SEMITRACKS, INC.

ISSUE #184
November 2024

INFOTRACKS

YOUR MONTHLY LOOK INSIDE SEMICONDUCTOR TECHNOLOGY

Transfer Molding

By Christopher Henderson

In this month's Feature Article, we continue our series on Transfer Molding. Transfer Molding is one of the more common steps in semiconductor packaging, and provides protection for the sensitive semiconductor components and packaging interconnect. In this article, we will continue our discussion of the constituents of mold compounds.

Next, let's briefly discuss mold release agents. Epoxy resins typically have very good adhesive properties, which helps to minimize moisture permeation. However, this also means that these resins will adhere to the mold plates. A release agent is therefore needed to assist in the release of the cured package from the mold cavity. Only very small amounts are needed to help with the release process. Mold release agents typically have a temperature-dependent behavior, so one must identify a release agent that will function properly to at least 25ºC above the curing temperature of the mold compound. The materials used for release agents include hydrocarbons like carnuba wax, as well as silicones, metallic salts of organic acids, and fluorocarbons. Although carnuba waxes are still the most common, silicones are becoming more commonplace. Figure 1 shows a typical mold release agent from CAPLINQ.

WHAT'S INSIDE?

Want to take control of your learning? See page 6

Upcoming Courses:

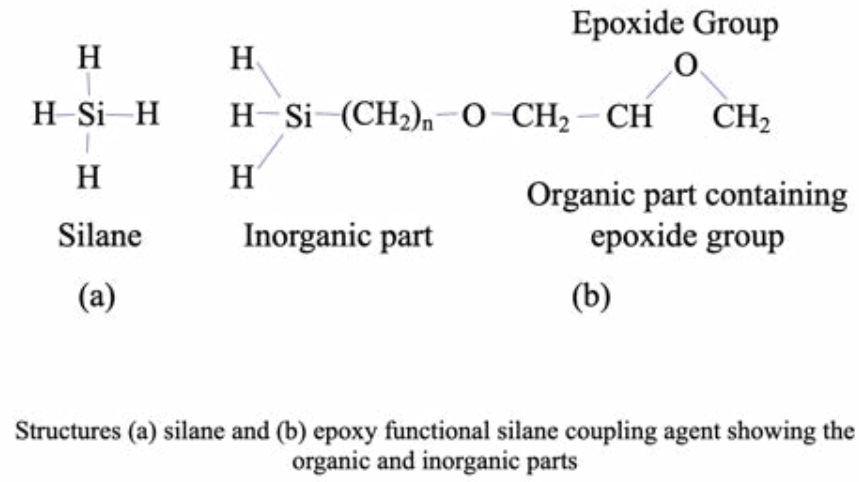
- Wafer Fab Processing
- Failure and Yield Analysis

See page 10 for more details

Figure 1- Mold release agent from CAPLINQ.

Next, let's briefly discuss coupling agents. Coupling agents increase the adhesion properties among the various components. While we don't want the epoxy resin to adhere to the mold cavity, we do want the epoxy resin to adhere to the silica particles, the die, the wirebonds, the die attach, and the leadframe. These agents also improve the processability of the encapsulating material by influencing releasability. They form links between the epoxy resin and the filler particles. For a coupling agent to accomplish this, it needs both organic and inorganic components in the same molecule. Some common additives that serve as coupling agents include: silanes, titanates, and aluminum chelates.

Figure 2 shows how a coupling agent works. We will use silane as an example. The silane molecule is shown on the left. This molecule can attach to the epoxide group by deprotonating, or losing a hydrogen atom, and connecting to a CH2, or methylene group that is part of the epoxide molecule.



Structures (a) silane and (b) epoxy functional silane coupling agent showing the organic and inorganic parts

Figure 2- Diagram showing the first part of coupling agent reaction process.

Once the coupling agent is bonded to the organic epoxy resin molecule, the coupling agent can further deprotonate, leaving just the silicon atom to connect with the silicon dioxide filler particles, like we show in Figure 3.

