

Product-Category Rules (PCR)  
for preparing an environmental product  
declaration (EPD) for

**Integrated Circuits**

PCR 2009:1

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Limited

Advanced Semiconductor Engineering, Inc.

Industrial Technology Research Institute

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## **1. General Information**

This document is to be used as the product category rules (PCR) for integrated circuits, including their global wafer manufacturing, as well as IC packaging and testing. The requirements specified in this PCR are intended to be used for environmental product declaration (EPDs) certified in accordance with ISO 14025 standard. This document shall be valid until July, 2011.

This PCR is jointly prepared by the Taiwan Semiconductor Manufacturing Company, Limited and the Advanced Semiconductor Engineering Inc. Representatives from major Taiwanese IC manufacturers and stakeholders were invited to the open consultation meeting on May 11, 2009, after which Environment and Development Foundation (EDF) approved of this PCR.

For further information concerning this PCR, please contact Taiwan Semiconductor Manufacturing Company, Limited Environment, Safety & Hygiene Strategic Planning Dept. M.L.Lo (tel : 886-3-5636688-7022242 , fax : 886-3-5643820 ; email : mlloa@tsmc.com).

## **2. Company and product description**

The EPD shall include information about the manufacturing company/organization. The information may include manufacturing process related information, and environmental related information, such as the environmental management system information. The information may also include special issues which the company/organization would like to emphasize, such as the product meeting certain environmental criteria, or environmental safety and health related information.

This PCR covers the integrated circuit (IC) products, and the products denoted here also include their packaging.

### **2.1 Product function**

The integrated circuit in this PCR denotes an assembly of electronic circuits which through assembling and inter-connecting various electronic devices with different functions is capable of performing the specified functions. The ICs have very wide applications and are used in almost all electrical and electronic equipment or devices, performing functions such as memories, microprocessors, logics, analogs, and individual components. Their fields of applications are generally divided into computers and peripherals, office automation, consumer products, communications, automobiles, industrial and miscellaneous applications.

## **2.2 Product components**

The basic components and major packaging materials for the ICs include:

2.2.1 Wafer, chip (die) produced from wafer, and packaging materials are also included.

2.2.2 Based on their functions, IC's major materials may be divided into:

- (1) core function: chip (die)
- (2) adhesive: epoxy, epoxy film
- (3) carrier substrate: substrate (organic/ceramic), lead-frame (Cu/Fe), tape etc.
- (4) electrical connection: metal wire (Au/Al/Cu), solder bump, solder ball, Cu pillar, Au stud etc.
- (5) encapsulant: molding compound, liquid compound, underfill etc.
- (6) heat dissipation: heat sink/slug/spreader, TIM etc.
- (7) packaging: tray, tube, carrier, box, other packing material etc.
- (8) others: ink, resistor, capacitor etc.

## **2.3 Product technical description**

The product technical description part of the EPD shall include the following information:

- (1) Package Name
- (2) Package Size L (mm)\*W (mm)\*H (mm)
- (3) Lead Count (Ball Count)
- (4) Chip Size (L (mm)\*W (mm)) & Quantity (including dummy wafer)
- (5) Weight (gram)
- (6) For wafer, the wafer size should be described, such as 150 mm (6-inch), 200 mm (8-inch) and 300 mm (12-inch).

## **3. List of parts and banned substances**

The contents of the following parts and substances in the product shall be declared:

- All parts with weight ratio (part weight/product weight)  $\geq 1\%$ ;
- All substances in the products regulated by legal and customer requirements (such as substances regulated by the RoHS Directive (2002/95/EC)) and their conformance declaration.

The declaration of halogen-free flame retardants, lead-free solders and no RoHS-regulated substances may only be made when appropriate evidences are

available (for example, test reports from accredited laboratories/testing facilities). The following organizations may provide accreditation for certification organizations: Taiwan Accreditation Foundation (TAF), Asia Laboratory Accreditation Cooperation (APLAC), International Laboratory Accreditation Cooperation (ILAC) or ILAC Mutual Recognition Arrangement (ILAC MRA). For definitions of testing methodology and confirmations of regulated hazardous substances based on the accredited laboratories' product testing methods, please refer to the standards recognized by the industry, such as the IEC 62321 Standard.

