Research On Thermal Management Technology of System-Level Electronic Integrated Package

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Abstract. With the rapid development of modern electronic products, electronic products present a development trend of increasing packaging density, miniaturization and diversification of the environment. System-in-package (SiP) with the advantages of large-scale, multi-chip, and 3D three-dimensional packaging has attracted more and more attention. Due to the high-density interconnection between the components of the system-in-package circuit, the power density of the package is greatly increased, which will inevitably lead to an increase in the heat generation rate, so the research on its heat dissipation characteristics is particularly important. Introduced the theories and concepts of thermal management and heat transfer, expounded the general method of chip thermal management, took the plastic package SiP module as the research object, introduced the device-level junction-case thermal resistance and board-level junction-board thermal resistance analysis methods, introduction The heat dissipation technology of thermal conductive glue. It provides a reference for SIP package heat dissipation technology.

Keywords: Thermal Management, Heat Dissipation, Electronic Integrated Packaging.

1. Introduction
With the integration of electronic equipment, higher requirements are put forward for the volume and quality of sub-systems and modules. Lightweight, miniaturization, and systemization are the future development trends of the whole machine. In the field of microwave technology, MMIC, RFIC, LTCC, MEMS and other technologies are the main body, supplemented by some chip discrete components, and high-density MCM technology is adopted for system-in-chip (SOC) and system-in-package (SIP). MEMS, digital circuits, medium video IC, radio frequency and microwave circuits are integrated in a small circuit unit to form a micro system to realize the microwave front-end frequency conversion and digital processing functions. SIP (system in package), or system-level packaging, refers to the various types of components that are loaded in a packaging system through different technical means, so that it has the function of a system [1]. Figure 1 is a picture of the SIP chip.
The main problem that affects the failure of electronic devices is the thermal problem. The failure rate of electronic devices increases exponentially with the increase of operating temperature. In the electronics industry, for every 10°C increase in the ambient temperature of a device, its failure rate tends to increase by an order of magnitude. This is the so-called "10°C rule." With the continuous update of power devices and the continuous improvement of power, many cooling technologies such as forced air cooling, forced liquid cooling, evaporative cooling, etc. have emerged, and these technologies have been widely used. Thermal technology of electronic equipment is a technology used to solve the problem of excessively high working temperature of electronic equipment and improve the reliability of electronic products. It is divided into three major technologies: thermal analysis, thermal design and thermal testing [2]. The research on thermal management and heat dissipation technology of SIP integrated packaging is getting more and more attention. Figure 2 is the growth chart of chip thermal density this year.

2. Package Thermal Management

2.1. Thermal Management Overview
Thermal management is the ability to control the temperature and noise of the system through technologies based on thermodynamics and heat transfer. Electronic packaging thermal management is to use appropriate and effective structural design optimization and cooling technology for the heat-consuming components of electronic equipment and the whole machine or system to control its temperature changes to ensure the reliability of the electronic equipment or system [31].
The heat sources in electronic packaging mainly include two parts: The first is caused by the flow of current inside the package. Electric energy can be converted into heat. Various devices, such as resistors, capacitors, polysilicon, and some high-power devices will generate heat after being energized. The second is the heat generated by the friction of the movable components inside the package. If this heat is not removed by effective measures, the heat will continue to accumulate, causing the temperature of the package to continue to rise, which will affect the normal operation of the electronic device, or even make it invalid. Figure 3 is a graph of the relationship between chip failure rate and temperature.

![Figure 3. The curve of relationship between chip failure rate and temperature](image)

2.2. Heat transfer theory
Thermal energy is related to the temperature of a substance. For objects with a certain material and quality, the higher the temperature, the greater the thermal energy. Heat transfer is the study of the heat exchanged between objects when there is a temperature difference between two objects. When two objects are at different temperatures, the heat energy is transferred from the higher temperature object to the lower temperature object, and the heat is always transferred from the hot to the cold direction.

There are three ways of heat conduction: heat conduction, heat convection and heat radiation [33]. Any energy exchange between objects occurs through one of these methods or a combination of them. Heat conduction is the transfer of heat through the inside of objects or surfaces that are in contact with each other. Thermal convection is the use of fluid movement to transfer heat. Thermal radiation does not require a medium to transfer heat. In this way, the electromagnetic radiation emitted by the object is used to exchange heat.

2.3. Thermal management solutions
The latest heat management technology revolves around the basic heat transfer methods (i.e. conduction, convection and radiation), and the development of technology is transforming from single-phase heat transfer to multi-phase heat transfer. Cooling technologies such as hot steam chambers, cold plates, and jet impingement have changed the future of thermal management. The heat dissipation method of electronic packaging in the thermal management industry includes passive

- The heat sink box actively dissipates heat.
- Passive cooling
  - Use low thermal resistance materials; use of thermal through holes.
- Active cooling
Conduction cooling; air cooling through natural convection and radiation; air through forced convection Cooling; liquid cooling; immersion cooling; advanced cooling technologies including cryogenic, refrigerant, hybrid, microchannel, spray and cold plate cooling; some thermal conditions require a mixture of cooling technologies.

3. Thermal resistance analysis
As an important parameter to measure the heat dissipation capacity of a packaged module, thermal resistance analysis is the basis of thermal reliability research. The heat dissipation characteristics of the package are generally measured by the concept of thermal resistance. Thermal resistance represents the temperature rise of the medium on the heat transfer path after the medium absorbs 1 W of heat. The unit is K/W or °C/W. In chip applications, each chip has a maximum allowable junction temperature, so junction temperature estimation is very important. In the case of multiple chips heating at the same time, the junction temperature of the chip can be analyzed by the principle of superposition, that is, the temperature rise of the chip is equal to the superimposed effect of the temperature rise caused by its own heating power and the temperature rise caused by other chips heating it [3]. Taking the existing plastic package SiP module as the research object, the finite element simulation method is used to calculate the junction-case thermal resistance matrix and the junction-board thermal resistance matrix.

![Figure 4. Junction-to-case and Junction-to-board Thermal Resistance Model](image)

4. Thermal conductive glue
In order to reduce the contact thermal resistance and improve the heat dissipation capacity, it is necessary to use a suitable thermal conductivity material to reduce the total thermal conductivity. Commonly used thermally conductive media usually include thermally conductive glue, thermal grease, thermally conductive gaskets, phase change materials, thermally conductive gels, and thermally conductive tapes. The research of various thermal conductive adhesive materials is in continuous progress. Literature [4] introduced an epoxy resin composite insulating thermal conductive adhesive that achieved good thermal conductivity.

5. Conclusion
This article introduces and studies the heat dissipation and thermal management technology of system-in-package. The development of SIP technology and the importance of heat dissipation are introduced, and the concepts and solutions of thermal management and heat transfer are explained. It focuses on the thermal resistance analysis method and the application of thermal conductive glue. It provides an introduction and reference for the thermal design and heat dissipation improvement of the SIP system chip.
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