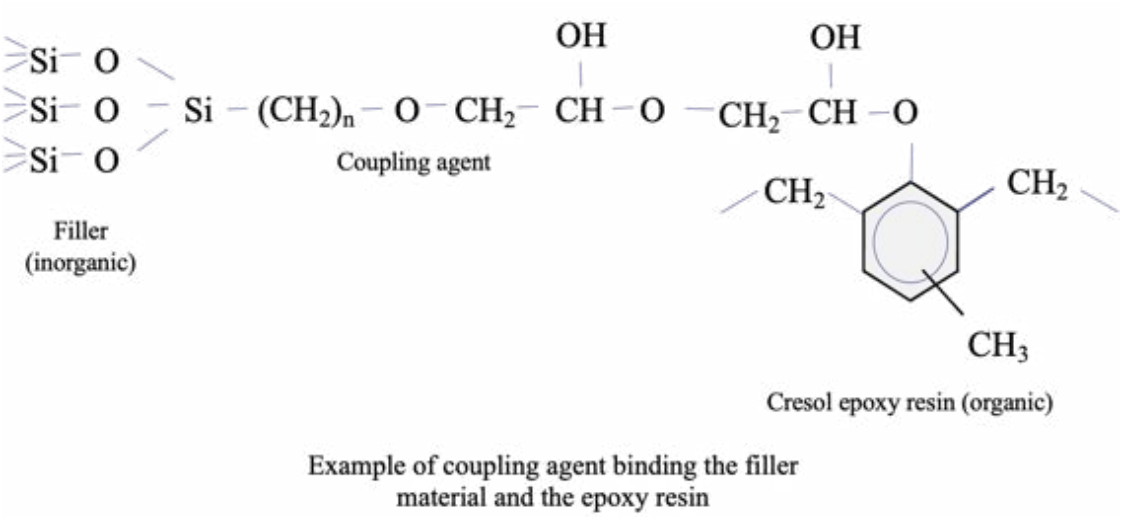


Figure 3- Diagram showing the second part of the coupling agent reaction process.

Finally, let's briefly discuss flame retardant agents. Flame retardants were first introduced into semiconductor packages in the 1960s following several instances of house fires due to television sets containing new electronic systems that used semiconductor chips. Packaged chips can generate significant amounts of heat, or can inadvertently short, creating the opportunity for fire to erupt. The epoxy resin itself has no inherent flame-retardant capabilities, and will sustain the fire, once started. Therefore, the semiconductor industry uses flame retardants to help meet safety requirements imposed after the 1960s fire debacles. The first fire retardant agents to be used were halogenated bisphenols. These are epoxy resins that include either bromine or chlorine. The bromine-loaded, or "brominated", novolacs provide better thermal stability, so those became the most popular. However, today, poly-brominated biphenyls and poly-brominated diphenyl ethers are on the Removal of Hazardous Substances, or RoHS list. Furthermore, bromine ions can cause corrosion of metallic components. Today, the alternatives include alumina trihydrate (ATH), zinc borate, and ammonium polyphosphate (APP). We show the chemical structure of ATH and APP in Figure 4.

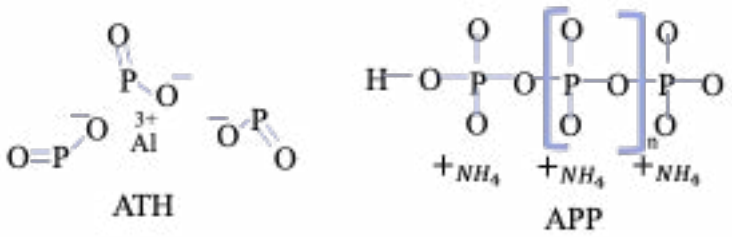


Figure 4- Chemical structure of ATH (left), and APP (right).

A flame retardant works by releasing bromine and other compounds from the epoxy resin once it reaches the combustion temperature. The bromine by itself, or bromine coupled with antimony oxide, generates gasses that quench radical formation in flames that sustain combustion.

A final constituent of mold compounds is the coloring agent. Without a coloring agent, the epoxy resin would give the mold compound a pale, yellow color. By coloring the mold compound a dark gray color, we now have a consistent appearance in the mold compound, which provides good contrast for symbolization or marking of components. The darker color also reduces the impact of light on the circuitry inside of the chip, and helps to prevent visibility of the die surface from the outside. Sometimes, companies will use different coloring agents to distinguish among different devices. Coloring agents are typically on the order of one half of a percent by weight in the mold compound. A common colorant is carbon black. It is produced from the incomplete combustion of hydrocarbons. The concentration is kept low to reduce electrical conductivity, moisture absorption and impurity problems. Brightly colored agents can also be used, although they are not common. These are typically made from thermally stable organic dyes.

Figure 5 shows the different crystallographic arrangement of atoms in different forms of carbon. Carbon black, shown on the right, is the most common coloring agent used in mold compounds. It has a sheet-like format, or flake-like format. As a black colorant, carbon black is useful since it has high light shielding properties and conductivity for preventing static electricity. Carbon black has an average particle size of 10 to 100 nm, a specific surface area of 50 to 500 m^2/gm, a pH value of 6.5 to 8.5, and the carbon black is close to 0% of the total epoxy resin composition.