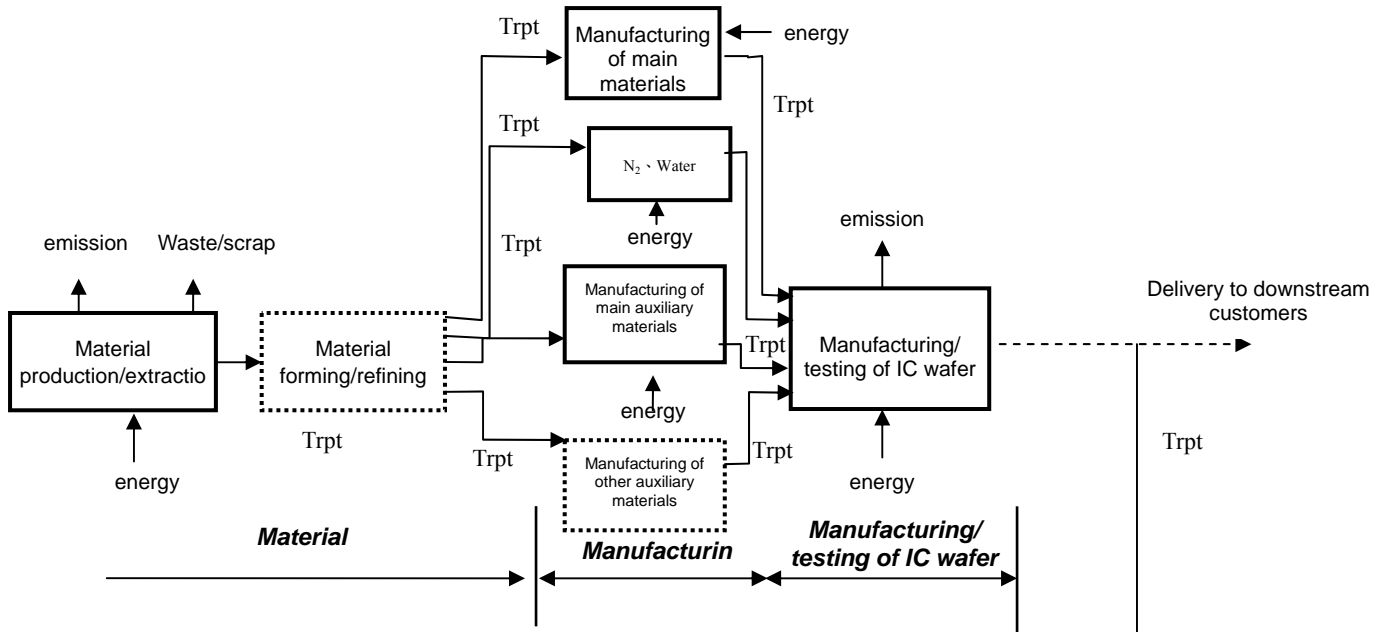
#### **4. Functional unit**

The functional unit is defined as one unit or one package of IC, as the ICs are marketed and sold in such units. (For description of the weight and dimension of each IC, please refer to Section 2.3) .The functional unit for wafer is defined as per wafer (such as 150 mm (6-inch), 200 mm (8-inch) or 300 mm (12-inch) wafer) or per layer.

