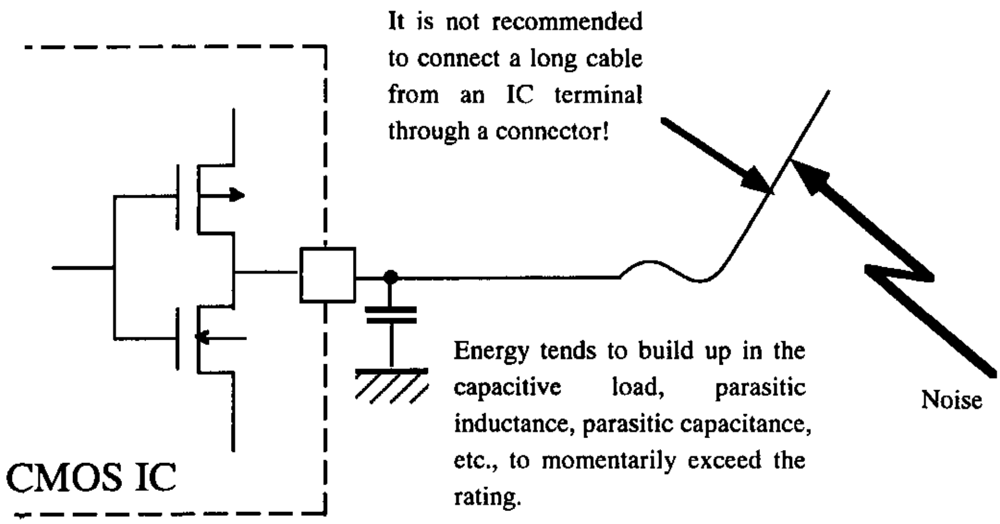
(2) **Mechanism of Latch-Up**

(a) **Causes of Latch-Up**

In the cases where the supply voltage (VDD) abruptly rises beyond its absolute maximum rating to cause part of the internal transistors or the P-N junction to break down, or where the input/output voltage exceeds the VDD and ground (GND) level, allowing a forward current to flow across the P-N junction, it sometimes happens that a parasitic thyristor turns on to produce a latch-up. Table 2 summarizes the possible causes that can induce latch-up in the use of ICs.

In actual use of semiconductors, latch-ups are posing little problems these days, since products today have ample latch-up resistance considered in their design, and ICs today are strong enough to withstand the disturbances. Nonetheless, in some harsh environments of service, where the working temperature remains high, or the IC is exposed to an excessive stress under heavy noise, special care should be exerted to prevent latch-up from occurring.

Fig. 7 Caution in Case an IC is Directly Connected to the External Cable



(b) **Influence of latch-up on other ICs**

In some cases, an IC can be developed false operation or suffered suffer degradation because of the latch-up of other IC. An example will be the case where a driver IC breaks down due to a high current generated by a latch-up it originates, and an abnormal current flows into the IC at the next stage.

(3) **Countermeasures in equipment design**

In designing an equipment, attention should be paid to the aspects indicated below for example, with a view to preventing CMOS ICs from suffering latch-up:

(a) **Do not connect an inductive circuit element as load.**

A great variety of parasitic elements could be connected to the input/output terminals of an IC. Depending on the combinations of those elements, energy arriving from the outside may build up, or resonance may be produced, eventually leading to an electrostatic discharge failure of the IC.

On the other hand, in the case where the input/output terminal of an IC is directly connected to an external cable through connector, etc., latch-up may take place due to the noise inducted by this cable. (Fig. 7) If that is the case, it will be necessary to clamp the IC using a diode or other element or to insert a high resistance in series, as remedial action against the possible latch-up.

(b) **Pay attention to the noise level at the power supply terminal.**

The noise at the power supply terminal must be covered within an appropriate range, and the overshoot and undershoot at the I/O terminals must not exceed the absolute maximum rating.

(c) **Difference in rise time among multiple power supplies**

In an LSI with multiple power supplies, such as an LSI with analog mix, care must be taken to avoid the occurrence of difference in the rise time among the analog and degital power supply terminals.

(d) **Insertion/pull-off of printed-circuit board with live line (Hotinsertion)**

Inserting or pulling off a printed-circuit board with its power supply on may momentarily generate noise, or allow the relation: VIH > VDD to hold. Sufficient precautions should be taken to avoid such situation.

(e) **Poor contact of IC terminals**

Since MOS products have extremely high input impedance, an input terminal in floating state could generate a very high through current, leading sometimes to degradation or failure of the products. In soldering those products, it is advisable to make certain of the absolute absence of deficient contact at the through holes of the board.

3. Electrostatic discharge and Their Precautions

3.1 What is the static electricity?

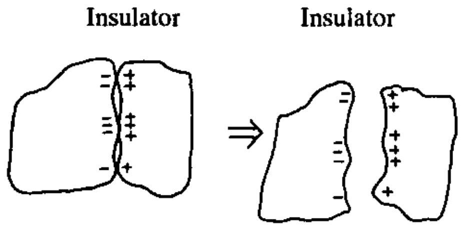
3.1.1 Generating Mechanism of Static Electricity

Static electricity refers to the electric charge existing excessively in the objects. When there are electrons in excess, the negative electric charge is excessive, and the object is charged negative.

Conversely, if electrons are insufficient, positive electric charge becomes excessive, allowing the object to be charged positive.

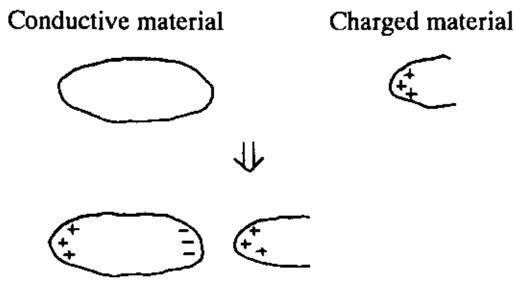
Generally speaking, when we compare two different types of substances with each other, we find that one type tends to receive electrons, while the other type rather tends to give electrons. Therefore, if these two different types of substances mutually come into contact, are rubbed against each other, or are separated away from each other shown in Fig.8, one substance receives electrons to be charged negative, and the other is charged positive by delivering electrons.

Fig. 8 Generating Mechanism of Static Electricity



Furthermore, when a charged object is brought close to an conductive object, an electric charge appears due to static induction, as shown in Fig. 9

Fig. 9 Static Induction



The amount of charge accumulated on an object depends on the properties of the object, ambient conditions (relative humidity and temperature), conditions of friction, and so on. Generally, plastics and chemical fibers assume large amount of electric charge (apt to be charged).
Since static charge builds up on the surface of an object, the surface conductivity of the object largely relates to the transfer of the static charge. Therefore, when the surface conductivity of an object is high, the charge is quickly diffused. Table 3 gives some examples of representative electrostatic voltages. From the table, it is observed that the static voltage falls as the relative humidity rises, perhaps because the higher the relative humidity is, the higher the surface conductivity of the object becomes.

Table 3 Examples of Representative Electrostatic Potential

Source	Electrostatic Voltage	
	10～20%RH	65～90%RH
Person walking on carpet	35000v	1500v
Person walking on vinyl tile floor	12000v	250v
Person working at a bench	6000v	100v
Plastic covering	7000v	600v
Plastic bag picked up from a bench	20000v	1200v
Chair stuffed with foam polyurethane	18000v	1500v

3.1.2 Electrostatic Discharge Failure of Semiconductor Devices

The changes which semiconductor devices and packages are undergoing in the device and package structure, as well as the automation of their assembling processes, have brought about changes also in their electrostatic discharge failure phenomena. For example, the advanced integration requires thinner gate oxide films in MOS structure devices, and this has made the devices themselves more vulnerable to the field induced breakdown caused by electrostatic discharges. On the other hand, friction type processes have increased in parallel with the progress of automation of the assembling processes, and consequently, there are more electrostatic discharge modes of the devices today.

The electrostatic discharge failures of semiconductor devices are considered to take place in the following cases:

(a) When external static electricity is discharged to the device.
(b) When a device with static electricity stored (incl. rise of induced potential) discharges its static electricity to an external conductive body.
(c) When the electric field environment around a device has rapidly changed.

The different electrostatic discharge models are classified based on the cases above. The relevant test methods are as follows:

(1) Models originating from electrostatic discharge to the terminals of a device, where a metal or conductive body located near the device acts as an object charged with static electricity.
 (a) Human Body Model (HBM)
 (b) Machine Model (MM)

Note; EIAJ ED-4701 classifies the Machine Model as one of the Human Body Models.

(2) Models originating from electrostatic discharges from the terminal of a device charged directly or indirectly with static electricity, to a nearby metal or conductive body.
 (a) Charged Device Model (CDM)
 (b) Charged Package Model (CPM)
 (c) Electrically charged Body Induction Model (EBIM)

3.2 Electrostatic precautions

The basics of antistatic protection reside in limiting the generation of static electricity in itself to a minimum, and in releasing the charge generated as soon as possible. To this end, the environment of the place in which semiconductor devices are to be handled needs to meet the said requirements.

It is necessary to exert the basic care to refrain from bringing in objects electrically charged or apt to be charged, and to avoid low humidity, among other preventative measures.

3.2.1 Precautions on Working Environment

	Precautions on Working Environment	Remarks
a.	Use of humidifiers It is desirable to maintain the relative humidity at 45% or more.	A low relative humidity reduces the diffusivity of electric charges, which promotes the charging of static electricity.
b.	Use of air ionizer Equipment that positively generates ions to neutralize static electricity in the work area. Note: Since air Ionizers are gradually deteriorated in performance, they need to be checked and serviced on a regular basis in order to secure balanced amount of ions.	Insulating materials should be removed from the process as far as possible, but they cannot be eliminated 100%. Therefore, electric charges produced by insulating materials need to be neutralized.
c.	Installation of conductive floor (conductive sheet) A conductive floor (conductive sheet) should be laid. Note: Its surface must be maintained clean at all times, as a dirty surface increases its resistance. - Check the resistivity of the surface regularly. - Secure a leakage resistance between ground connections between 1M Ω and 1000M Ω.	In works that require the worker to move around over a wide area inside a process or warehouse, it is impossible to wear grounding wrist strap. In this case, electric charges on carts have to be released to the conductive floor, and the body charges discharged through the worker's conductive shoes.
d.	Improvement of work chairs Chairs should be covered with a conductive covering material and grounded to the conductive floor (conductive sheet), in order to to avoid build-up of electric charges.	When a worker stands up from the chair, a sudden increase of charge occurs in the human body. This charge needs to be released.
e.	Elimination of insulating materials or inductive bodies	If there is an electrically charged insulating material or inductive body near a device or a mounted printed-circuit board, Induced charging will take place, threatening a discharge failure should it come into contact with a conductive body.

Fig. 10 Improvement of Working Environment [3.4]

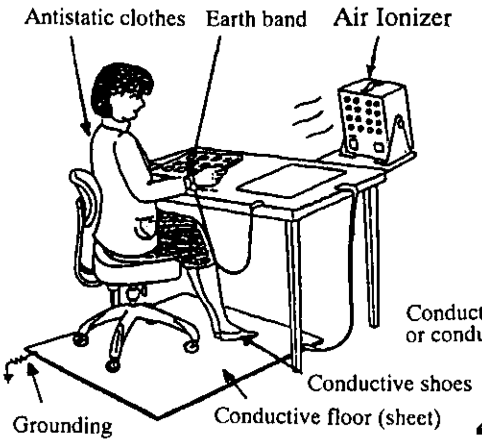


Fig. 11 Improvement of Chair

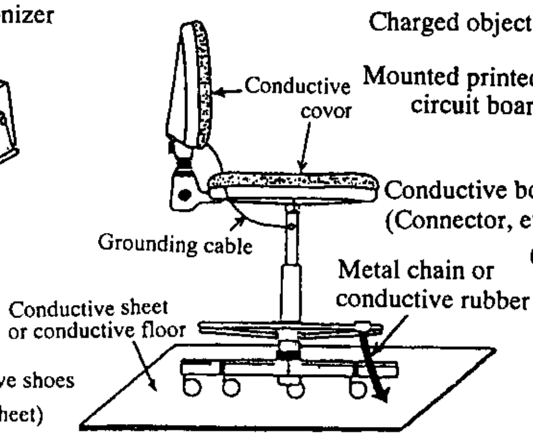
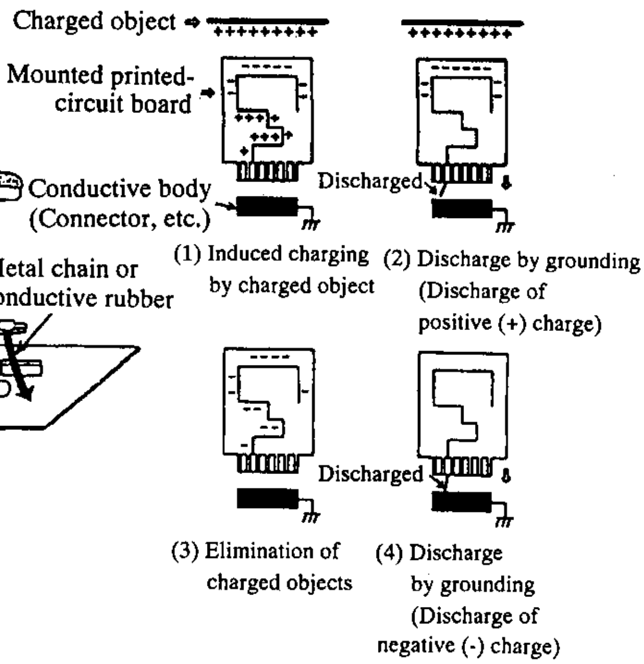


Fig. 12 Examples of Induction Charge



3.2.2 Precautions on Storage Environment

	Precautions on Storage Environment	Remarks
a.	Short-circuit of printed wiring board connectors The connectors of a printed wiring board should be short-circuited using conductive objects or board short-circuiting bars. When covering the process facilities with a dustproof plastic sheet, an antistatic sheet must be employed.	Prevention of discharge failure of devices due to induction charge or friction charge.
b.	Use of conductive storage containers and racks When storing and transporting printed wiring boards, conductive bags, containers and racks should be used.	Prevention of discharge failure of devices due to induction charge or friction charge.
c.	Accommodation of semiconductor devices in cases (in the middle of the process) When parts were taken out in the middle of the process, they must be put back in the original storage case. (Or, a storage case designated by the manufacturer must be used).	Prevention of discharge failure of devices due to induction charge or friction charge.
d.	Improvement of storage racks Racks and shelves should be covered with conductive sheet, and grounded, so that the devices and printed wiring boards will not directly touch their metallic part.	When an electrically charged device or printed wiring board is placed in contact with a metallic part, it may break down due to a sudden discharge produced. (Electrostatic discharge failure by CDM/CPM)