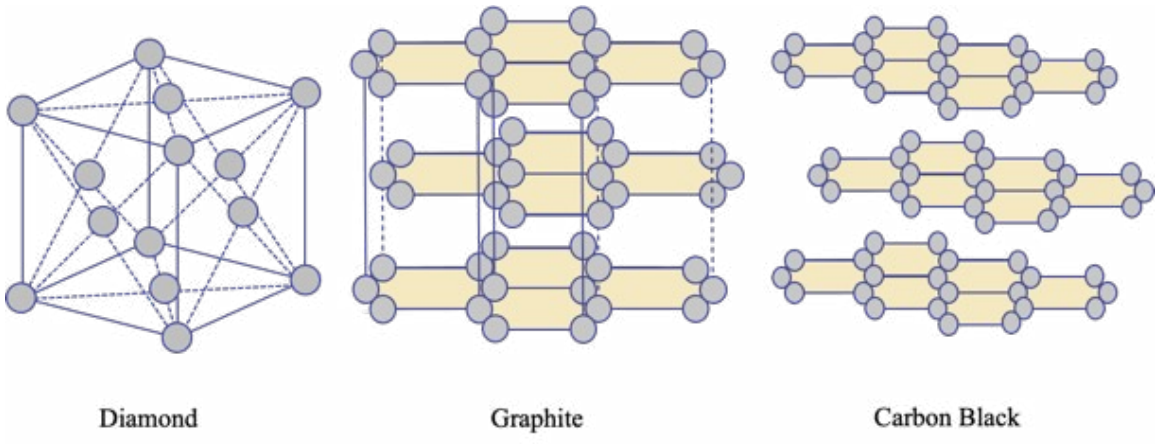


Figure 5- Atomic structure of diamond (left), graphite (center), and carbon black (right).

This concludes our discussion of the mold compound constituents. In next month's Feature Article, we will discuss transfer molding characteristics in more detail.

Technical Tidbit: Ishikawa (Fishbone) Diagrams

This month's Technical Tidbit briefly highlights Ishikawa diagrams. Ishikawa diagrams were first proposed by Kaoru Ishikawa in the 1960s, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management. Ishikawa is the Japanese word for fishbone, so that is why these diagrams are often referred to as fishbone diagrams. The main axis has spines and sub-spines, which correspond to causes. Causes in the diagram are often based around a certain category or set of causes, such as the 6 M's, 8 P's or 4 S's (described below). Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behavior. Causes in a typical diagram are normally arranged into categories, called the 6 M's. The 6 M's are Machine, Method, Materials, Maintenance, Man and Mother Nature (or Environment). Ishikawa recommended these for the manufacturing industry. However, a more modern selection of categories used in manufacturing includes: Equipment, Process, People, Materials, Environment, and Management. Other categories can also be used. For example, there is the 8 P's categorization, where the categories include: Physical evidence, Personnel, Place, Product (service), Price, Promotion, Process, and Productivity/quality. Another example is the 4 S's categorization, where the categories include: Systems, Surroundings, Skills, and Suppliers. Figure 1 shows an example of an Ishikawa diagram. This Ishikawa diagram shows factors that affect electromigration. This particular Ishikawa diagram uses different names for the main spines than the traditional names. There is no particular requirement that they follow the three conventions (6 M's, 8 P's, or 4 S's) mentioned above.