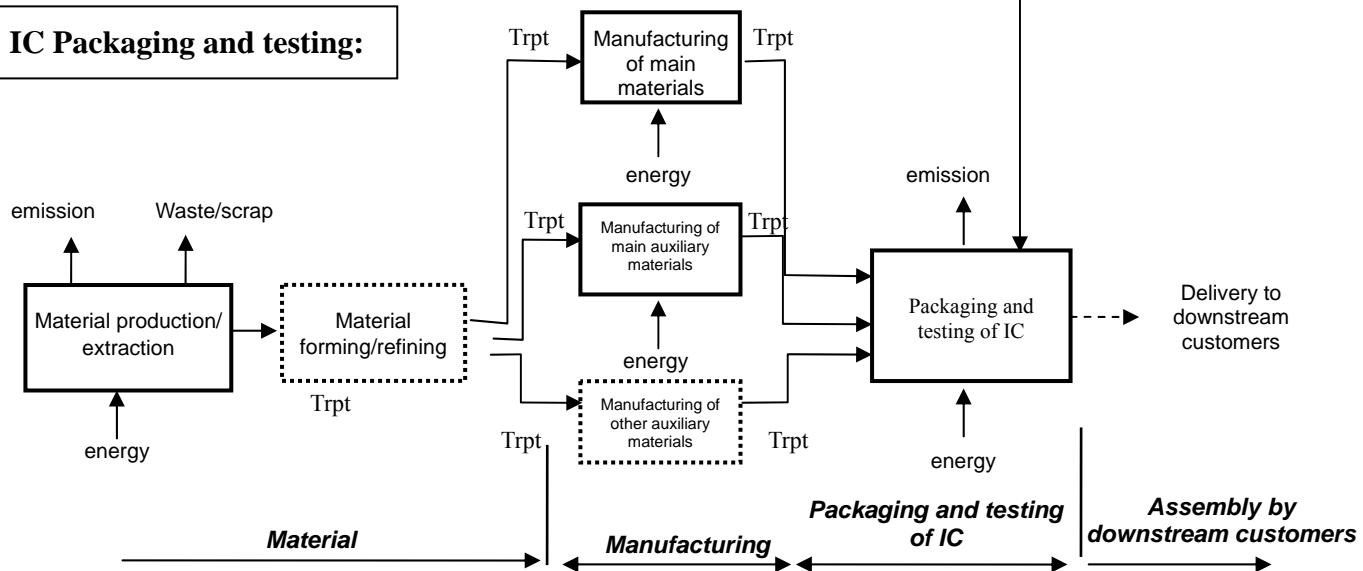
## 5. System boundaries

5.1 The system boundaries of the product system are presented as follows:

### Manufacturing and testing of wafer / IC:



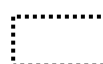
### IC Packaging and testing:



Trpt =transportation



Mandatory inclusion



Voluntary inclusion

Notes:

1. Main materials mean materials which will contain in the product;
2. Auxiliary materials are used in the manufacturing process but will not contain in the product;
3. Main auxiliary materials mean auxiliary materials which weigh more than 85% of all auxiliary materials used in the process;
4. Other auxiliary materials mean the remaining auxiliary materials which weigh less than 15% of all auxiliary materials used in the process;
5. The packaging materials are calculated based on actual consumption.

### **Figure 1 System boundary of the main product system**

As described in the Figure 1 above, the life cycle of an IC covers only the phases described in Figure 1. Provision of recycling information is of the voluntary declaration nature (see Section 11).

#### **Manufacturing Phase**

The LCA shall include information for the following unit processes:

- Material extraction and production for main materials and their raw materials
- Manufacturing of main auxiliary materials
- Manufacturing and assembly of product
- Transportation of materials and/or products.

The inclusion in the LCA the information on the material forming and refining and manufacturing of other auxiliary materials is of the voluntary reporting nature. When voluntarily reported information is included, they shall be explained in the EPD.

## **5.2 Specification of different boundary settings**

### **Boundary in time**

The validity period for the LCA results presented in the LCA report shall be defined.

### **Boundary towards nature**

If the manufacturing processes are located within Taiwan, the waste categories as defined in Taiwan's Waste Disposal Act shall be adopted. If the processes are located in the other countries, equivalent legal requirements shall be considered.

The natural boundary of the system shall describe the boundary where the materials and energy resources flow from nature into the system, and where the water and air emissions and waste are released out of the system.

Only the waste which is required to be disposed of needs to be considered; the landfilling process does not need to be included. If the waste will be treated through water treatment or incineration, these processes need to be included.

### **Boundaries in the life cycle**

The boundaries in the product life cycle are described in the Figure 1. The construction of the site and infrastructure, as well as the production of manufacturing equipment and activities of the workers, do not need to be included.

### **Boundaries towards other technical systems**

Boundaries towards other technical systems describe the inputs of material and other components towards other systems, as well as outputs of materials towards other systems. For the inputs of recycled materials and energy towards the product manufacturing phase, the transportation between the recycling process and use of recycled materials shall be included in the data set. For the production of recyclable products during the manufacturing phase, the transportation towards the recycling process shall be included.

*(Note: Further explanations are provided in Section 7 on open-loop recycling)*

### **Boundaries regarding geographical coverage**

The manufacturing phase may cover manufacturing processes located on any sites around the world. For processes located in a specific region, the data used should be representative of the region. The data for the main components shall be the specific regional data for the region where the process takes place (see Section 9). For ease of comparison, no matter where the emissions are generated, the same impact potential parameters should be used for life cycle impact assessment (see Section 10).