Fig. 13 Storage of Printed Wiring Boards

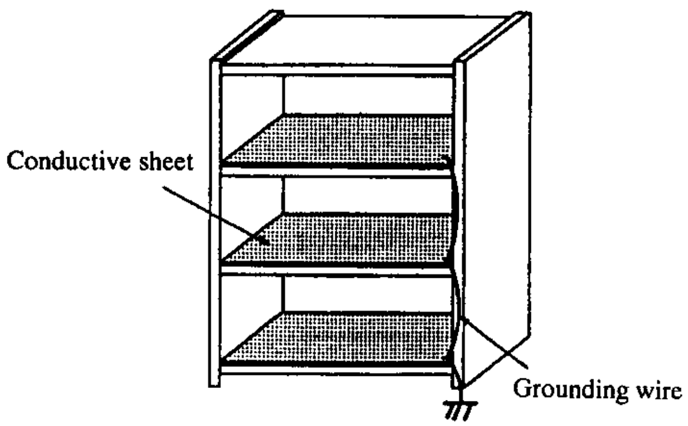


Fig. 14 Improvement of Storage Containers

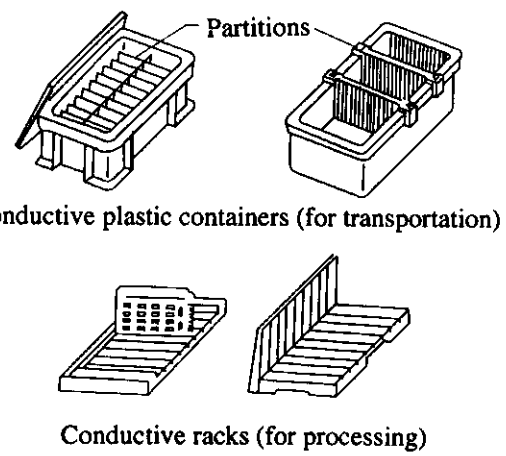


Fig. 15 Storage of Semiconductor Devices

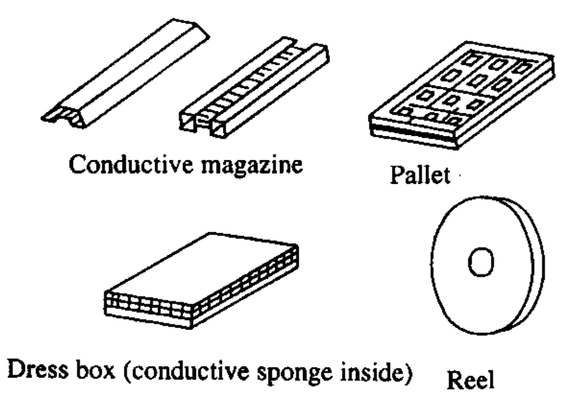
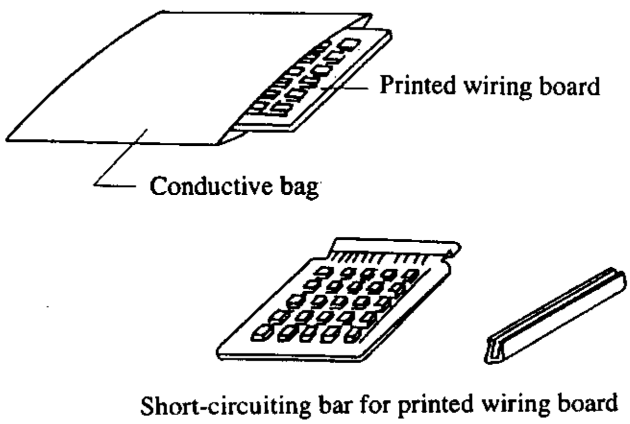


Fig. 16 Improvement of Storage Shelf



3.2.3 Precautions on Workers

	Precautions on Workers	Remarks
a.	Wearing of wrist strap Wearing a wrist trap is a very effective grounding means of human body. However, in case the worker gets an electric shock, the body will be exposed to higher danger than normal. Attention must be paid to the following points: Notes: -Place the conductive part of the strap in close contact with the bare skin. -To prevent electric shocks, insert a protection resistance (some 1 M Ω) on the human body side of the conductor. -Connect the conductor to a dedicated grounding point. -Check the continuity at least once a day.	Prevention of discharge failure due to charge accumulated in human body (Failure by HBM)
b.	Wearing of conductive shoes and antistatic clothes Commercial conductive shoes and antistatic clothes should be used. Notes: -Keep the protection gear always clean. Especially, conductive shoes with soiled soles will have resistance increased, and lose the efficiency. -Examine the resistance at least once a day on a foot checker. Human body + conductive shoes: 1M Ω to 100 M Ω (JIS-8103)	Since a wrist strap cannot be worn in works that involve movements over wide areas, it will make an effective solution to discharge electric charge to a conductive floor or conductive sheet through antistatic clothes and conductive shoes. Those protective gears are equally effective should the wrist strap come off unexpectedly from the arm while working.

Fig. 17 Example of Wearing Wrist Strap

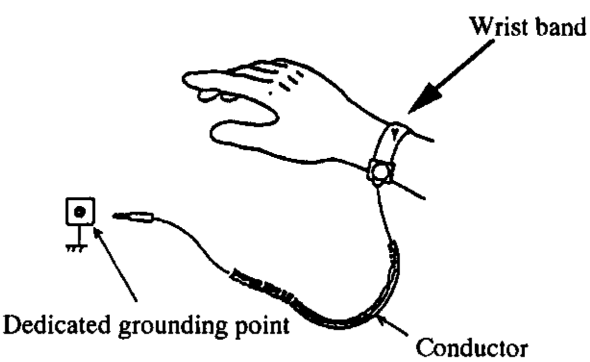
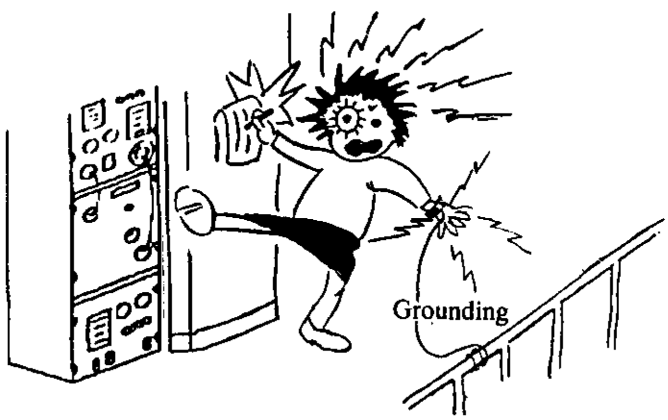


Fig. 18 Example of Inappropriate Case



3.2.4 Precautions on Work Facilities, Jigs and Tools

	Precautions on Work Faclities, Jigs and Tools	Remarks
a.	Grounding of facilities Manufacturing facilities, measuring and test equipment and instruments, belt conveyors, work benches, floor mats, and tools should securely be connected to ground.	Prevention of discharge failures due to electrostatic accumulation and leaks from power source. The facilities need to be grounded securely also from the safety viewpoint. (Prevention of discharge failure by Machine Model.)
b.	Improvement of semiconductor device conveying section in the facilities Metallic parts that are likely to come in touch with the pins of semiconductor devices should be covered with conductive material. It is also a good idea to reduce the contact area of the packages as a way to prevent charges from building up in the packages because of friction. Note: Be careful that a metal tool (tweezers, pliers, etc.) brought into contact with the lead pins of a semiconductor device may cause a discharge to the detriment of the device.	In an automated assembly line, electrostatic discharge failures could take place due to friction and contact with semiconductor devices. These accidents should be prevented. (Prevention of discharge failures by CDM/CPM)
c.	Grounding of soldering iron When a manual soldering iron is used to mount components or to correct soldering, it must be a dedicated soldering iron for semiconductor (low-voltage solder of 12 V to 24 V), and the forward part of the iron should be connected to ground.	Discharge failures by power leak (an electric leakage) must be prevented.
d.	Improvement of personal computers and displays of measuring instruments CRT displays should have their front face covered with a conductive mask.	The surface potential of a CRT display could bear a high voltage in excess of several thousands of volts, posing the danger of destruction by induction charge.

Fig. 19 Sample Improvement for Prevention of Charges to Package

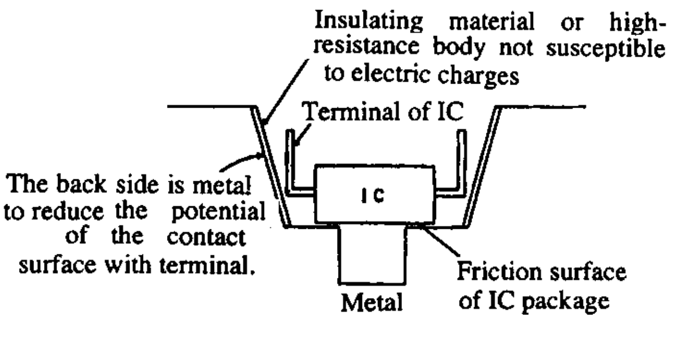


Fig. 20 Example of Discharge on Tools

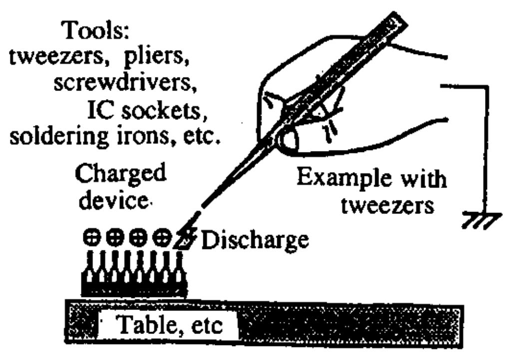


Fig. 21 Grounding of Soldering Iron

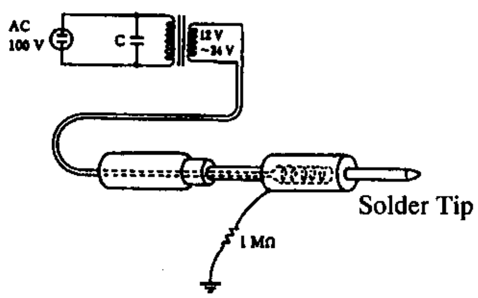
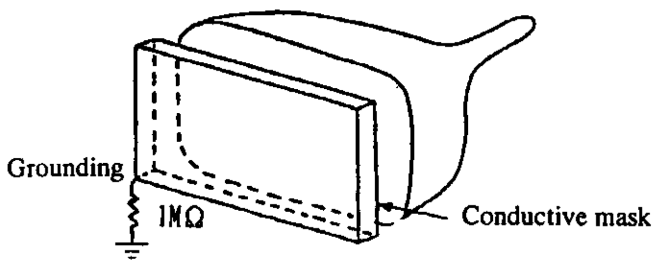


Fig. 22 Sample Improvement of Display



3.2.5 Precautions on Transportation Methods

	Precautions on Transportation Methods	Remarks
a.	Use of conductive containers Containers, reusable boxes, carrier boxes, and the like should be of the non-chargeable type.	In the transportation process, printed wiring boards are likely charged with static electricity as they are rubbed against each other under vibration. Therefore, the charges produced need to be discharged using conductive containers or reusable boxes, which come into direct contact with the wiring boards.
b.	Improvement of carts Lay a conductive sheet on the outside of the cart, and drag a metal chain or conductive rubber strip from the cart, so that it will have contact with the conductive floor. Notes: -Do not use metal trays or aluminum wheels. (Could cause discharge failures when they touch the pins of devices.) -The continuity with ground is not necessarily secured 100% during the transportation process. Therefore, appropriate precautions should be taken, such as to place the cart briefly on a conductive floor or conductive sheet before it is brought into the process area for unloading the wiring boards transported.	Charges produced during the transportation have to be discharged.

Fig. 23 Sample Handling of Conductive Container

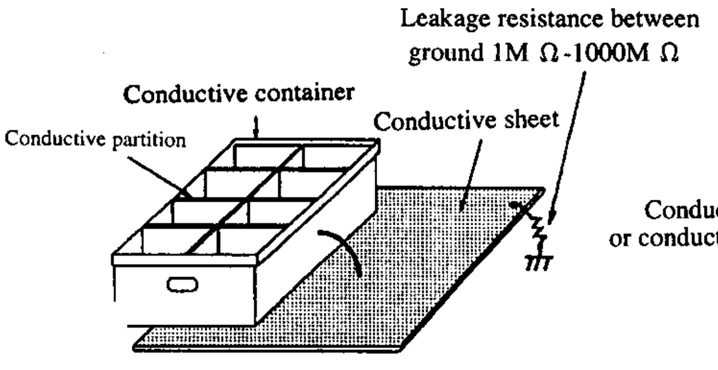
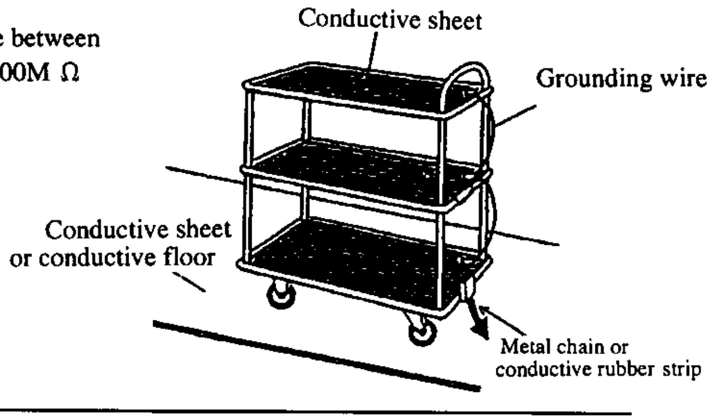


Fig. 24 Sample Improvement of Cart



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4. Packing, Storage and Transportation

4.1 Storage Cases and Packing

Semiconductor devices are essentially designed to hold high quality. However, there are many factors that lead to the destruction and quality degradation of semiconductor devices, depending on the working conditions.

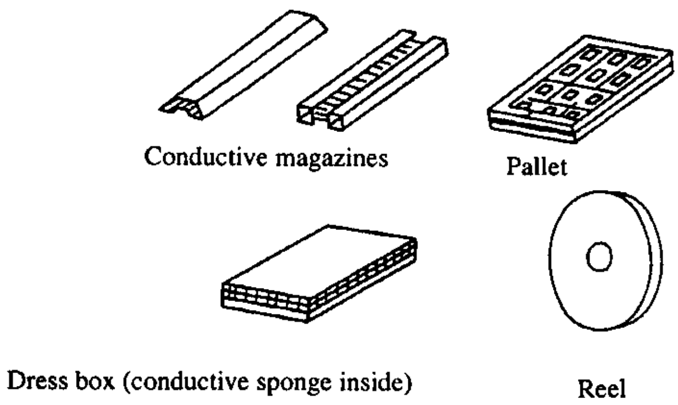
SMDs have thinner resin than that of through-hole mounting type packages (e.g., DIP) and, therefore, they are more vulnerable to mechanical stresses. Besides, when they absorb moisture, they sometimes suffer package cracks in the mounting process. Utmost care must be taken in handling this type of semiconductors.

Some aspects that deserve special attention in placing semiconductor devices in storage cases or packing will be described below.

4.1.1 Storage Cases

(1) To make storage cases for semiconductor devices, semiconductor manufacturers use such materials and construction as assure to hold their initial quality even under the worst environmental conditions. In the manufacturing process of equipment, the users of semiconductors should employ storage cases that are designated by the semiconductor manufacturers as far as practicable, with attention directed to the following aspects:

Fig. 25 Storage Cases



Note: The magazine is sometimes called tube or sleeve, and the pallet, tray.

(a) The magazines and the stoppers are not made heat-resistant. To dry the products at high temperature, they must be taken out of the magazine, and accommodated in a metal magazine or the like.

(b) When magazines made of transparent polyvinyl chloride and coated with antistatic agent are employed:
Do not store the magazines in places of high temperature and high moisture, lest their antistatic efficiency be impaired.
Be careful not to wet the magazines. When they are wet, the antistatic agent is dissolved to lose its efficiency.

(c) There are two types of pallets: heat-resistant type and normal temperature type. Use only heat-resistant type pallets for drying at high temperature.

(d) The tapes and reels are not heat-resistant. They cannot be dried at high temperature.
If they need to be dried, observe the specified temperature for drying.

(2) If storage cases specified by the semiconductor manufacturer cannot be employed for any reason, the devices need to be accommodated at least in the cases that meet the following conditions:

(a) Not made of a material that reacts to chemicals or emits noxious gases.

(b) So constructed as to prevent internal semiconductor devices from being destroyed by vibration and impacts, and from having their lead pins flexed or damaged otherwise.

(c) The storage case must use a conductive material or non-chargeable material (coated with antistatic agent) in the part where the lead pins of semiconductor devices can touch the storage case. (External lead pins of semiconductor devices are mutually shorted to protect them from static electricity from the outside and to thus prevent them from being charged by friction with the storage case.)

(3) When picking up semiconductor devices especially vulnerable to static electricity, such as high-frequency devices and MOS type devices, the static electricity charged in the human body and clothes should priorly be discharged through a high resistance (around 1M Ω). Moreover, when finger caps and gloves are used for handling semiconductors, they must be of conductive type.

4.1.2 Packing

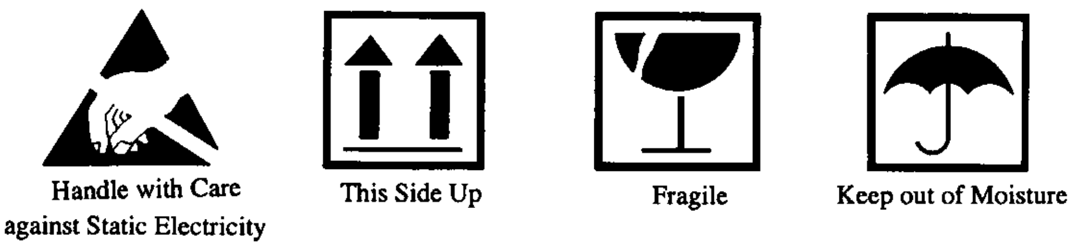
Semiconductor devices accommodated in storage cases are packed for protection from adverse effects of external shocks, rainwater, pollution, and other factors.