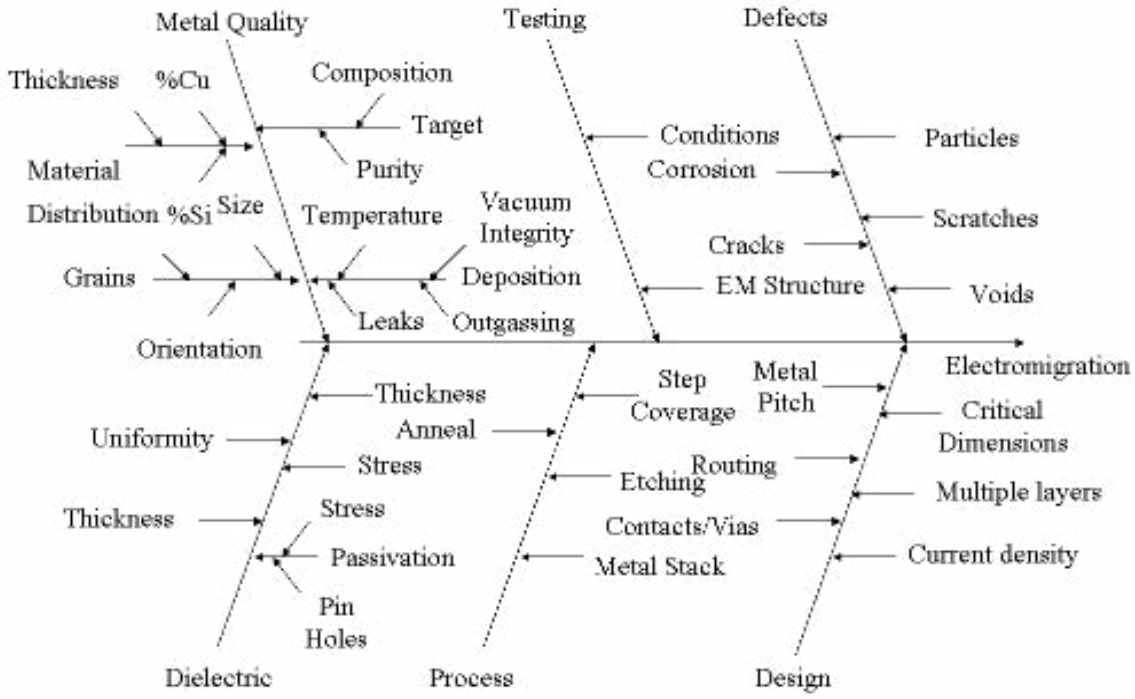


Figure 1- Example of an Ishikawa diagram showing factors that affect electromigration (courtesy Rao).

Ask The Experts

Q: I have a question about killer defects. Which levels in the fab process are more prone to killer defects?

A: This is a complex question, and depends on the fabrication process to a great extent. However, there are some rules of thumb to help answer this question. Generally, levels in the process that produce very thin dielectric layers, like the gate dielectric, will be more susceptible to killer defects. Also generally, levels in the patterning steps that involve minimum feature sizes or spacings will be more susceptible to killer defects. Some examples of this would include: contacts, vias on lower levels, and spacings between lower-level interconnects, such as local interconnect (metal-0), or local interconnect to gate metallization (tungsten or polysilicon, depending on the process).

Course Spotlight: FAILURE AND YIELD ANALYSIS

OVERVIEW

Failure and Yield Analysis is an increasingly difficult and complex process. Today, engineers are required to locate defects on complex integrated circuits. In many ways, this is akin to locating a needle in a haystack, where the needles get smaller and the haystack gets bigger every year. Engineers are required to understand a variety of disciplines in order to effectively perform failure analysis. This requires knowledge of subjects like: design, testing, technology, processing, materials science, chemistry, and even optics! Failed devices and low yields can lead to customer returns and idle manufacturing lines that can cost a company millions of dollars a day. Your industry needs competent analysts to help solve these problems. ***Failure and Yield Analysis*** is a 4-day course that offers detailed instruction on a variety of effective tools, as well as the overall process flow for locating and characterizing the defect responsible for the failure. This course is designed for every manager, engineer, and technician working in the semiconductor field, using semiconductor components or supplying tools to the industry.

By focusing on a ***Do It Right the First Time*** approach to the analysis, participants will learn the appropriate methodology to successfully locate defects, characterize them, and determine the root cause of failure.

Participants will learn to develop the skills to determine what tools and techniques should be applied, and when they should be applied. This skill-building series is divided into three segments:

1. **The Process of Failure and Yield Analysis.** Participants will learn to recognize correct philosophical principles that lead to a successful analysis. This includes concepts like destructive vs. non-destructive techniques, fast techniques vs. brute force techniques, and correct verification.

2. **The Tools and Techniques.** Participants will learn the strengths and weaknesses of a variety of tools used for analysis, including electrical testing techniques, package analysis tools, light emission, electron beam tools, optical beam tools, decapping and sample preparation, and surface science tools.

3. **Case Histories.** Participants will identify how to use their knowledge through the case histories. They will learn to identify key pieces of information that allow them to determine the possible cause of failure and how to proceed.

COURSE OBJECTIVES

1. This course will provide participants with an in-depth understanding of the tools, techniques and processes used in failure and yield analysis.

2. Participants will be able to determine how to proceed with a submitted request for analysis, ensuring that the analysis is done with the greatest probability of success.

3. This course will identify the advantages and disadvantages of a wide variety of tools and techniques that are used for failure and yield analysis.

4. This course will offer a wide variety of video demonstrations of analysis techniques, so the analyst can get an understanding of the types of results they might expect to see with their equipment.