## **6. Cut-off rules**

For any impact category, if the sum of various impacts from a specific process/activity is less than 1% of the impact equivalent in that category, such a process/activity may be neglected during the inventory analysis. Parts and materials omitted from the LCA shall be documented.



(Note: This judgment for this “1% Rule” is based on the environment relevance assessment of material input to the system, and does not consider special and exceptional environmental impacts.)

## 7. Allocation rules

While selecting allocation rules, the following principles are recommended:

- Multi-output: The allocations are based on the changes in the resource consumption and pollutant emissions (for example, adopted quantity allocation for some main component, or surface allocation for some components), following the changes in the studied system’s output product or function or economical relationship.
- Multi-input: The allocation is based on actual relationship. For example, the manufacturing process’s emissions may be affected by the change in waste flow input.
- Open loop recycling: For the input of recycled materials or energy during the manufacturing phase of the product system, the transportation between the recycling process and the recycling to material use shall be included in the dataset. For the product which shall be recycled during the manufacturing phase, the transportation towards the recycling process shall be included.

*Notes:*

- *The main allocation rules shall be valid for the entire product system. For other secondary processes, other allocation rules may be defined; however, the use of these rules should be justified.*
- *Product-specific information should be preferentially collected in order to avoid the need for allocation.*
- *Allocation may be avoided through avoidance of dividing processes, for example as described in Section 6.3 of ISO/TR 14049; or through expansion of system boundary (for example as described in Section 6.4), so that the amended system shares the same product exchanges as the original system.*

## 8. Units

The following units shall be used:

SI units (Système International d'unités)

Preferentially used units:

- power units use kW or W;
- energy units use kWh or MJ;
  
- weight units use g, kg;
  
- volume units use mm<sup>3</sup>.

## **9. Calculation rules and data quality requirements**

- Site-specific data (for example, specific factory data or transportation data for a specific manufacturing process) shall be used for the production of main materials, main auxiliary materials, and IC wafer, as well as IC packaging and testing. If other types of data are used, the data and motives for using them shall be described.
- Generic data may be used in the IC manufacturing process materials. Generic data may also be used for the production of bulk materials (see Appendix I for sources of generic data). For example, when bulk materials are purchased in the spot market or while treating waste; or when suppliers refuse to provide specific data; or when the lack of specific data will not greatly affect the final outcome. The general rule is that if generic data are used in place of specific data, their combined contribution for all life cycle phases shall not greater than 10% of the total impact for any impact category. However, there may be exception for some specific products.
- The data shall be representative for the average of a specific year.

### Data quality requirements for the manufacturing phase

- Site-specific data shall be used for the production of main materials, main auxiliary materials, and IC wafer, as well as IC packaging and testing.
- The electricity mix for the manufacturing phase should be site-specific data. If site-specific data can not be obtained, the official electricity mix for the country where the site is located may be used as approximate value. The electricity mix should be documented.
- For the definition of hazardous waste, the definition as defined in Taiwan's Waste Disposal Act should be used for sites located in Taiwan. For sites located outside Taiwan, legal requirements for the host country shall be observed.

- For the transportation from the manufacturers, the transportation modes and distances from the suppliers shall be considered.

## **10. Parameters to be declared in the EPD**

For the manufacturing phase, the following parameters shall be declared:

### Resource Use

Use of non-renewable resources:

- without energy content, e.g., iron, aluminum
- with energy content, e.g., petroleum, coal

Use of renewable resources:

- without energy content, e.g., water, nitrogen
- with energy content, bio-ethanol, bio-diesel

Electricity consumption for the main assembly and assembly of main materials is considered optional declaration information, as energy for production of electricity are already listed under renewable and non-renewable resources.

### Impact equivalents expressed as potential environmental impacts

-Global warming	kg CO <sub>2</sub> equivalent
-Acidification	kg SO <sub>2</sub> equivalent
-Ozone depletion	kg CFC-11 equivalent
-Photochemical oxidant formation	kg C <sub>2</sub> H <sub>4</sub> equivalent
-Eutrophication	kg PO <sub>4</sub> equivalent
-Water	kg
-Energy	MJ

### Additional information

Recyclable materials (optional)

Information on secondary materials (optional)

Waste (classification):

- Hazardous waste as defined in Taiwan's Waste Disposal Act. Follow host countries' laws for sites outside Taiwan.
- Other waste.