(1) External packing

(a) To minimize the shocks, vibration, and moisture to the semiconductor devices, the packing should be studied thoroughly with respect to the mechanical strength, vibration-proofness and moisture resistance, according to the transportation method to be employed. When shipped from the manufacturer, usually the storage cases are firmly packed with conductive polyethylene film with Al coat or plastic, again accommodated in a corrugated cardboard box, then protected against vibration with conductive cushioning material stuffed, and finally closed with gummed-cloth tape or ropes.

(b) The corrugated cardboard boxes are normally marked on the outside with the signs of Caution against Static Electricity, This Side Up, Fragile, Keep out of Moisture, etc., as shown in Fig. 26

Fig. 26 Sample External Markings



(c) Where unfavorable environmental conditions are anticipated, such as in ocean transportation, it is necessary to use moisture-proof packing material and sealed containers.

(2) Internal packing

Unlike through-hole mounting type semiconductor devices, SMDs are particularly vulnerable to moisture absorbed in their packages during transportation and warehousing. Therefore, special care must be taken to their internal packing.

(a) Ordinary packing

Basically, semiconductor devices with ordinary packing suffer little influence from absorbed moisture on their quality when stored in ordinary storage environment. This is the case with through-hole mounting type semiconductor devices, and individual elements and small-sized packages among SMDs, such as SOP.

(b) Moisture-proof packing

SMDs (generally corresponding to large-sized packages, such as large-chip QFP, etc.) are provided with a moisture-proof packing, such as the one illustrated for example in Fig. 27. Semiconductor devices with moisture-proof packing need to be consumed within the period specified by the manufacturer after their packing is opened. If the products have been laid out for long time, they should be used after they are subjected to baking. Besides, once their packing is opened, they should be placed in a dry box for storage, in lieu of the original moisture-proof packing.

In some cases, even SMDs provided with moisture-proof packing need to be subjected to baking, if they have been stored for long time. Because moisture can infiltrate and be absorbed in the resin, depending on the type of packing material in use, despite the moisture-proof packing. Fig. 28 shows an example of coefficient at moisture absorption of products with moisture-proof packing and non-packed products under environmental conditions of 40℃ and 85% RH.

Fig. 27 Sample Moistureproof Packing

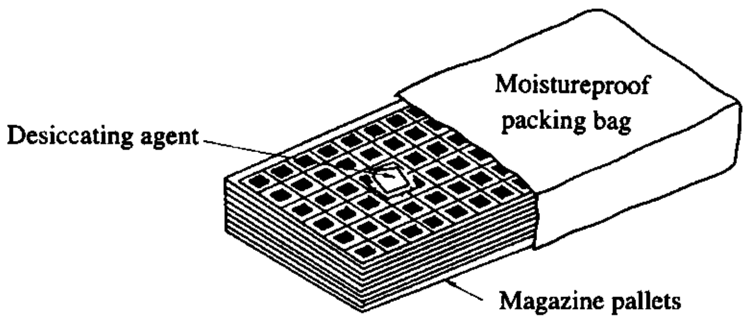
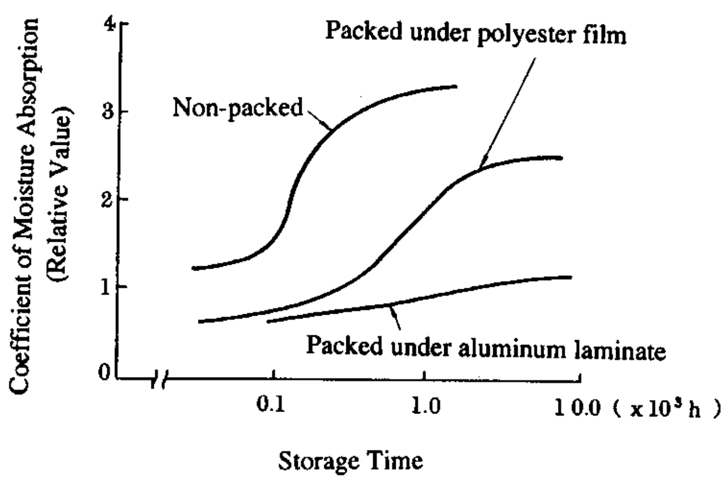


Fig. 28 Sample Coefficient of Moisture Absorption of Products with Moistureproof Packing and Non-Packed Products



(c) Taping

Taping has been in use for individual semiconductor devices since quite some time ago, as shown in Fig.29. Today it is used also for SMD ICs. The advantages offered by this packing method are as follows:

-Easy to handle products in automated mounting.

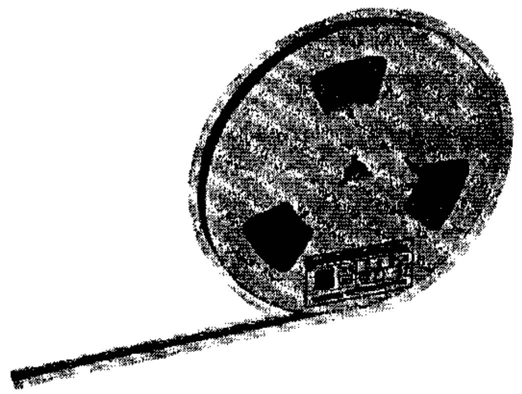
-High in packing density

-Insertion method: The lead parts of SMDs are fixed to a tape, which is wound on a reel or folded in a zigzag form. It is often used for diodes.

-Chip type: The tape has boxes to accommodate individual SMDs, and is covered with a top tape (covering).

-Adhesive method: SMDs are pasted to an adhesive tape, which is wound on a reel.

Fig. 29 Sample Tape Wound on a Reel

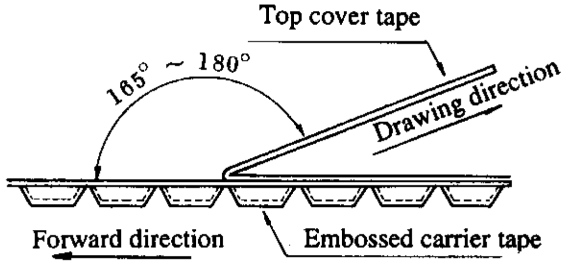


When using the taped products, the following precautions should be taken:

-Too fast a peel-off speed may generate static electricity. The carrier tape and the top tape should be peeled off at a rate of 10 mm/sec or less.

-The peel-off angle should be between 165 and 180 degrees with respect to the adhesive surface of the tape, as illustrated in Fig. 30.

Fig. 30 Peeling of covertape from a carrier tape



4.2 Storage

4.2.1 Environment of Storage Place

(1) Ranges of temperature and relative humidity:

Semiconductor devices should preferably be stored in places of normal temperature and normal humidity (5 - 35℃, 45 - 75% RH). Places that largely deviate from those ranges should be avoided. In case it is supposed that semiconductor devices were likely stored in a highly humid place, SMDs in particular should preferably be first treated with the baking specified by the manufacturer. When semiconductor devices were stored in plastic magazines for automatic insertion, not designed for high temperature, be careful that the plastic material may be distorted if the magazines containing the devices are baked at a temperature over 40℃.

In regions where air gets extremely dry in any season of the year, it will be necessary to humidify the ambient by using humidifiers, since static electricity is apt to be generated in dry seasons.

For the purpose of humidification, pure water or boiled water should be used, and not tap water, since chloride contained in the tap water could cause rusting in the leads of the devices.

(2) Storage place

(a) Clean place

Avoid places where corrosive gases are emitted, or places with heavy dust.

(b) Place with little variation of temperature

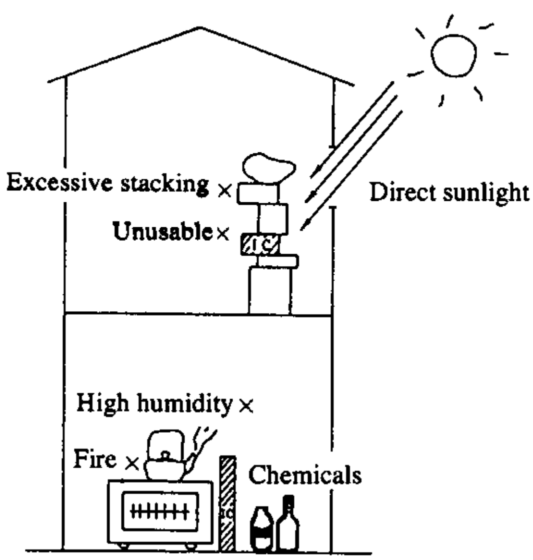
In places susceptible to rapid variations of temperature, semiconductor devices may produce dew condensation. Such environments must be avoided.

4.2.2 Form of Storage

(1) Care should be taken not to impose load on the semiconductor devices in themselves or their packings while they are stored. Especially, when they are stored in stacks, unexpected load may act on them. Also it must be avoided to place heavy stuff on them. Fig. 31 represents examples of inadequate storage places and storing forms.

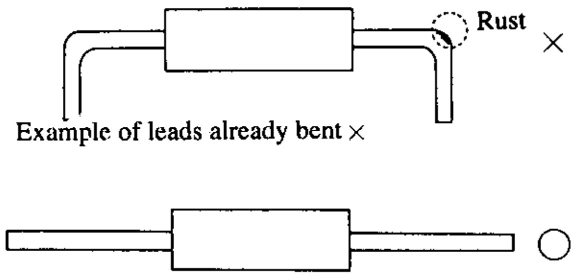
(2) Containers used to accommodate semiconductor devices must be of a type that is not readily susceptible to static electricity.

Fig. 31 Examples of Inadequate Storage Places and Storing Methods



(3) Flexed or distorted lead pins adversely affect the reliability of the joints formed in mounting. Be careful not to apply impact to the packing magazines and pallets. For semiconductor devices whose lead pins are prone to be flexed, it is desirable to adopt magazines or pallets in which lead pins will not rub against the packing material.
The semiconductor devices should be stored with their external lead pins unprocessed, so that rusting will not take place during the storage, which could hinder perfect soldering. (See Fig. 32)

Fig. 32 Storage Form



4.2.3 Storage Time

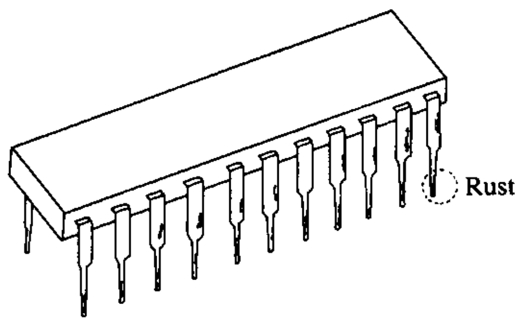
(1) Semiconductors with specified storage period

If the manufacturer of semiconductor devices specifies a specific period of storage to guarantee their quality, these devices must be consumed within that period.

(2) Long storage

If semiconductor devices are laid out in store for prolonged period (one year or more), it should be borne in mind that the solder at the lead pins may be deteriorated and bear rusting. (See Fig. 33)

Fig. 33 Example of Rusting Produced on a Lead



After long storage, the lead pins may have their solderability deteriorated.

(a) Moistureproof storage

If long storage is anticipated from the beginning, it should be considered to adopt moistureproof packing or use sealed containers with silica gel.

(b) Ordinary storage

If storage in ordinary storage environment (See Para 4.2.1) has been protracted more than expected initially (1 to 3 years), it will be necessary to examine the solderability, and to search for any rust on the leads before using them, in order to make sure that such semiconductor devices can be used.

(c) **Storage in poor environment or prolonged storage under ordinary environment**
If the products are stored in an extremely unfavorable environment, or have been in storage for more than 3 years in ordinary environment (see Para. 4.2.1), these products need to be inspected with respect to the solderability, rusting on the leads, and electrical characteristics.

(3) **Precautions on storage of taped products**
In addition to the precautions of general nature on the storage of semiconductor devices in packing magazines and pallets, the following aspects should also be heeded to:

(a) The mechanical performance (elongation, tensile strength, peel-off force of tape, etc.) are likely to be impaired at a temperature over 40℃ or relative humidity over 60% RH (Note 1). Taped SMDs should preferably be stored under the temperature and humidity conditions that are specified in Item 4.2.1 (1).
Besides, the devices must be kept out of direct sunlight.

(b) A tape drawn out of the reel should not be left out as is for long time. It must be rewound on the reel till next use.

(c) The tape must not be flexed more than necessary.

(d) The products should be consumed within the period recommended by the manufacturer. (The adhesive strength of the tape may change with time, depending on the way it is stored.)

Note 1: The JIS C 0806 specifies the conditions of -5 to +40℃ and 40 to 60% RH for storage of tapes.

4.3 Transportation

SMDs in particular have a larger number of thin and short, narrowly pitched lead pins, as compared to through-hole mounting package devices (e.g., DIP). Therefore, sufficient care must be taken in transporting them, since their leads are apt to suffer flexure or floating under vibration or shocks.

4.3.1 Transportation in Packing

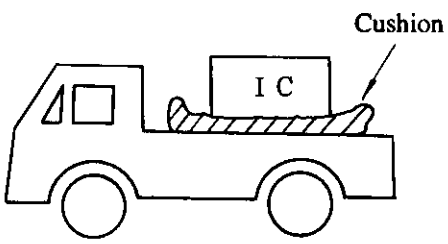
(1) While in transportation, the packing boxes should be placed in correct orientation according to the markings given on their outside. If placed upside down or against walls, the contents may be destroyed by undue force imposed on them. ("This Side Up")

(2) If packings are tossed or dropped, the devices inside may be damaged. ("Fragile")

(3) The packing boxes should be kept out of water. Care must be taken to prevent the boxes from getting wet during transportation under rain or snowfall. ("Keep Out Of Moisture")

(4) Try to avoid mechanical vibration or shock to the packing boxes during the transportation as far as possible. (See Fig. 34.)

Fig. 34 Precaution for Transportation



4.3.2 Transportation after Opening

(1) If the packing boxes need to be transported after they are opened, the contents are particularly vulnerable to flexures under mechanical vibration and shocks. Utmost care must be taken in handling those boxes.

(2) To protect the semiconductor devices from static electricity generated by vibrations during the transportation, antistatic type packing materials and packing boxes should be used for the transportation.

4.4 Flexure of Lead Pins

In anticipation of automated insertion, each manufacturer finishes semiconductor devices within the tolerance of lead pin flexure it has defined for each specific product. However, heavier lead pin flexure could be produced depending on the handling made of the products by each user. Therefore, the following precautions should be taken:

(1) Precautions on handling

(a) Do not apply shocks to magazines and pallets.

(b) When transferring semiconductor devices from their magazine or pallet to a case for purposes of baking, do not handle the semiconductor devices roughly.

(c) Do not drop semiconductor devices.

(2) Correction

When it is inevitable to rectify a flexed lead pin, avoid applying force to between the package itself and the lead pin, lest the package be cracked or the internal wire be broken. For such operation, secure the package itself, not the bending point, and bend the lead pin by applying force to its tip. In the case of SMDs in particular, it is desirable to employ an automatic pin flexure correcting machine recommended by the manufacturer.

5. Mounting Methods and Precautions on Mounting of SMD

5.1 Mounting Method of Through-Hole Mounting Semiconductor Devices

5.1.1 Treatment of Leads

The interface between the external leads and the package is a part that affects the sealing performance in the case of hermetic type and the moisture resistance in the plastic type. Therefore, care must be taken to prevent unusual external forces from working on this part in processing the external leads.

(1) Especially, when forming external leads before mounting the device to the printed-circuit board, the base of the leads should be secured, so that the device in itself will not receive stress. Also, avoid bending the base part of the leads. (See Fig. 35.)

(2) When inserting the device in, or drawing it out of, the through-hole of the printed-circuit board, be careful not to impose excessive force on the base part of the leads. (See Fig. 36.)

Fig. 35 Lead Forming Method

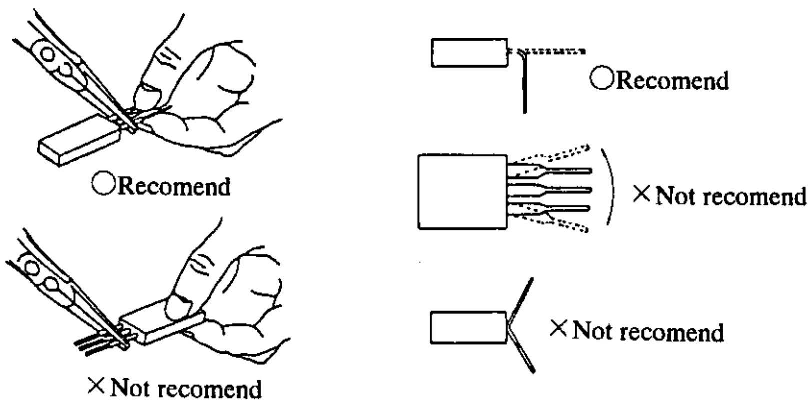
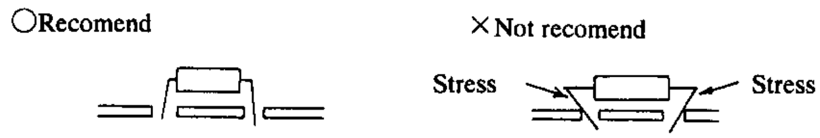


Fig. 36 Methods of Assembling to Printed-Circuit Board



5.1.2 Soldering

When mounting a semiconductor device by soldering, the leads are usually subjected to a heat (temperature) in excess of the maximum rated storage temperature of the device. Soldering heat-resistance tests are perfomed at the levels of Table 4. Work of soldering must be carried out within the ranges not surpassing these levels.