5. Participants will be able to identify basic technology features on semiconductor devices.

6. Participants will be able to identify a variety of different failure mechanisms and how they manifest themselves.

7. Participants will be able to identify appropriate tools to purchase when starting or expanding a laboratory.

COURSE OUTLINE

DAY 1

1. Introduction

2. Failure Analysis Principles/Procedures
    a. Philosophy of Failure Analysis
    b. Flowcharts

3. Gathering Information

4. Package Level Testing
    a. Optical Microscopy
    b. Acoustic Microscopy
    c. X-Ray Radiography
    d. Hermetic Seal Testing
    e. Residual Gas Analysis

5. Electrical Testing
    a. Basics of Circuit Operation
    b. Curve Tracer/Parameter Analyzer Operation
    c. Quiescent Power Supply Current
    d. Parametric Tests (Input Leakage, Output voltage levels, Output current levels, etc.)
    e. Timing Tests (Propagation Delay, Rise/Fall Times, etc.)
    f. Automatic Test Equipment
    g. Basics of Digital Circuit Troubleshooting
    h. Basics of Analog Circuit Troubleshooting

DAY 2

6. Decapsulation/Backside Sample Preparation
    a. Mechanical Delidding Techniques
    b. Chemical Delidding Techniques
    c. Backside Sample Preparation Techniques

7. Die Inspection
    a. Optical Microscopy
    b. Scanning Electron Microscopy

8. Photon Emission Microscopy
    a. Mechanisms for Photon Emission
    b. Instrumentation
    c. Frontside
    d. Backside
    e. Interpretation

9. Electron Beam Tools
    a. Voltage Contrast
        i. Passive Voltage Contrast
        ii. Static Voltage Contrast
        iii. Capacitive Coupled Voltage Contrast
        iv. Introduction to Electron Beam Probing
    b. Electron Beam Induced Current
    c. Resistive Contrast Imaging
    d. Charge-Induced Voltage Alteration

DAY 3

10. Optical Beam Tools
    a. Optical Beam Induced Current
    b. Light-Induced Voltage Alteration
    c. Thermally-Induced Voltage Alteration
    d. Seebeck Effect Imaging
    e. Electro-optical Probing

11. Thermal Detection Techniques
    a. Infrared Thermal Imaging
    b. Liquid Crystal Hot Spot Detection
    c. Fluorescent Microthermal Imaging

12. Chemical Unlayering
    a. Wet Chemical Etching
    b. Reactive Ion Etching
    c. Parallel Polishing

DAY 4

13. Analytical Techniques
    a. TEM
    b. SIMS
    c. Auger
    d. ESCA/XPS

14. Focused Ion Beam Technology
    a. Physics of Operation
    b. Instrumentation
    c. Examples
    d. Gas-Assisted Etching
    e. Insulator Deposition
    f. Electrical Circuit Effects

15. Case Histories

Upcoming Courses:

Public Course Schedule:

Wafer Fab Processing - November 25-28, 2024 (Mon.-Thurs.) | Munich, Germany - $2,095 until Mon. Nov. 4

Failure and Yield Analysis - December 2-5, 2024 (Mon.-Thurs.) | Munich, Germany - $2,095 until Mon. Nov. 11

Semiconductor Reliability and Product Qualification - December 9-12, 2024 (Mon.-Thurs.) | Munich, Germany - $2,095 until Mon. Nov. 18

Semiconductor Technology Overview - February 3-4, 2025 (Mon.-Tues.) | Phoenix, Arizona - $1,195 until Mon. Jan. 13

Product Qualification Overview - February 5, 2025 (Wed.) | Phoenix, Arizona - $595 until Wed. Jan. 15

IC Packaging Technology - February 10-11, 2025 (Mon.-Tues.) | Phoenix, Arizona - $1,195 until Mon. Jan. 20

Advanced CMOS/FinFET Fabrication - February 19-20, 2025 (Wed.-Thurs.) | Phoenix, Arizona - $1,195 until Wed. Jan. 29

Failure and Yield Analysis - March 3-6, 2025 (Mon.-Thurs.) | Phoenix, AZ - $2,095 until Mon. Feb. 10

Have an idea for a course? If you have a suggestion or a comment regarding our courses, online training, discussion forums, or reference materials, or if you wish to suggest a new course or location, please email us at info@semitracks.com

To submit questions to the Q&A section, inquire about an article, or suggest a topic you would like to see covered, please contact Jeremy Henderson at jeremy.henderson@semitracks.com

We are always looking for ways to enhance our courses and educational materials and look forward to hearing from you!