*(Note: The declared waste includes both solid and semi-solid waste)*

## **11. Recycling information**

The recycling information shall include information such as which parts/components are suitable for recycling or not suitable for recycling.

Information for the parts which can not be recycled and therefore should be disposed of properly during the end-of-life phase may also be included.

## **12. Other environmental information (Optional)**

The EPD may cover information including technology adopted, site of product manufacturing and assembly, as well as information on other working environment, health and risk-related aspects. The declaration may also include information which the manufacturers possess and customers are interested in (such as on risk related issues), proper handling of products during usage and maintenance, reduction of environment impacts during product use, and environmental information systems (such as eco-labeling) products are in conformance.

The declaration shall include most commonly seen emission information. The odor information shall also be included, as customers may request them while purchasing.

### 13. Information about the certification

The information on PCR review, EPD verification and verification organization shall be included.

EPD Certification is valid until 2011-6-26

According to the Requirements for the international EPD system. General Programme Instructions, version 1 (2008) – [www.environdec.com](http://www.environdec.com)

The PCR review for **Integrated Circuits** (PCR 2009 : 1.0) was administered by the Environment and Development Foundation and carried by an LCA expert panel chaired by Dr. Ning Yu ( [ningyu@edf.org.tw](mailto:ningyu@edf.org.tw) )

Independent verification of the declaration, according to ISO 14025 : 2006

Internal  External

Third party verifier : Environment and Development Foundation in Taiwan.

Accredited by :

Organization \_\_\_\_\_ Signature \_\_\_\_\_

Organization \_\_\_\_\_ Signature \_\_\_\_\_

Organization \_\_\_\_\_ Signature \_\_\_\_\_

Environmental declarations from different programmes may not be comparable.

## **14. References**

The EPD shall make reference to the following documents:

- EPD General Program Instructions, Version 1.0 (2008-02-29), The International EPD Cooperation, downloaded from <http://www.gednet.org>;
- Relevant PCR documents;
- The underlying LCA report.

When available, the following documents shall also be referenced:

- Other documents and recycling instructions which verify and complement the EPD.

## Appendix I – Generic Data Sources to Refer to

For processes located within Taiwan, the Taiwan generic data or the data published by the commercial, industrial and energy competent authorities of the Republic of China (ROC) government, may be used. However, for other regions (such as EU), if there are more relevant generic data available, these data should be used instead. When data from the following generic databases are used, the most current and updated data should be used:

<b>Material</b>	<b>Database</b>	<b>Published</b>
Steel	IISI (International Iron and Steel Institute)	1998
Copper	ICA (International Copper Association)	1998
Copper semi products	ICA (International Copper Association) + IME (Institut für Metallhüttenwesen und Elektrometallurgi, Aachen)	1998 1995
Electricity	ETH (Eidgenössische Technische Hochschule) Data combined with IEA (International Energy Agency) statistics 1998  DoITPro	1996
Aluminum	EAA (European Aluminum Association)	2000
Plastics (and some chemicals)	APME (Association of Plastics Manufacturers in Europe)  DoITPro	1993-1998
Electronic components	EIME (Environmental Information and Management Explorer) EcoBilan	1998-2000
Material (Data of Taiwan)	ITRI Doitpro Data	1992
Energy	Boustead model 5.0	2007

## **Appendix II – Reporting Format for the EPD**

This appendix provides guidance information for the titles of sections, types of data and required information to be reported in the mandatory reporting part of the EPD. As a generic reporting template, the following titles and sub-titles are recommended:

*(Refer to the PCR manual for the section numbering, the information in Italics are the recommended data/information for inclusion)*

### **Introductory part**

Each EPD should have an introduction part on the top part of the EPD which includes the following information:

- *EPD system logo (LOGOTYPE)*
- *Company/organization name*
- *Product name*
- *EPD registration number*

### **Description of the company/organization and product/service**

#### ***Company/Organization***

- *Description of company/organization*
- *Description of overall working environment, existing quality system and environmental management system*

#### ***Product and services (see Section 2)***

- *Product's main application*
- *Description of product specification, manufacturing process, manufacturing sites (if there are several sites)*
- *For product's environmental performance aspects, characteristics which may improve the usefulness of product*
- *Other types of relevant information, for example, special manufacturing processes with special advantages*

### **List of materials and chemical substances**

- *Content declaration (see Section 3)*

### **Presentation of the environmental performance**

- *Outline of the LCA methodology, for example, period of LCA, functional units, system boundaries (graphical presentation), cut-off and allocation rules, and*