(1) Solder temperatures and dipping times

Table 4 Soldering Heat Resistance Test Conditions

Symbol of Test Conditions	Solder Temperature ℃	Dipping Time s
A	260± 5	10±1
B	350±10	3.5±0.5

(2) Lead dip position

The dipping depth of leads should be limited to 1 to 1.5 mm from the device main body.

The specifications of **(1)** and **(2)** above are prescribed in the EIAJ ED-4701 [Testing Method A-132 Soldering Heat-Resistance Test (Other than SMD)].

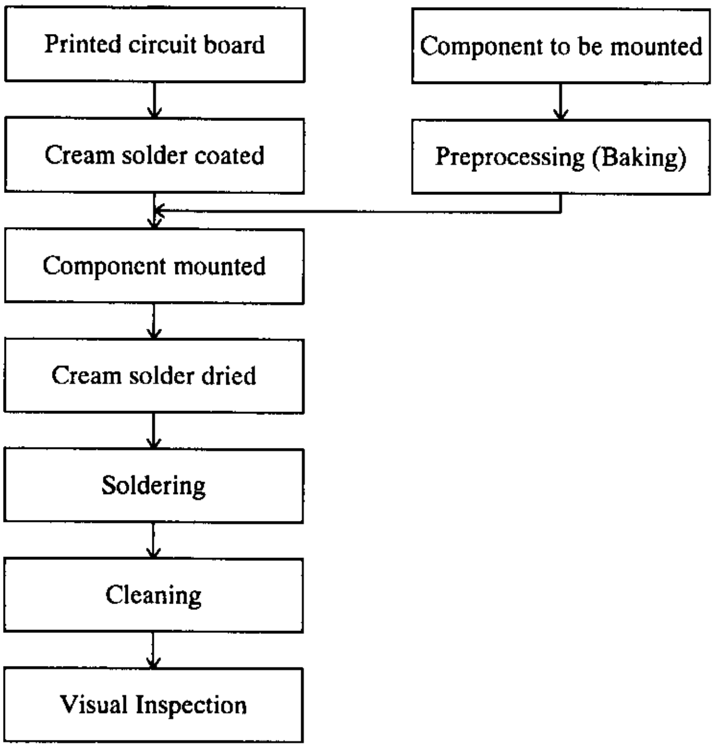
(3) Flux

If flux is to be used, select a rosin-base type, not a chloride-base type.

5.2 Basic Mounting Flow of SMDs

Since an SMD type device needs to be jointed to the component side of the printed-circuit board by soldering, the whole device is exposed to a high temperature, and this requires to take special care that is different from the one for through-hole mounting packages. Fig. 37 represents a sample mounting flow of the reflow method for SMDs.

Fig. 37 Sample Mounting Flow of Reflow Method [5.2]



5.2.1 Printed-Circuit Board

The boards are generally made of glass, epoxy resin, paper phenol, ceramics or others materials. The following aspects, among others, should be taken into consideration in designing the boards:

(1) Difference in coefficient of thermal elongation from devices

(2) Electrical characteristics

(3) Mechanical characteristics

(4) Heat dissipation property

(5) Flammability

5.2.2 Cream Solder and Flux

Cream solder is a mixture in creamy state, prepared by homogeneously mixing powder solder, flux and binder, which can be applied by coating.

Generally, the solder contained in cream solder has a composition ratio of Sn 60-63/Pb 40-37, and the flux to be used is of rosin (RMA) base containing 0.1 to 0.5 wt%, as specified in JIS Class A. The same specifications apply to the wire solder and flux that are used in soldering with soldering irons. Halogen-base fluxes should be avoided, since halogen (especially chloride) tends to remain on the perimeter of SMD packages, adversely affecting the product reliability.

5.2.3 Preconditioning (Baking and Restorage after Opening of Containers and Dry Packing)

SMDs sealed in resin absorb moisture in indoor storage due to the property of the resin, and as the steam pressure of the moisture content in the SMD rises under soldering heat, it may cause cracks in the package, and sometimes occurs degradations of the subsequent reliability.

(1) Baking

In the cases described below, the baking treatment may be indispensable before soldering SMDs.

(a) SMDs not provided with dry packing

The baking treatment is not necessary in particular.

(b) SMDs in which cracks can be prevented with dry packing

Baking is necessary when the storage conditions specified (storing environment and storage time) for the SMD are surpassed after the packing is opened, or when the specified storage conditions are surpassed after baking is conducted. Also, if the moisture indicator inside the packing reveals a color change just after the packing is opened (e.g., when blue particles mixed in the desiccating agent present pink color), baking is necessary,

(c) SMDs that basically require baking

In the cases where it is difficult to prevent cracks in SMDs with dry packing, such as extremely large-sized chips, the baking treatment is often indispensable. In these cases, severer storage conditions after baking than those of (b) are usually specified. For these types of devices, handling guidances (in catalogs, on packings, contracts, and so on) are issued by the manufacturers.

(d) When mounting under severer conditions than the soldering conditions recommended by manufacturer

The soldering conditions recommended by manufacturers are specified in a range in which the SMDs can well maintain their reliability after they are mounted by soldering. However, even in case they have to be mounted under conditions that exceed those recommended ones, sometimes it is possible to do so by using the baking treatment. In such case, it is advisable to directly consult with the manufacturer of the device in question.

(2) Repacking and storage inside dry box after opening of dry packing.

SMD devices provided with moistureproof packing can sometimes be stored continuously after the packing is opened, if they are repacked, as long as they are stored within the storage conditions specified for that purpose.

The above restorage can be made of those SMDs that are applied the moisture soaking conditions considered temperature and humidity conditions (30℃ and 30% of relative humidity, for example) of dry packing, such as the moisture soaking (Fig. 38) in the soldering heat-resistance test of the EIAJ ED-4701-2 (Test Method A-133A).

However, the time after opening of the packing, till the repacking, should preferably be limited to one day. If repacked within one day, SMDs will recover the initial condition of absorbed moisture in seven days of storage in repacked state. When the packing is opened later, the specified storing conditions can be applied to the devices, as in the case of first opening.

When repacking devices, desiccating agent to be placed in the moistureproof bag must be one that has not yet been degraded. If the devices are going to be stored for long time after they are repacked, the moistureproof bag has to be sealed by thermocompression sealing. For storage for one month or so, the moistureproof bag may be closed by folding back the mouth two to three times and sealed with seeling tape.

Moreover, the devices may as well be stored in dry box, instead of being repacked. In this case also, the temperature and moisture conditions of the dry box must meet the same conditions as assumed in the humidifying treatment (30℃ and 30% of relative humidity, for example).

Fig. 38 Soldering Heat-Resistance Test Flow

Drying treatment (Baking) → [Humidifying treatment (2-stage processing): Humidifying treatment corresponding to moisture absorbed inside packing (Note) → Humidifying treatment corresponding to moisture absorbed after opening of packing] → Solder heating process

Note: Assuming 30℃ and 30% of conditions inside the packing, humidification is done for 168 hrs at 85℃ and 30%.

(3) **SMDs that must not be stored with repacking or inside dry box**

In the cases where the soldering heat-resistance test applies a moisture soaking that assumes that the interior of the dry packing is perfectly dry, the SMDs and trays are usually packed in dry packing after they are completely dried by baking. In such cases, the packing must never be opened at the stage of distribution of products. If opened, the SMDs and trays need to be subjected to baking treatment before they are repacked. Since dry box that provide perfect dryness are hard to come by in practice, no dry box should be used for storing those devices.

(4) **When solder heat is applied several times**

When solder heat is applied several times, such as in double-side mounting or resoldering, the heat application by soldering should be limited to the plurarity of times guaranteed by the manufacturer, and the last soldering process needs to be completed within the storage time after opening of dry packing that is recommended by the manufacturer.

5.2.4 Mounting

SMDs are mounted on printed-circuit boards by vacuum adsorption method, component chucking method, and so on.

The components are placed automatically or manually on a board which is coated cream solder. When adopting the adsorption method that imposes external force on the SMD chip surface by cylindrical collet, etc., care must be taken to avoid impact force, unless otherwise chip crack will be induced.

In case components to be mounted need to be provisionally fastened with adhesive agent, the adhesion will degrate the self-alignment capability. This must be taken into account in handling multipin packages. Moreover, care must be taken, since any residual stress left by the adhesion could adversely affect the soldered joints.

5.2.5 Drying of cream solder

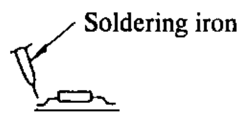
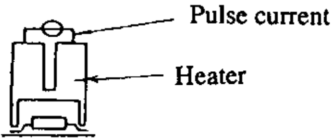
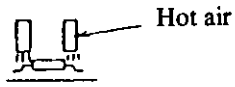
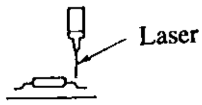
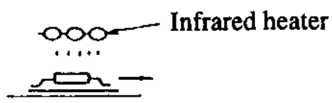
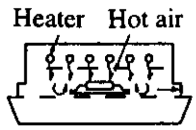
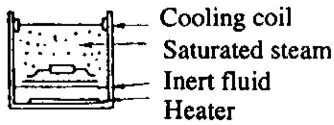
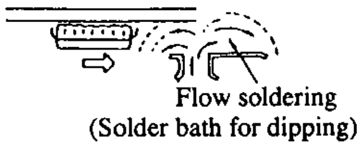
When it is necessary to suppress changes caused by cream solder in the self-aliment capability of components, oxidation of the paste, and its changes due to exposure along time, the cream solder is sometimes dried after the component is mounted.

5.2.6 Different Soldering Methods

Table 5 shows the major soldering methods for SMDs, which can be classified into two large groups: partial heating methods that heat only the soldered part, and total heating methods that heat the whole component or board for soldering.

Those different methods will briefly be explained further below.

Table 5 Soldering Methods for Surface-Mounting Packages[5.3]

	Abbreviated Designation of Mounting Method	Mounting Method	Reference Paragraph
Partial Heating Methods	Soldering iron method		(1)
	Pulse heater method		
	Hot air method		
	Laser method		
Total Heating Methods	Infrared reflow method		(2)-(a)
	Convection reflow method		(2)-(b)
	Vapor-phase reflow method		(2)-(c)
	Flow soldering method (Wave soldering method)		(2)-(d)

(1) **Partial Heating Methods**
When adopting a partial heating method, such as the soldering iron method, pulse heater method, hot air method or the laser method, the heating conditions should be limited to within the range of conditions specified in **5.1.2.** In these methods, care must be taken not to apply heat to the entire package body.

(2) **Overall Heating Methods**
When a overall heating methods is followed for soldering, problems relating to the product reliability may occur, such as package cracks and deteriorated moisture resistance, since the whole SMD devices are heated at high temperature. For this reason, the manufacturers of semiconductors specify their recommended soldering conditions, which are defined by

considering the heat resistance and solderability of SMDs. The recommended conditions are usually expressed in upper-limit values of the package surface temperature, from the viewpoint of heat resistance of the SMDs. Moreover, since these recommended conditions are studied in conjunction with the moistureproofing conditions (dry packing, etc.) of each device, the expected effect of the dry packing may not necessarily be obtained, if devices are mounted under the conditions outside the recommended range. [See **5.2.4 (1)(e)**.] Take this point well into account.

(a) Infrared reflow method

This refers to the method that concentrates infrared rays emitted from a halogen lamp by means of a reflector to generate high temperature for soldering. Since this method allows to use not only a point light source, but also a linear light source, it can solder many components at a time, and therefore, it is considered suitable for mass production.

Infrared rays are classified into far infrared rays (l = 5.6 to 1000 μ m), intermediate infrared rays (l = 1.5 to 5.6 μ m), and near infrared rays (l = 0.7 to 1.5 μ m), according to their wavelengths. Many apparatuses employ far infrared rays (or intermediate infrared rays) in the preliminary heating section, and far infrared rays in the primary heating section.

The reflow conditions vary depending on the package shape, board shape, equipment in use, and so on. Generally speaking, manufacturers' recommended reflow conditions refer to the upper-limit values of package surface temperature that must not be exceeded.

To define temperature conditions for mounting, it is a usual practice to note lead pins or other parts of high heat capacity on the printed-circuit board, so that the soldered joints will assume a temperature high enough to allow perfect jointing by soldering. And, at the same time, SMDs of low heat capacity on the same board are noted to make sure that the package surface temperature does not exceed the manufacturer's recommended conditions.

The conditions of Fig. 39 are defined for small-sized packages with low heat capacity, susceptible to fast temperature rise. To the contrary, lower temperatures than those indicated in Fig. 39 are often recommended for large-sized packages with high heat capacity, since the package temperature is less than the temperature of parts to be soldered, as can be seen in Fig. 40.

Fig. 39 Sample Infrared Reflow Conditions (for Small-Sized Packages)

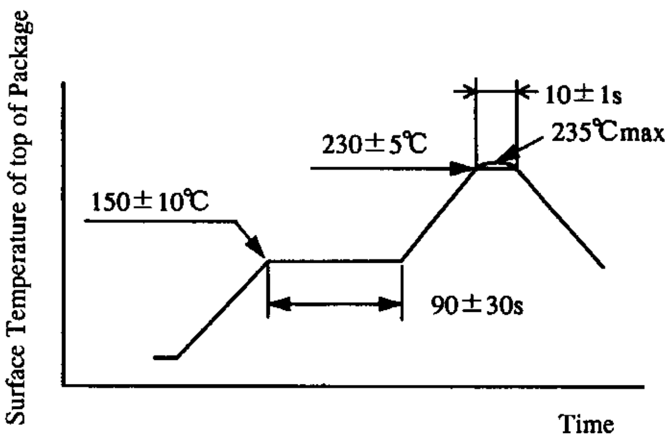
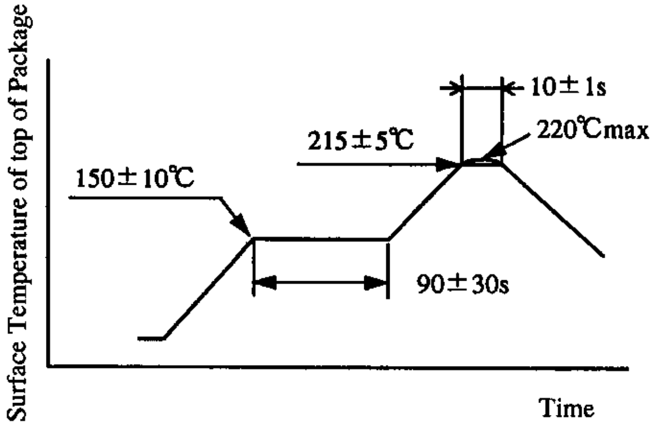


Fig. 40 Sample Infrared Reflow Conditions (for Large-Sized Packages)



(b) **Convection reflow method**

This method supplies hot air to the printed-circuit boards by heating air or inert gas by means of a heater, and often uses a combination of hot air and infrared ray. Because the heating in this method takes place by heat convection from the hot air, temperature deviations in the components and board can be held small. Moreover, because the hot air directly heats the part to be soldered, the parts to be jointed registers faster temperature rise than when done with infrared ray alone (radiant heat), which allows to hold down the temperature rise of the SMD main body in itself.

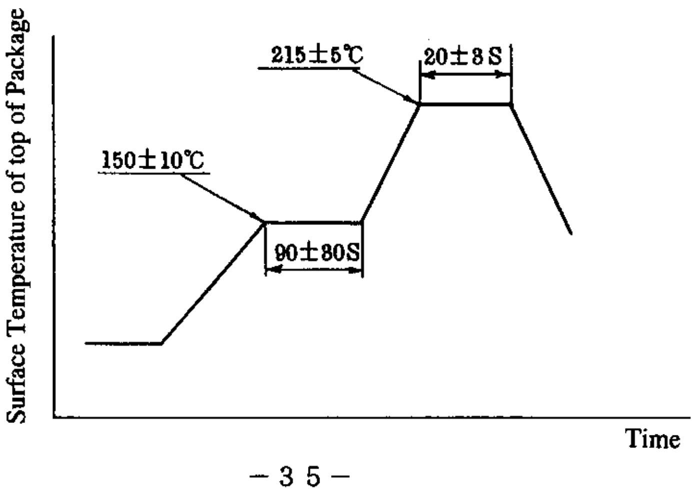
The temperature conditions for mounting are defined in the same manner as for the infrared reflow method.

(c) **Vapor-phase reflow method**

This refers to the method that heats a special solution (e.g., fluorocarbon-base solution) to create a vapor layer, and passes the board through this vapor layer to take advantage of the vapor latent heat of the solution for soldering. This method features the ability to heat the component and the soldered joint uniformly, without the risk of overheating, since the temperature is determined by the boiling temperature of the solution, and, therefore, damages to the component can be minimized. Besides, the reflow soldering conducted in inert atmosphere eliminates the possibility of oxidation of the solder and burning of the flux, which translates to ease in the subsequent cleaning.

Fig. 41 indicates sample reflow conditions for vapor-phase reflow. This example employs a solution with the boiling point of 215℃. It should be noted that solutions in this use rise their boiling points as they take in impurities during prolonged use. Therefore, the conditions need to be checked and the solutions and solutions replaced periodically.

Fig. 41 Sample Vapor-Phase Reflow Conditions



(d) Flow soldering method (Wave soldering method)

In this method, components are provisionally fixed to the board by adhesive agent, and the component side is flipped over to face down and passed through moten solder (flow solder).

This method is not suitable for mounting SMDs with fine-pitched pins, as it tends to form bridges. The flow soldering conditions include a preheating at 80 to 120℃ for 90 ± 30 sec, followed by dipping in a flow solder at 240℃ for 5 seconds. One of these methods requires to dip large packages in a flow solder at 250℃ for 5 seconds.

5.2.7 Cleaning

Flux residue remaining after soldering affects the reliability of the components and printed circuit boards. To remove this residue, cleaning is usually required. Table 6 gives examples of cleanliness achieved by cleaning printed circuit boards. Even when cleaning is not required, attention must equally be directed to the cleanliness of the boards.

Table 6 Cleanliness of Printed-Circuit Boards after Cleaning Specification (Converted from Values Specified under MIL-P-28809A)[5.3]

	Item	Standard
Boards after Washing	Cleanliness of Printed-Circuit	
	Residual amount of Cℓ	1 μg/cm² or less
	Resistance of extracted solvent (after extraction)	2×10^6 Ω·cm or more

Notes:

(1) Board area: Both sides of printed-circuit board + mounted components

(2) Extracted solvent: Isopropyl alcohol (75% vol%) + H2O (25 vol%) (before extraction) (Resistance of extracted solvent is 6×10^6 Ω·cm or more)

(3) Method of extraction: Both sides of board are washed with 10 ml/2.54 x 2.54 cm2 (Min. 1 minute)

(4) Measurement of resistance of extracted solvent: Conductivity meter

For details on the MIL Standard, refer to MIL-P-28809A.

When a rosin-based flux is used, washing is done in organic solvent, and if a water-soluble flux is used, washing is done by spraying hot water at 60 to 70℃.

The organic solvent must be selected by considering the solubility, toxicity, inflammability, corrosivity of rosin, washing effect, and the possible adverse effects on the characteristics of the components and printed-circuit boards.

(1) Restrictions on the use of freon-base solvents

Freon used to be an indispensable and excellent solvent for washing electronic parts. However, since it was detected that Freon and Halon are the factors destroying the ozone stratum, their reduction is being promoted worldwide, and it was resolved under the Montreal Protocol to cut back on the use of First Class Specified Freon to less than 15% with respect to the record of 1986 by the year 1997, and to 0% by the year 2000. Therefore, beware that solvents controlled as First Class Specified Freon cannot be used.

(2) Cleaning method

The cleaning methods in use include the ultrasonic cleaning method, dipping method, spray cleaning method, steam cleaning method, and so forth, which come with the following features, respectively:

(a) Ultrasonic cleaning method

This method washes the products by applying ultrasonic vibration under solvent. It is suitable for cleaning fine clearances, but care must be taken, since it may destruct the soldered joints between the semiconductor device and the printed circuit.

Many semiconductor devices have their mechanical resonance points of internal elements (bonding wires in particular) in the proximities of several tens of kHz, because of the structural or dimensional reasons. Resonance could cause vital destruction to hallow type packages, such as hermetic packages. Therefore, the ultrasonic cleaning method must be avoided for washing hallow packages. Also, adverse effects may result if plastic type packages are dipped for long time under cleaning solution. Hence, the need to limit washing time to a minimum. (See Fig. 42.)

Fig. 42 Ultrasonic Cleaning

× Hermetic package
(Cerdip, laminated ceramic, etc.)

○ Plastic package

Exfoliation of wires, wire breakage and other irregularities may be caused by ultrasonic washing.

Long time cleaning could deteriorate the adhesion of the lead - resin interface, affecting the moisture resistance.

(b) Dip cleaning

This method washes the products by dipping them into a washing solution. The washing solution needs to have high degree of cleanliness.

(c) Spray cleaning

This method sprays high-pressure jets to wash the products. Improved cleaning effect is obtained in fine clearances between the components and the board when sprayed at an angle.

(d) Steam cleaning

This method washes products with steam of solvent. Since cleaning can be achieved with solvent free from impurities, the method is usually employed in the final cleaning process.

A general practice is to conduct cleaning by a combination of those cleaning methods outlined above, and many cleaning machines presently in use are designed to attain washing by applying several times of ultrasonic cleaning - dip cleaning - steam cleaning continuously.

(3) Precautions on cleaning

(a) Prolonged washing could erase the stamped markings on the packages, depending on the solvent in use.

(b) When a solvent has an excellent washing effect, the stamped markings are more likely to be peeled off. The stamped surfaces must not be rubbed, until the solvent has dried up.

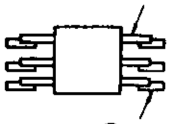
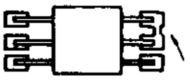
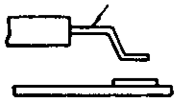
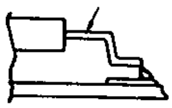
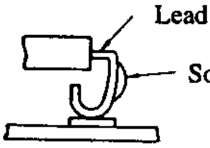
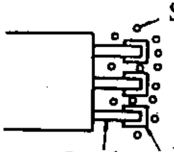
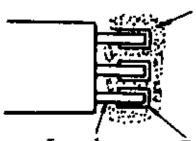
(c) Flux remaining in the grooves of laser-stamps may make the stamped markings invisible.

(d) In the steam washing, the washing effect will be lost when the product reaches the washing temperature. Therefore, prolonged washing provides little effect.

5.2.8 Visual Inspection

SMDs should be inspected by visual inspection with respect to the items indicated in Table 7, and corrected with a soldering iron, if repairable. Sufficient care must be exerted in the case of multipin packages. If a package is taken out of the board for such purpose, it will be difficult to reuse the SMD later, due to problems of dimensional accuracy of the leads.

Table 7 Examples of Visual Inspection Items for SMDs[5.2]

Item	Outline	Cause
Positional displacement		(1) Deteriorated accuracy of equipment (2) Deviation of component dimensions from tolerance (3) Deficient data on mounting position
Bridge, excessive solder		(1) Excessive volume of solder, dislocation in printing, spread (2) Flexed lead of component (3) Deficient accuracy of board patterns and resist
Floated lead		(1) Deficient adjustment of press-on pressure (2) Floated or flexed lead of component (3) Leads distorted by mutual contact of leads during handling of components
Nonwetting		(1) Insufficient supply of solder (2) Insufficient calorific value in reflow (3) Covered resist
Solder suction		(1) Leads of the component reach the solder melting temperature faster than the board foot print
Solder particles		(1) Abrupt heating of cream solder (2) Degradation of cream solder
Flux residue		(1) Deficient washing (2) Burning of flux due to overheat

5.3 Mounting Methods of Various Package

The soldering heat resistance of SMDs should be considered variable depending on the type of package, and even when their package type is the same, it varies according to the chip size. Therefore, the manufacturers recommend the most suitable mounting method for each product type.

Moreover, the DIP and SIP packages for through-hole mounting type semiconductor devices are not supposed to be mounted by a total heating method, such as reflow method, since they are not meant to be mounted in this way, and are not packed moistureproof either. Nonetheless, in the case where these packages have to be mounted by a total heating method for any specific reason, it may be possible to do so, provided that some protective measure is adopted, such as the control of moisture absorption or baking. The manufacturer should be consulted in advance.

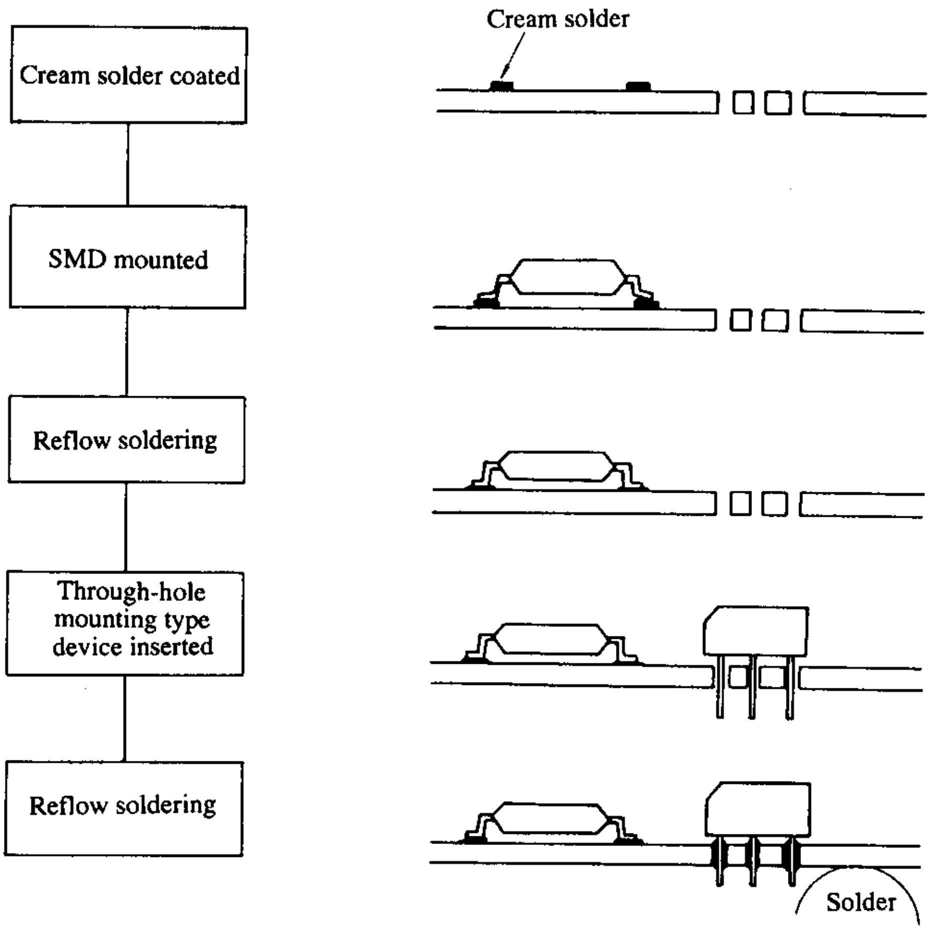
5.3.1 Single-Side Mounting of SMD

Refer to Paragraph **5.2** for mounting flow, when SMDs are mounted on the component side of the board (single-side mounting).

5.3.2 Mixed Mounting (Through-Hole Mounting Type Devices and SMDs)

Fig. 43 represents the case where through-hole mounting type device and SMD device are mounted jointly on the same board.

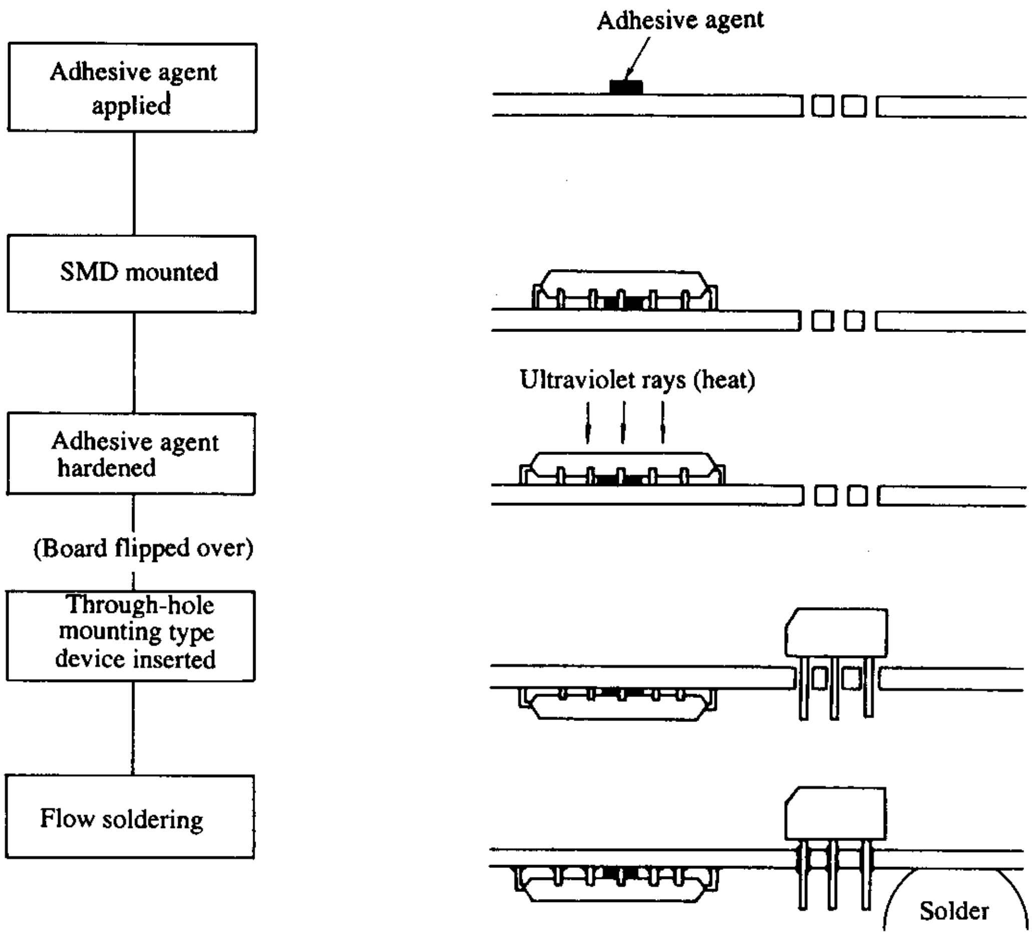
Fig. 43 Mixed Mounting Flow[5.2]



5.3.3 Double-Side Mounting (Through-Hole Mounting Type Device on One Side and Flow-Solderable SMD on the Other)

Fig. 44 depicts the case where a through-hole mounting device is mounted on one side of the board, and a flow solderable SMD device on the other side.