*data sources.*

***Manufacturing phase*** (see Section 10)

***Use phase*** (see Section 10)

- *Geographical region for product delivery*
- *Transportation data*
- *End-of-life information*

### **Information about Company and Certification Organization**

***Recycling information*** (see Section 11)

***Other environmental information*** (see Section 12)

***Information regarding certification***

- *Names of certification and verification organizations*
- *Validity of certification certificates*
- *Compliance with legal and relevant requirements*

***References*** (see Section 14)

- *relevant PCR documents*
- *EPD Requirements, MSR 1999 : 2*
- *underlying LCA study*
- *other supporting documents for LCA information*
- *other relevant documents regarding company/organization's environmental activities*

### **Appendix III – Information on Terms Used**

Wafer: a carrier used in the manufacturing of ICs, often means single crystal silicon wafer.

Chip: a carrier for IC, obtained through cutting a wafer into multiple chips.

IC packaging: the manufacturing process in which the chips are packaged with organic chemicals, metals or ceramic materials into IC components. IC packaging may serve to protect the chips as well as connecting the chips with external components or systems.

Core function: the core components for each IC products, such as die, GaAs etc.

Adhesive: the material which binds the components together, such as epoxy or epoxy film.

Carrier substrate: the carrier which redistributes the chip circuits, enlarges the external contact points, and provides structural strength (such as substrate (organic/ceramic), lead-frame (Cu/Fe), tape, etc.).

Electrical connection: provides the electrical connection between components and between product and external system (such as metal wire (Au/Al/Cu), solder bump, solder ball, Cu pillar, Au stud etc.).

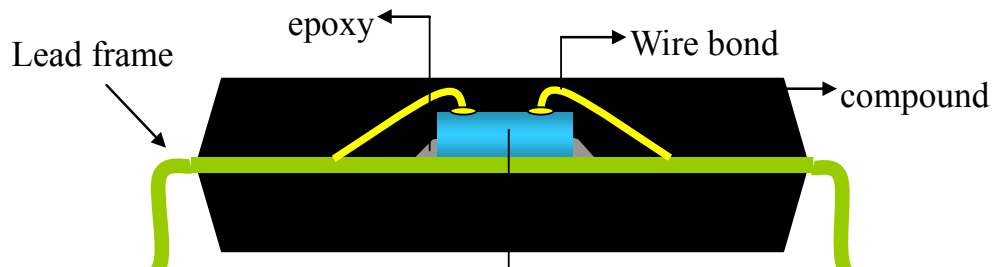
Encapsulant: provides product and components with protection against external environment such as humidity and outside contact (such as molding compound, liquid compound, underfill etc.).

Heat dissipation: provides effective means for product to dissipate the heat generated during IC working (such as heat sink/slug/spreader, TIM etc.).

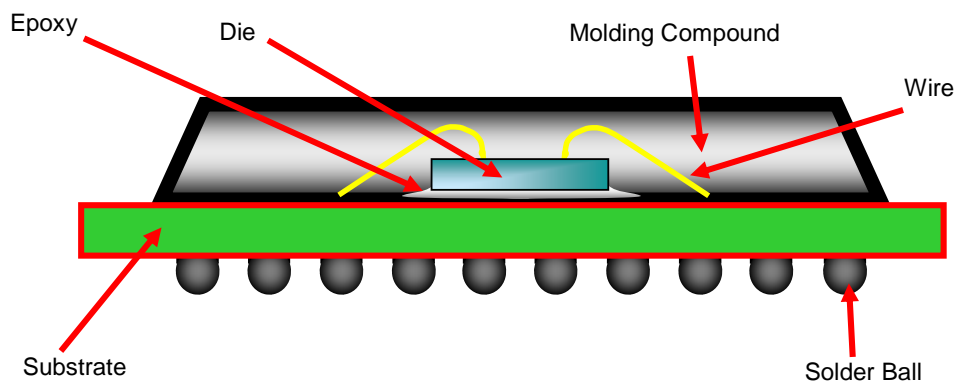
Packaging: protective packaging materials used to provide protection during product storage and shipping (such as tray, tube, carrier, box, packing material etc.).

Schematic Diagram

Typical Lead Frame Package :



Typical BGA Package :



Typical FCBGA Package :