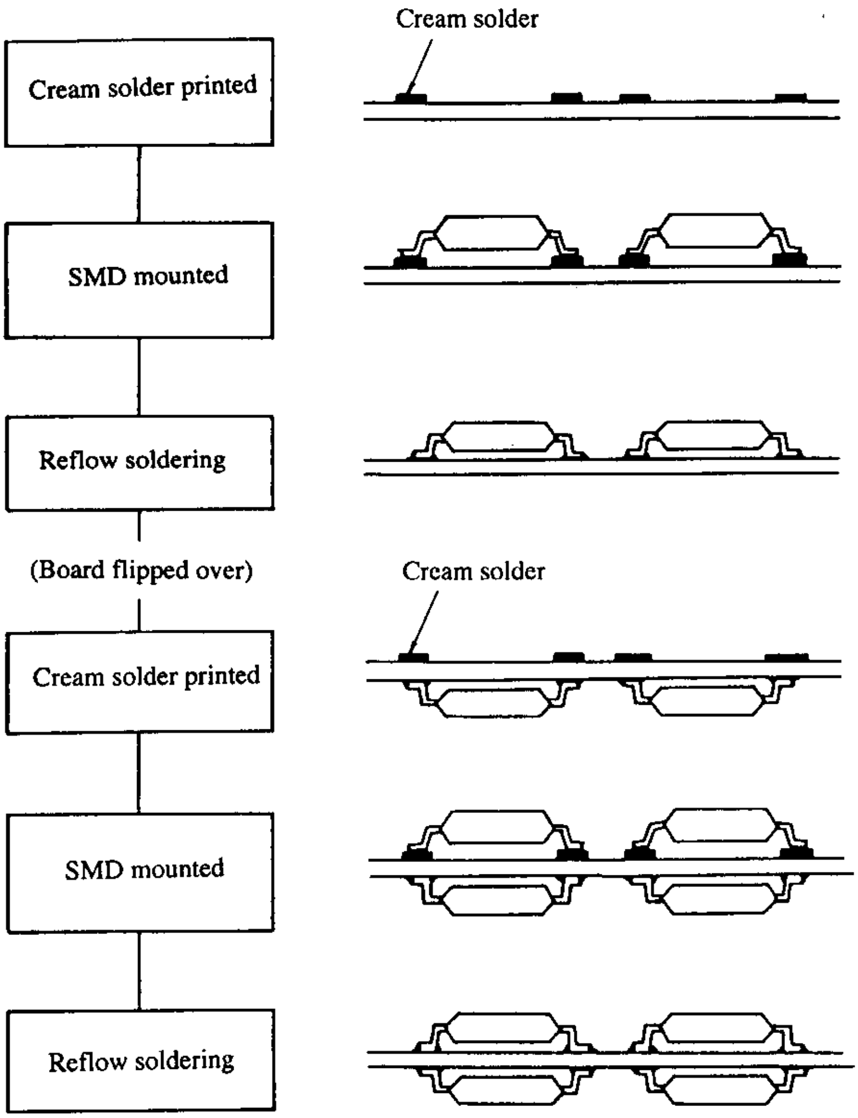
Fig. 44 Double-Side Mounting Flow (Through-Hole Mounting Type Device on One Side)[5.2]



5.3.4 Double-Side Mounting (SMD on Both Sides)

Fig. 45 shows an outline of the both-side mounting method for SMDs. This method is limited to a soldering method that heats only one side of the board, such as infrared reflow method.

Fig. 45 Both-Side Mounting Flow (Surface-Mounting Devices on Both Sides)[5.2]



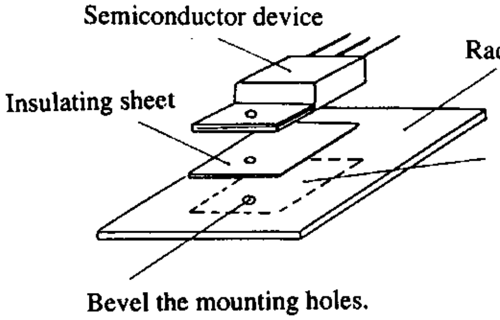
5.3.5 Screwed Mounting

In semiconductor devices that are mounted by screwing or any other method than soldering (mainly devices for power), any deviation in the dimensional accuracy of mounted components or inadequacy of the mounting method largely affects the heat radiating surface and the magnitude of mechanical stress, resulting in malfunction or shortened service life. For this reason, the following aspects have to be taken well into account in mounting this type of devices.

(1) Use cooling bodies, insulating sheets, insulated washers and screws, and other fixing parts that are recommended by the manufacturers.

(2) Keep the fixing parts of the device, such as cooling body and chassis, clean by preventing foreign articles from penetrating into the clearances.
(See Fig. 46.) It could damage the insulating sheet and impair the heat radiation effect.
In the worst of the cases, it could distort the device or cause cracks in the chip.

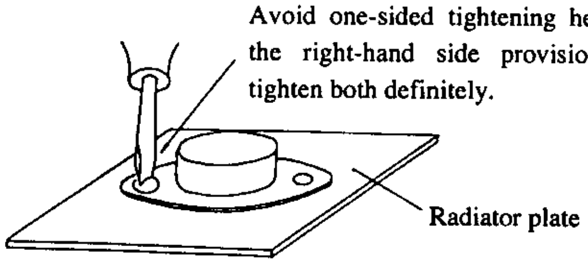
Fig. 46 Mounting Surfaces When Screwed



The mounting surface must be finished level (to be better than ▽▽, and follow the manufacturer's instructions). Also, keep the surface clean, avoiding the deposit of dirt when tightening the screw (the radiation effect will be improved with a thin coat of silicon grease applied to the contact surfaces). For mounting holes and screws, follow the manufacturer's instructions.

(3) When a device is mounted by screwing, an excessive tightening torque leads to an increased heat resistance, while too large a tightening torque product distortion in the device, causing chip destruction, wire breakage or other malfunction. Therefore, tightening torque values recommended by the manufacturers must be observed. (In some cases, silicon grease is applied to the contact surfaces to enhance the radiation effect between device and cooling body. However, it should be noticed that the presence of grease or compound could alter the tightening torque in stud type devices.) Moreover, when a device needs to be fastened at two locations or more, avoid to tighten one screw fully to the specified torque value, with the other fixing parts left open, but tighten all the fixing parts lightly in a provisional manner, and then tighten them to the specified torque. (See Fig. 47.)

Fig. 47 Screwed Method



(4) When silicon grease is employed for plastic products, certain combination of chip coating material and grease adversely affects the material of the chip coat. Check with the manufacturer before using such grease.

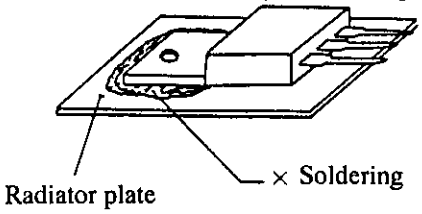
(5) When tightening screws, the tightening tool used (screwdriver or jig) could hit the plastic package, causing a crack in it. Or, the mechanical stress of the hit may be transmitted to the chip or joint, with resultant malfunction.

(6) Do not flex the radiator piece or fixed type pins of a plastic package device. Do not apply solder directly to the radiator piece. (See Fig. 48.)

Fig. 48 Examples of Inadequate Use of Radiator Piece

○ Processing or distortion of radiator piece

○ Direct soldering to radiator piece



5.3.6 Socket Mounting

When mounting an integrated circuit (hereinafter, IC) on a printed-circuit board, it should preferably be attached directly to the board, from viewpoint of the reliability. If it is inevitable to use an IC socket (see Fig. 49) because a memory IC will be added to allow change of the content stored in memory in the middle of operation, or for ease of maintenance service, then the following points should be heeded to:

(1) The contact part must have an adequate contact pressure.

Several times of repeated insertion and pull-off of an IC could reduce the contact pressure, originating poor contact along time, or could conversely bend or damage the leads of the IC due to an excessive contact pressure. Hence, the importance of selecting sockets with adequate contact pressure. (See Fig. 50.) If viable, it will be ideal to select sockets with contact structure made in self-cleaning type. The same precaution should be taken about the measuring sockets that are used in acceptance inspections or on other occasions.

(2) No rise of flux must be allowed during soldering.

When soldering an IC socket to the printed-circuit board, certain type of socket construction allows the flux to infiltrate into the contact part, posing the risk of poor contact while the IC is in service. Therefore, the socket must be so constructed as to fully prevent the flux from rising or to allow to clean the socket perfectly even when there is penetration of flux.

(3) To be heat-resistant and chemical-resistant.

When the printed-circuit board is subjected to flow-soldering, the socket is also exposed to high temperature temporarily. Besides, it may be exposed, for example, to ultrasonic washing under organic solvent for the purpose of removing flux after the soldering process. Therefore, the material and construction of the IC sockets need to be resistant to heat and chemicals.

(4) To be vibration-proof.

In case the mounted printed-circuit board undergoes vibration from the outside, the socket needs to remain free from the vibration as far as possible. If the vibration cannot be suppressed fully due to the constructional characteristics of the board, a special socket with very high contact pressure should be used, so that the IC socket and the IC will not vibrate or slide against each other.

Especially when the contact part of the IC socket and the IC leads are tin-plated, poor contact is likely to result because of oxidation of tin particles produced by fine sliding friction. Therefore, special care should be exerted to avoid mutual vibrations.

When the leads of a socket are heavily flexed due to repeated insertion and pull-off of the socket, it will be rather safe not to use such socket any more (to avoid breakage of leads and poor contact). In case it is absolutely necessary to reuse the socket with its leads rectified or corrected for any reason, do not use the socket if it suffers flexure in the leads again. (See Fig. 51.)

Fig. 49 Sample IC Sockets

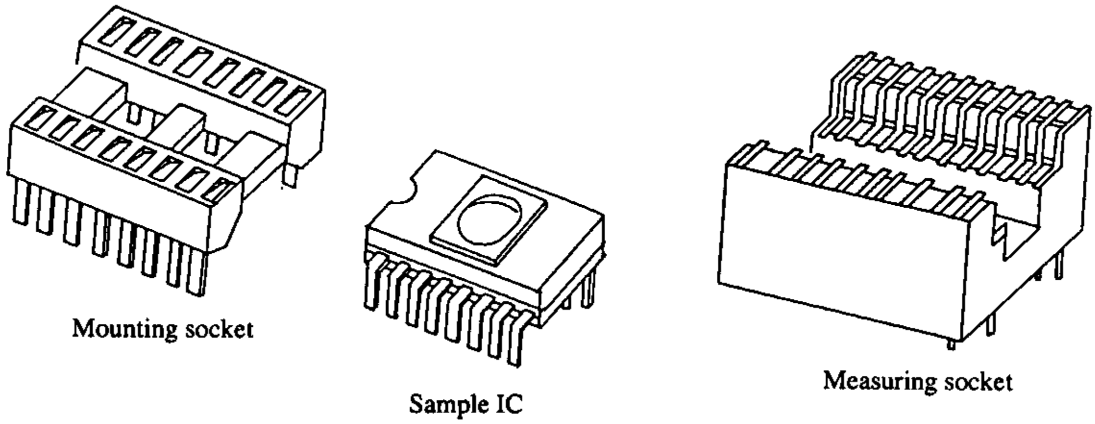


Fig. 50 Sample Contact Construction of Socket

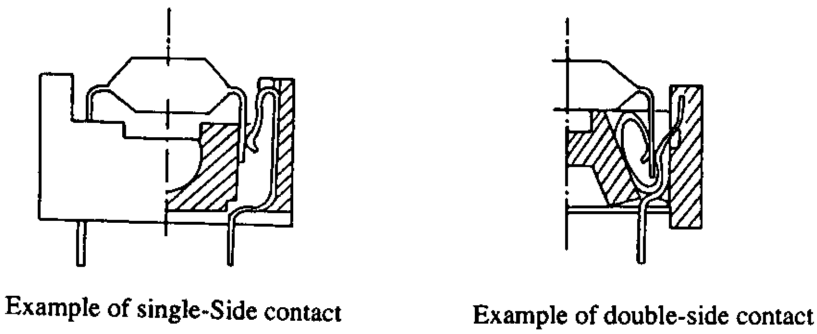
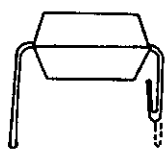


Fig. 51 Sample Distortion of Lead



(6) **Precaution to be taken in coating of printed-circuit boards**
Be careful about the coating agents to be applied to the printed-circuit boards for moitureproofing purposes, since any deposit of such agents at the contacts of the socket may result in poor contact.

(7) **Leads to be clean and free from damage**
Irrespective of whether an IC is directly mounted on a printed-circuit board or a socket is used for that purpose, an important thing is not to touch the IC lead by hand. Likewise, the leads must be maintained free from dust and dirt, and remain in perfect condition.

5.4 Mounting Temperature Conditions for SMD

Since the whole SMD is exposed to high temperature when a total heating method is employed, such as infrared reflow, air reflow, vapor-phase reflow, or flow soldering, the surface temperature of the package needs to be strictly controlled, together with the temperature of the soldered joint.

While some temperature conditions were indicated in 5.2.6 by way of example, the reasons for defining those conditions will briefly be explained below with the help of Fig. 52.

(1) Temperature gradient 1

In case the temperature rises suddenly, the SMD presents an uneven temperature distribution among the different parts of the package (e.g., package surface, interior, back side). Difference in the coefficient of thermal elongation from one material to another could result in warpage of the package, damaging the chip. Therefore, the upper limit of the temperature rise must be watched carefully. Its lower limit depends on the working efficiency of the reflow equipment.

(2) Preheating

This is intended to prepare the temperature of the components and wiring board at a temperature below the melting temperature of solder, so that soldered joints will stabilize and thermal shocks will be eased. The preheating temperature is usually defined in the proximities of the rated temperature.

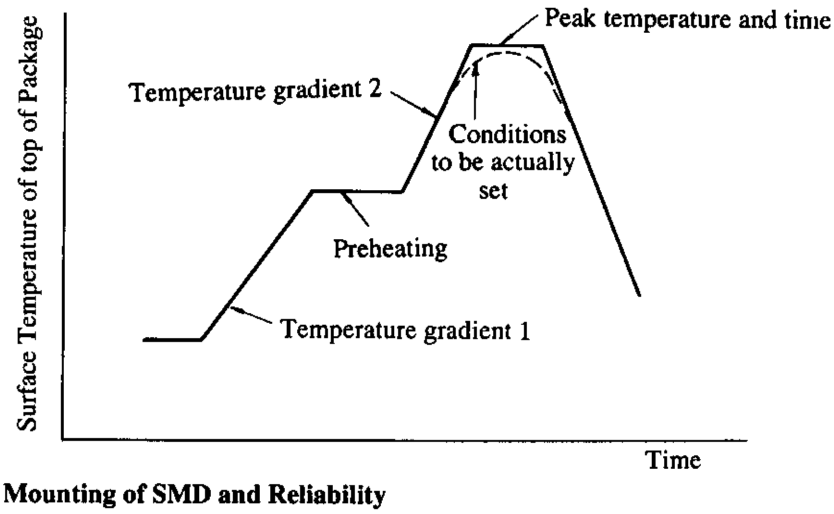
(3) Temperature gradient 2

The upper limit of temperature rise is the same as in (1) above, and the lower limit is determined from the need to limit the peak temperature and time to within the prescribed values.

(4) Peak temperature and time

These parameters must be the object of utmost care to minimize damages to the package. The peak temperature should preferably be as low as possible, since it directly relates to the loss of strength of the package (depending on the heat characteristics) and the steam pressure inside the package. In addition, the time should be held as short as possible, because the steam pressure rises along time. The conditions indicated by manufacturers represent the points where the said permissible range concurs with the feasible range of soldered joints, and are expressed in upper-limit values, not in mean values. Therefore, care must be taken not to exceed those upper limits in setting up the conditions (e.g., dotted line in Fig. 52).

Fig. 52 Sample Temperature Conditions



5.5 Precautions on Mounting of SMD and Reliability

Unlike through-hole mounting type devices, SMDs are often mounted by a soldering method that heats the SMD main body at high temperature, which includes infrared reflow, air reflow, and vapor-phase reflow.

For this reason, the swelling, cracks, and deteriorated moisture resistance of the molded resin which is used as package material of the SMD are cited as the problems relating to their reliability.

Furthermore, SMDs have extremely short lead pins to allow high-density mounting, besides their narrow

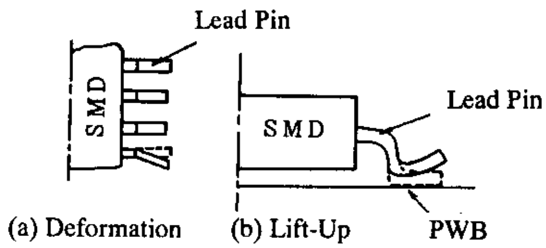
when these are handled improperly, which could lead to a damage of the soldered joints to the associated wiring board.
This section will discuss the reliability-related problems and their remedial actions that are involved when an SMD sealed in molded resin is soldered, exposing the SMD main body to high temperature.

5.5.1 Problems and Actions in Handling SMDs

(1) Flexure and float of lead pins

When the leads of an SMD present a flexure or float in excess of the prescribed tolerance, it is no longer possible to obtain reliable soldered joints, as can be seen in Fig. 53. Normally, manufacturers have a value established around 0.10 to 0.15 mm for the flatness (float) of SMD lead pins and, in practice, are shipping products that are better than this value. In actual mounting, due care must be exerted not to bend or float those lead pins. In the case of multipin SMDs, a very high accuracy is required in locating them in line with the wiring patterns of the associated boards. It is, therefore, preferable to employ automatic mounting machines with a view to avoiding float and flexure in the leads.

Fig. 53 Sample Flexure and Float of SMD Lead Pins



On the other hand, good soldered joints will not be obtained in the mounting of SMDs, if the wiring boards are not controlled properly, no matter how strictly the lead pins may be controlled. Warpage of the boards, thickness of the cream solder film and its uniformity must be checked, so that they will remain within the specified ranges.

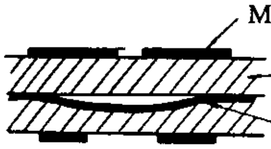
(2) Electrostatic discharge failure

Given the high-density integration, semiconductor devices are extremely sensitive to static electricity, and can even be destroyed in some cases. Extreme care must be exerted in handling them or mounting them to the wiring boards. For details on the preventative measures against electrostatic discharge failures, refer to **3** (Electrostatic Discharge Failures and Their Remedial Actions).
Moreover, the same precaution needs to be taken when removing taped SMDs from their carrier tape. Static electricity is generated when the cover tape (top tape) is peeled off the carrier tape, allowing the taped SMDs to be electrically charged. This charge voltage goes higher as the peel-off speed increases. Do not peel off the tape at a speed higher than the specified one. Preferably, peel-off should be carried out at a speed of 10 mm/sec or less. For further details, refer to **4.1.2**.

(3) Delamination of printed-circuit board

The material mainly used in making printed-circuit boards is epoxy resin, the same material as that of molded resin of semiconductor devices. For this reason, moisture absorption is inevitable, as moisture penetrates through the interface between glass cloth and epoxy resin, requiring ample moistureproofing control in the storage and mounting operations. Especially in laminated boards, absorbed or condensed moisture evaporates and expands under the heat of reflow soldering, causing a delamination like the one illustrated in Fig. 54. In the case where moisture absorption is suspected after prolonged storage, it will be necessary to apply dehydrating treatment (at 125℃ for some 10 hours) before mounting any component.

Fig. 54 Delamination Phenomenon of Printed-Circuit Board



5.5.2 Problems at Lead Pin Joints of SMD and Precaution

(1) Deficient soldering

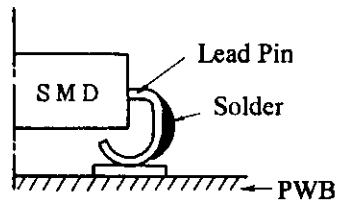
Since the lead pins of SMDs are extremely short, many in number and narrowly pitched, inadequate work and insufficient control of soldering operation could result in deficient soldered joints. For example, cream solder must be stored in accordance with the relevant instructions for use, and once the container is opened, the whole content should be used up, or stored in a cool dark place with low humidity. If cream solder absorbs moisture, defective bond or solder particles will be produced at soldered joints.

If an abrupt temperature rise is given to the SMD and the associated printed wiring board during soldering process, the printed wiring board, SMD lead pins, and the SMD in itself will register inconsistent temperature rises, respectively, at the time when cream solder melts, thereby originating a suction of solder ([1]) like the one shown in Fig. 55, or solder particles. In addition, such defects as voids and wetting will occur under those conditions, because the volatile component and moisture contained in the cream solder cannot evaporate completely. These defects make it impossible to obtain reliable soldered joints.

Note ([1]) Suction of solder

When a printed wiring board with an SMD mounted is heated in an infrared reflow oven without applying preheating to it, the SMD and the wiring board will quickly rise in temperature according to their respective heat capacities. If the SMD has a lower heat capacity and thermal resistance than the board, the lead pins and package of the SMD will present a temperature rise faster, and the printed wiring board will be delayed a little in temperature rise, because of its higher heat capacity. In this process of temperature rises, the temperature of the lead pins goes up beyond the melting point of the cream solder, while the printed wiring board remains below the said melting point. Consequently, the cream solder printed on the printed wiring board begins to melt from the part that is in touch with the lead pins, and is sucked up toward the lead pins by the surface tension of the melted solder. The term suction of solder refers to this phenomenon that results in deficient soldering (opening).

Fig. 55 Suction of Solder



(2) Remedial action

To secure reliable soldered joints in soldering SMDs, observe the following points:

(a) Preheat the SMD and the printed wiring board thoroughly.

The preheating temperature and time, as well as the soldering temperature and time, should be decided in line with the temperature profiles recommended by the manufacturer.

(b) Control the cream solder film thickness fully and obtain a uniform thickness.

When applying cream solder in screen-printing, the film thickness and the particle shape and viscosity of solder make important factors. As the lead pin pitch becomes narrow, so does the solder pad pitch of the printed wiring board. If cream solder is supplied in excessive volume, adjacent lead pins may be short-circuited (bridged) due to roll-over of solder. Therefore, the thickness of solder film and its uniformity need to be controlled strictly.

(c) Wash the wiring board prior to the mounting process.

The foot-print surface of the printed wiring board needs to remain in an activated state that facilitates good wetting of solder. If that surface is dirty or oxidized, the board needs to be subjected to degreasing and oxide film removing treatments, and so on.

One of the customary ways of degreasing consists in washing under fluorocarbon-base solvent. To remove oxide films, an idea is to use one of the pretreatment agents available in the markets. However, note that some types of solvents dissolve copper. Therefore, the treating agent and the conditions of treatment must be selected and decided with utmost care.

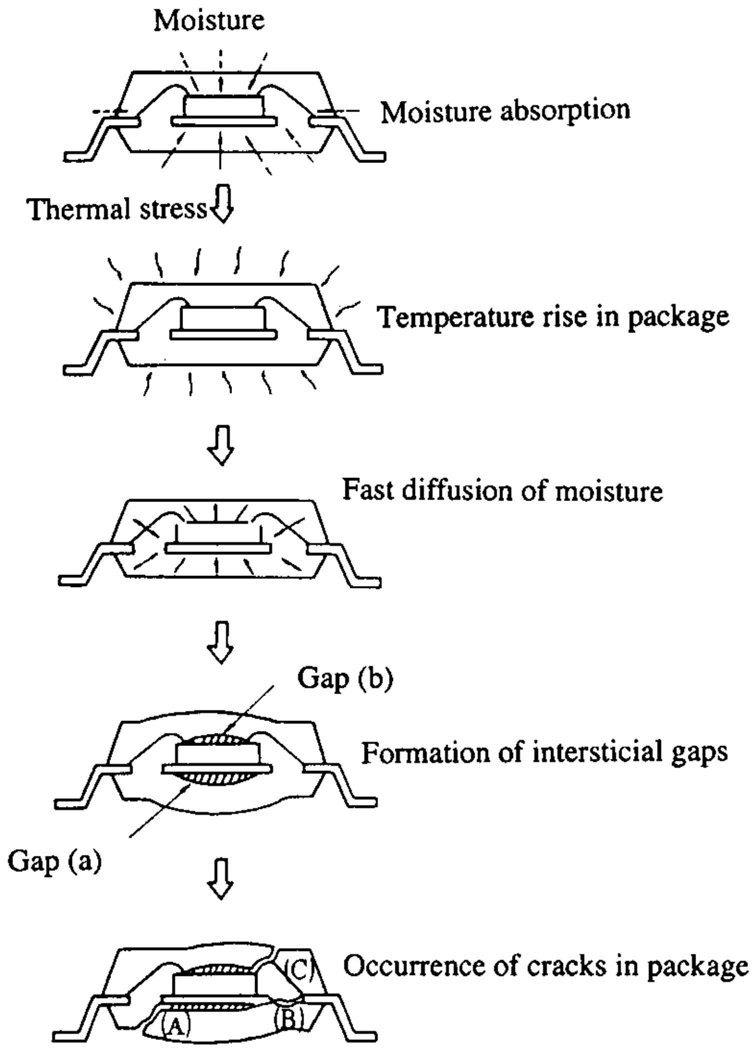
5.5.3 Influence of Soldering on Quality of SMDs

(1) Influence of absorbed moisture

(a) Occurrence of cracks in molded resin due to evaporation of moisture

When SMDs which contain absorbed moisture after having been in store for long time in an ordinary environment or a highly humid environment are soldered by a total heating method, such as infrared reflow, the molded resin sometimes presents swelling and cracks. These defects are closely related to the amount of moisture absorbed in the molded resin. The process of occurrence of this phenomenon is graphically represented in Fig. 56. The moisture (steam) absorbed by the molded resin is accumulated in it. This steam increases its moving speed (rise of diffusional speed) under the heat of the infrared reflow process, and blows out through the intersticial delamination caused by difference in coefficient of thermal expansion between the materials. With the passage of time, the steam pressure at the delaminated part rises. This pressure expands the intersticial delamination further and, at the same time, dilates the molded resin, eventually giving rise to cracks in it. The cracks are produced in the back surface of the die-pad or in the top surface of the chip.

Fig. 56 Process of Occurrence of Cracks in Molded Resin due to Absorbed Moisture [5.4]



(b) Susceptibility to cracks

(b-1) Relationship between strength of molded resin and occurrence of cracks

Generally, the strength of a molded resin falls under the condition of soldering temperature to around 1/10 of its value at normal temperature. Fig. 57 shows the dependence on temperature of the stress generated by steam pressure and the strength of resin. There, it can be observed that the generated stress surpasses the strength of the resin, under the temperature conditions of reflow soldering.

Fig. 58 is an example of the relationship between the peak temperature and the occurrence ratio of cracks in molded resin. It indicates that the occurrence ratio of cracks is dependent on the temperature of the reflow process.

Fig. 57 Example of Relationship between Stress Generated in Reflow Process and Strength of Molded Resin(5.2)

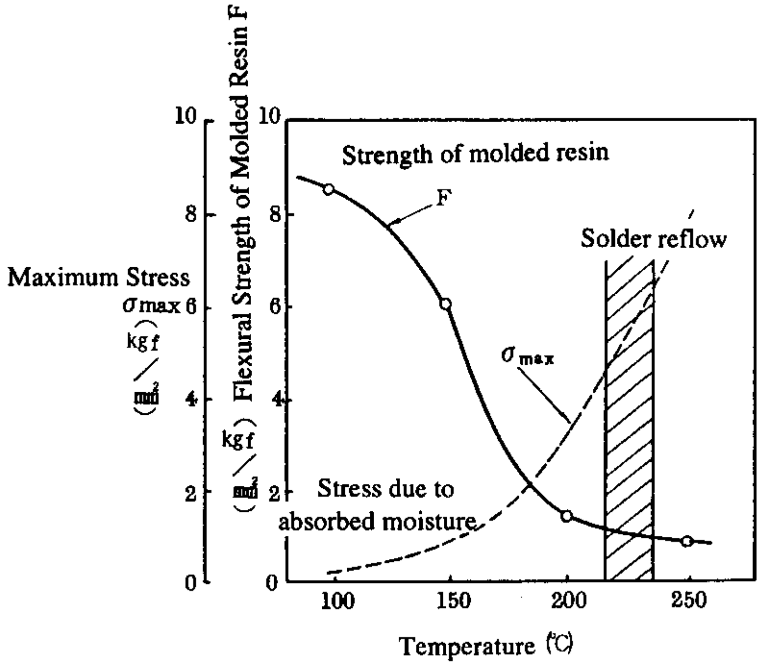
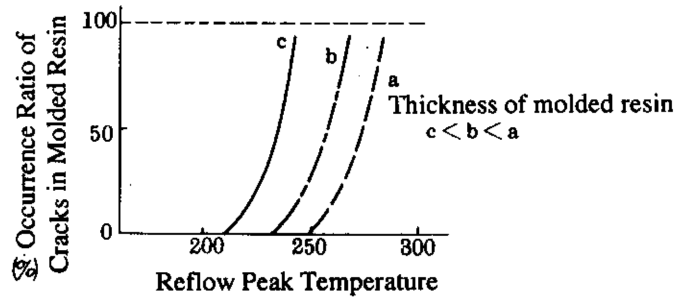


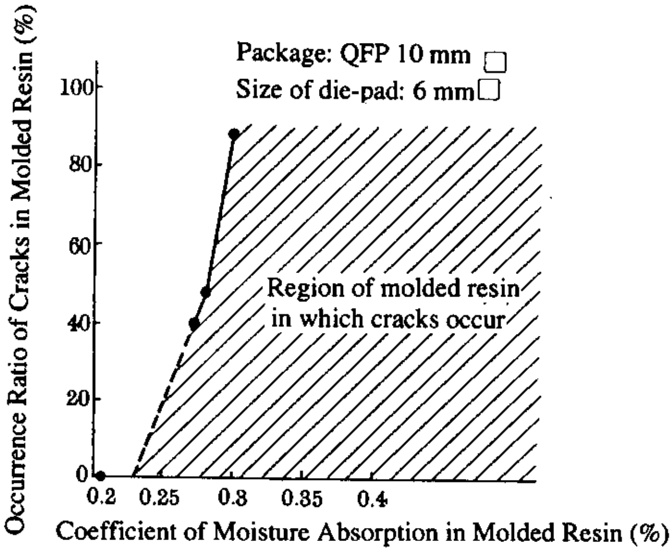
Fig. 58 Example of Relationship between Reflow Temperature and SMD Molded Resin(5.4)



(b-2) Relationship between amount of absorbed moisture in molded resin and occurrence of cracks

The more the absorbed moisture increases, the higher the steam pressure rises under heating (Boyle-Charles' law). From there, as the absorbed amount of moisture increases, the occurrence ratio of cracks goes up all the more. Fig. 59 depicts the relationship between the coefficient of moisture absorption of a molded resin and the occurrence ratio of cracks. However, be aware that strictly speaking, cracks are caused by the moisture that is contained in the back side of the die pad and the top surface of the chip, although the foregoing explanation was based on the relationship with the coefficient of moisture absorption. For example, in the process where a dry package absorbs moisture while it is stored indoors, the coefficient of moisture absorption is large, but the amount of moisture in it is small. Meanwhile, in the process where packages containing absorbed moisture are dried, the amount of moisture they contain is often large, even though the coefficient of moisture absorption may be low. In this way, it sometimes happens that the coefficient of moisture absorption, which represents an average amount of moisture in packages, does not perfectly correspond with the occurrence ratio of cracks in the transitional period of moisture absorption and dehydration, and this fact should be borne well in mind.

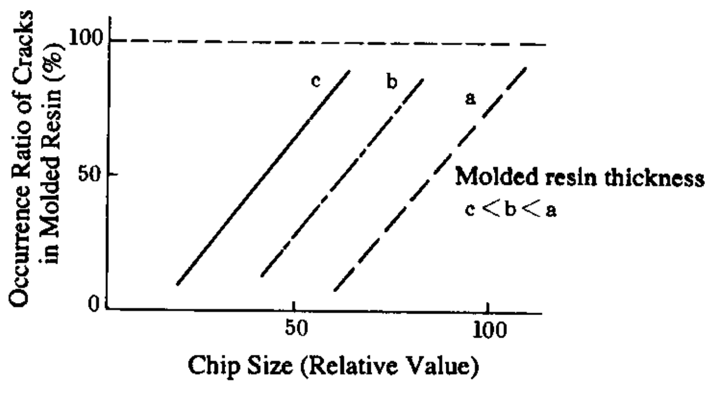
Fig. 59 Example of Relationship between Coefficient of Moisture Absorption and Occurrence Ratio of Cracks in Molded Resin (5.5)



(b-3) Relationship between Chip Size/Molded Resin Thickness and Occurrence of Cracks

Cracks are produced in molded resin as the stresses generated by steam pressure and thermal expansion of materials concentrate on the corner of the die-pad of a lead frame. These stresses are more intense as the die-pad is larger, namely, the chip size is larger. Fig. 60 indicates the relationship existing between the chip size/molded resin thickness and the occurrence of cracks in molded resin. In the illustration it can be observed that the occurrence ratio of cracks goes higher as the chip size becomes larger and the molded resin thickness thinner. The occurrence ratio of cracks becomes higher as the molded resin thickness becomes thinner, because the package has a low strength or absorbs moisture quickly.

Fig. 60 Example of Relationship between Chip Size/Molded Resin Thickness of SMD and Occurrence Ratio of Cracks (5.4)



(3) Influence of Cracks in Molded Resin on Reliability

In case cracks or delamination take place in the top surface for any reason, such as deviation from the manufacturer's recommended conditions, care must be taken, since the reliability of the mounted product may be affected as explained below.

(a) Deterioration of moisture resistance

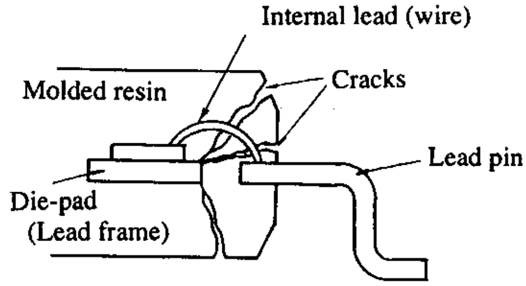
In case delamination occurs in the interface between the molded resin and the lead frame or chip, or crack are produced in the resin, the subsequent reliability of the SMD could be impaired. For example, cracks in the resin facilitates the penetration of moisture and impurities from the outside, and the intersticial delamination between the lead frame or chip and the resin helps the infiltration of moisture, and both of them promote the corrosive action on the Al wiring on the chip surface, eventually deteriorating the moisture resistance of the product.

(b) Opening of internal lead (wire)

Cracks occur in molded resin under stresses concentrated on the corner of the die pad. However, the directions in which cracks are produced vary from one SMD to another, i.e., above, by the side, or underneath the lead frame.

If cracks are formed above or by the side, they sometimes involve the internal lead (wire), which cuts off the internal lead or opens up the joint between the internal lead and the chip.

Fig. 61 Cracks in Resin Involving Internal Lead (Wire)



(3) Remedial Action

Because the cracks and other problems mentioned above can be prevented when components are mounted within the limits of storage conditions and temperature conditions recommended by the manufacturers, the subsequent decline in the reliability can be prevented (See **5.2.3**, **5.2.6**, and **5.4.**)

5.5.4 Other Precautions

(1) Precautions on coating

After SMDs or other semiconductor devices are mounted, the assemblies are sometimes coated with resin. Some of these coating materials absorb moisture and thus augments the leakage current.

Besides, soldered joints and semiconductor device resins are subjected to a mechanical stress, depending on the type of the coating resin. Therefore, due care must be exerted in selecting the coating material, and the reliability must be checked after it is applied.

5.5.5 Reliability Test Method for SMDs

The EIAJ ED-4701 and ED-4702 Standards establish the following test methods for reliability evaluation of SMDs in connection with the package cracks and other defects discussed above.

EIAJ ED 4701-2 (Test Methods for Semiconductor Device Environment and Durability)

Test method A-131A Solderability Test

A-133A Soldering Heat Resistance Test (SMD)

A-101A Humidification + Mounting Stress Series Test

EIAJ ED 4702 (Mechanical Test Methods for Surface-Mounting Semiconductor Devices) [5,6]

Test method 5.1 Main Body Strength Test

5.2 Peel-Off Test
5.3 Board Flexural Resistance Test
5.4 Sticking Tendency Test
5.5 After-Mounting Heat Cycle Test
(Reference test) Impact Resistance Test

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(5.2) "Mounting Manual for Hitachi Plane-Mounting Packages," 3rd Edition, Hitachi, Ltd.
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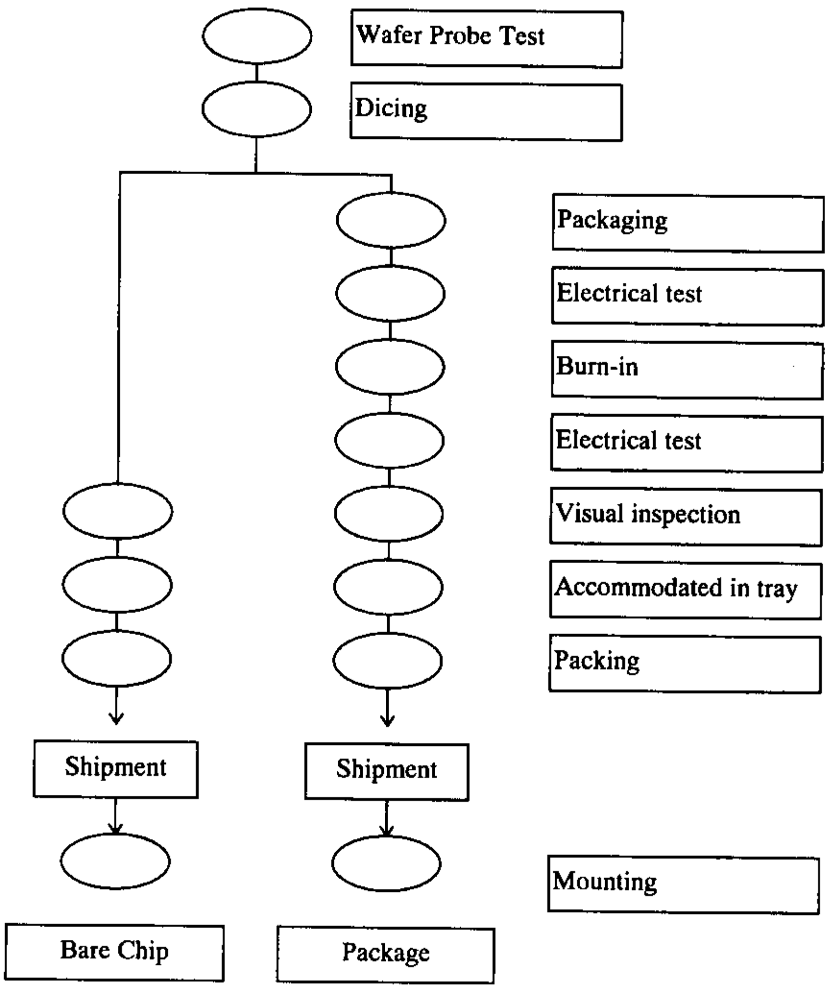
(5.4) "Reflow Capabilities of Surface-Mounting Devices," NEC Device Technology, No. 19, p. 64 - p 71, 1987.
(5.5) Ishiguro: "Latest Trends in Surface-Mounting Electronic Components," Industrial Investigation Association, No. 9, p. 16 - p. 21, 1988.
(5.6) EIAJ ED-4702 "Mechanical Strength Test Methods for Surface-Mounting Semiconductor Devices," Electronic Industries Association of Japan (Foundation), 1992.

6. Handling of Bare Chips

6.1 Bare Chips

Bare chips are the semi-finished semiconductor devices that are sold in the form of chips (see Fig. 62). Their handling calls for stricter control, as compared to that of packaged products.

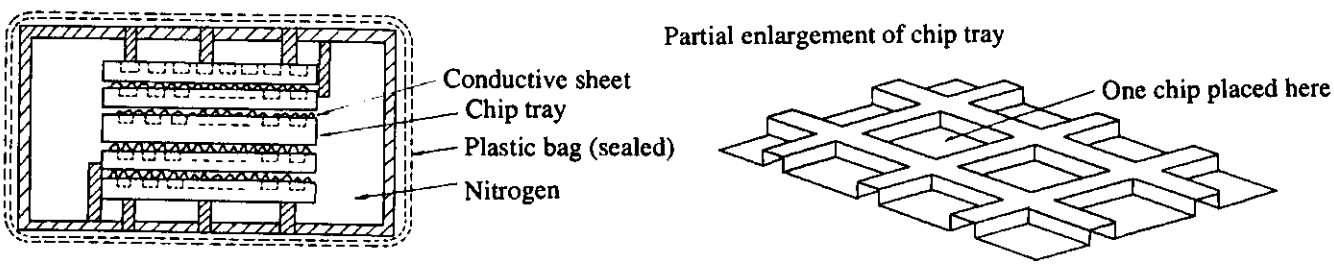
Fig. 62 An example of Shipping Process Flow for Bare Chips and Packaged Products



6.2 Packing and Storage

(1) Chips should be accommodated in the specified container, which must not be opened, unless absolutely necessary. Normally, the containers for chips are built in airtight construction to protect the chips from temperature, humidity, and harmful gases, as well as from vibrations and shocks encountered during transportation. (Fig. 63)

Fig. 63 An example of Container for Chips



(2) Do not leave the container open, lest the chips inside be oxidized or corroded by changes of temperature and humidity, or by gases, dust, and chemicals.

(3) The container should be stored in an atmosphere of 15 to 35℃ and relative humidity of 45 to 75%, and in a place not susceptible to the influence of chemicals or volatile substances.

(4) To take chips out of the container, they must be handled cavefully in such a manner as may not damage the chip surface.

(5) Standard storage times

(a) When chips are accommodated in the prescribed container and this container has not yet been opened (3 months or less)

(b) When the container is opened and stored in dry nitrogen (less than -30℃ dew point) or in dry air (20 days or less)

(c) Time after chips are taken out of the container, till they are assembled (during this period, the chips must be stored in dry nitrogen or air at night when no work is conducted) (5 days or less)

6.3 Mounting

(1) Chips must be mounted in a clean environment where chip surface is not exposed to polluting atmosphere or substance.

(2) The mount must be handled in such a way that chip surface will not be damaged. Preferably, a cylindrical collet should not be used, since it sometimes leaves scratches on chip surface.

(3) In handling chips, be very careful not to expose them to static electricity. (See Paragraph **3.2**)

(4) To mount chips, adopt the most suitable assembling method that guarantees appropriate electrical, thermal and mechanical characteristics of the semiconductor products.

6.4 Washing

(1) Chips should not preferably be washed in their naked state. If they must be washed in such condition, care must be taken to prevent them from being polluted.

6.5 Precautions on Reliability

(1) Since bare chips have not yet been subjected to high temperature tests and screening, they may include chips that result in early failure. Therefore, to achieve good quality assurance level equal to that of package products, an adequate screening has to be made after the mounting process. Since KGD is required these days, some techniques capable of assuring an equal quality to that of packaged products are being established, but such techniques likely bring about a cost increase equal to or more than that of packages products.

(2) The mounting methods to be adopted must be such that sufficient moisture resistance, and thermal and mechanical reliability will be obtained in the products. Especially, the selection of materials and the control of assembling process need to be considered thoroughly, so that the required moisture endurance will be secured.

7. Safety Management and Environment

7.1 Influence of Semiconductor Devices on Environment

Semiconductor devices are industrially manufactured electronic parts, and an important point in their relation to the natural environment resides in their disposal method.

Given the composition, semiconductor devices should not forthwith be disposed of by incineration, but need to be treated as industrial wastes.

7.2 Substances Composing Chips

A semiconductor device chip consists of a silicon board, impurities, oxide film, metals, and so on. The impurities contained in the silicon board include phosphor, boric acid, boron, fluoride, arsenic, and others. Of these impurities, fluoride and arsenic are feared to affect human body, but their amounts contained in semiconductor devices are extremely small, and, besides, incorporated in the silicon boards in a chemically stable form.

7.3 Substances Composing Packages

The substances contained in a semiconductor device package vary with the type of the package. Their representative materials are classified as follows: molded resin and lead frame for plastic packages; ceramics for ceramic packages; polyimide tape for TAB-IC, and epoxy board and molded resin for P-PGA. Among those materials, the bromic fire-retarding material of molded resin and the lead contained in the solder of pins are cited as materials that require special care.

(1) The bromic fire-retarding material gives out soot and foul smell when burned. It should not readily be incinerated.

(2) The solder contained in external leads should be the object of the same attention as in handling lead in general, with respect to its disposal method and the need of ventilation in soldering process.

7.4 Disposal Method for Semiconductor Devices

Semiconductor devices in themselves do not directly do harm to the environment. Yet, they should not easily be disposed of by crushing or incineration, but ought to be treated as industrial wastes, in accordance with Paragraphs 7.2 and 7.3.

Moreover, particles and residues resulting from dicing of silicon wafers must be recovered and treated by way of industrial wastes.

7.5 Disposal Method for Packing Materials

The packing materials for semiconductor devices include corrugated cardboards, trays, magazine tubes, vinyl chloride, styrene foams, metal reels, and so on, and they are made of a wide variety of raw materials. All of these materials are well known, and can be classified among paper, plastics, and metals. Therefore, they are materials that can be disposed of as industrial wastes.

On the other hand, those materials which already have their recycling methods established can be disposed of according to the respective rules.

Some semiconductor manufacturers are recovering trays, magazine tubes, reels, etc., for recycling, as part of their commitment to the environmental issue. In order to promote the recovery of packing materials further, the users are requested to handle them with care as far as possible .

7.6 About Washing after Mounting Process

To remove flux residue after mounting, semiconductor devices, as well as printed-circuit boards with those devices mounted, need to be washed. However, at a time when it is strongly required to do away with freon that causes the destruction of ozone layer, a washing solution that meets the social demand must be employed.

7.6.1 Prohibition to Use the First Class Specifiend Freon

The Montreal Protocol stipulates a requirement to cut back on the use of the First Class Specified Freon to less than 15% with respect to the records of 1986 by the year 1997, and to nil by the year 2000. Based on this stipulation, the use of the First Class Specified Freon for purposes of washing semiconductor devices and wiring boards should be discontinued.

7.6.2 Use of Freon Substitutes

From this time forward, freon substitutes must be used for washing semiconductor devices, wiring boards, and so on. It should be noted that even those substances called freon substitutes today may be prohibited to use, depending on the social trends in the future.

By the way, washing fluids that do not belong to the freon family are now produced and available in the markets. These products should be studied for possible use.

Explanation

1. Background

In February 1993, the Electronic Industries Association of Japan (hereinafter, EIAJ) conducted a review of the EDR-4701 that contained descriptions pertaining to the handling of semiconductor devices which is most important to maintain their quality and reliability. As a result, the EIAJ published the EDR-4701A, soon followed by Supplements -1 and -2 to the ED-4701, which is a standard regulating the environment and durability test methods for semiconductor devices. All these activities led to the need of another revision of the EDR-4701A, which has now culminated in the EIAJ EDR-4701B.

2. Major Contents

The EDR-4701A was put together centering on the difference between the SMDs, which began to spread to the markets in 1993 and the traditional lead-insertion type devices, and it mainly referred to the relationships between problems inherent to SMDs (mounting, storage, etc.) and reliability. The EDR-4701B now provides precautions on the handling of semiconductor devices in general, including the said part relating to the SMDs.

(1) Features and Types

The new version adds new packages and mounting forms, such as BGA, MCM, TCP, CSP, and so forth.

(2) Points of Notice in Design Work

A new chapter was created covering the "relationship between absolute maximum ratings and recommended operating ranges, and reliability," "noise," and "latch-up."

(3) Electrostatic Discharge Failures and Their Remedial Actions

Through courtesy of RCJ, the EDR-4701B now explains antistatic remedies based on the "Guidelines on the Electrostatic Discharge Failure Preventive Technologies for Semiconductor Devices," which was edited by RCJ.

(4) Packing, Storage and Transportation

This part of the EDR-4701A was included without modifications.

(5) Mounting Methods

The EDR-4701A provided an ample explanation of SMDs, but now the EDR-4701B has simplified the explanation to some extent, and incorporates the contents of the ED-4701-2.

(6) Handling of Bare Chips

The Standard also includes handling of bare chips which are drawing attention of late. The relevant descriptions contained in the ED-4701A were put together under this chapter. Moreover, precautions on the reliability were added.

(7) Safety and Environmental Control

The safety control and environmental control are now big issues, as can be observed in the stipulations of the ISO14000, etc. The new Standard explains the disposal methods and related aspects for semiconductor devices.

3. Committee Members

This technical report was discussed mainly by "Sub-Committee on Semiconductor Devices Reliability" of the Technical Standardization Committee on Semiconductor Devices/Semiconductor Devices Reliability Group. The Sub-Committee are as shown below.

<Technical Standardization Committee on Semiconductor Devices/Semiconductor Devices Reliability Group>

Chairman	Hiroshi Ozaki	Hitachi, Ltd.

<Sub-Committee on Semiconductor Devices Reliability>

Chief	Tetsuaki Wada	Matsushita Electronics Coap.
Sub-Chief	Masaki Tanaka	Hitachi, Ltd.
Member	Han Nakajima	NTT Electronics Technology Coap.
	Masayuki Kubota	Oki Electric Industry Co., Ltd.
	Osamu Nakayama	Kawasaki Steel Coap.
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	Nobuyuki Kawayoshi	Sharp Coap.
	Matsuo Fujita	Shindengen Electric Mfg. Co., Ltd.
	Shinichi Murata	New Japan Radio Co., Ltd.
	Koichi Sakaguchi	Seiko Epson Coap.
	Shizuo Okada	Sony Coap.
	Mikio Numakawa	Toshiba Coap.
	Gengo Kikuma	Nippon Steel Semiconductor Coap.
	Satoshi Sadaike	Texas Instruments Japan Ltd.
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	Akira Yamakawa	Fujitsu Ltd.
	Toshiharu Kurihara	Fuji Electric Co., Ltd.
	Hiroshi Yoshiyama	Mitsumi Electric Co., Ltd.
	Nobuharu Yoshioka	Ricoh Campany, Ltd.
	Takaharu Ito	Rohm Co., Ltd.