THERMAL ANALYSIS AND OPTIMIZATION OF THERMAL PAD THICKNESS FOR TRANSISTOR MOUNTING IN FOR CPU’S

S. Balakrishnan*, M. Manikandan

Department of Mechanical Engineering, Nandha Engineering College, Erode, Tamilnadu

*Corresponding Author

Received: 03/11/2015, Revised: 02/01/2016 and Accepted: 10/03/2016

Abstract

When electronic components like FET (Field effective transistors) are employed, 50% of their power is lost by means of heat. This heat in turn reduces the life of the device. To prevent it, these devices are attached to heat sinks. But even a small gap in microns between the heat sink and the device will create an air gap, and the device fails. So, thermal interface materials are used in junctions. One such thermal interface material is thermal pad, which is made up of silicon (trade name: Sil-Pads).

The challenge in optimizing thermal pad because of the thickness selection to withstand a specific amount of pressure generated from the torque driver applied for fixing the transistor over the heat exchange. The optimized and most effective thermal pads and their thickness will be identified and analyzed in this project.

Reviewed by ICETSET’16 organizing committee

1. Introduction

Today’s electronics are smaller and more powerful than ever, leading to ever increasing thermal challenges for the systems designer. While fans, heat sinks, and even liquid cooling and thermoelectric devices can be used to provide enough cooling power, the problem remains to get the heat from the hot components into the cooling hardware.

Thermal Interface Materials (TIMs) are designed to fill in air gaps and microscopic irregularities, resulting in dramatically lower thermal resistance and thus better cooling is obtained. In industries the optimization and selection of correct thermal pad is still a challenging task, as identifying this will result in greater cost advantage and also reduces the possibility of failure.

Basically the challenge in optimized thermal pad lies in the thickness selection to withstand a specific amount of cut out force generated from the screw torque applied to the screw used for fixing the electronic component with the heat sink, where the thermal pads are sandwiched in between. In this project the above said problem will be analyzed.
2. Thermal Pads (Silicon Pads)

2.1 Sil-Pad material

Sil-Pad Thermally Conductive Insulators are designed to be clean, grease-free and flexible. The combination of a tough carrier material such as fiberglass and silicone rubber which is conformable provides the engineer with a more versatile material than mica or ceramics and grease. Sil-Pads minimize the thermal resistance from the case of a power semiconductor to the heat sink.

2.2 Why thermal pads are used?

Sil-Pads electrically isolate the semiconductor from the heat sink and have sufficient dielectric strength to withstand high voltage. They are also tough enough to resist puncture by the facing metal surface. With more than 30 different Sil-Pad materials available there is a Sil-Pad matched to almost any application.

2.3 Thermal pad construction

Sil-Pads are constructed with a variety of different materials including fiberglass, silicone rubber, polyimide film, polyester film and fillers used to enhance performance. Sil-Pads are typically constructed with an elastomeric binder compounded with a thermally conductive filler coated on a carrier.

The characteristics of your application often determine which Sil-Pad construction will produce the best performance. Sil-Pads are typically constructed with an elastomeric binder compounded with a thermally conductive filler coated on a carrier.

3. THE CARRIER

The carrier provides physical reinforcement and contributes to dielectric strength. High dielectric and physical strength is obtained by using a heavy, tight mesh, but thermal resistance will suffer. A light, open mesh reduces thermal resistance, dielectric strength and cut-through resistance. The carrier materials used in Sil-Pad materials include fiberglass, dielectric film and polyester film which is used in Poly-Pad® materials.

3.1 Fillers

The thermal conductivity of Sil-Pad products is improved by filling them with ingredients of high thermal conductivity. The fillers change the characteristics of the silicone rubber to enhance thermal and/or physical characteristics.

3.2 Binders

Most Sil-Pad products use silicone rubber as the binder. Silicone rubber has a low dielectric constant, high dielectric strength, good chemical resistance and high thermal stability.

3.3 Thermal Pad mechanical property

Woven fiberglass and films are used in Sil-Pads to provide mechanical reinforcement. The most important mechanical property in Sil-Pad applications is resistance to cut-through to avoid electrical shorting from the device to the heat sink.

Cut-through resistance is very dependent on the application and depends on several factors:
A very sharp burr may cause cut-through with less than 100 pounds while a blunt burr may require several hundred pounds to cause cut-through when two flat parallel surfaces are brought together on a Sil-Pad, over 1000 pounds of force can be applied without damaging the insulator.

3.4 Thermal pad electrical property

The most important electrical property in a typical assembly where a Sil-Pad insulator is used is dielectric strength. In many cases the dielectric strength of a Sil-Pad will be the determining factor in the design of the apparatus in which it is to be used.

Dielectric breakdown voltage is the total voltage that a dielectric material can withstand. When insulating electrical components from each other and ground, it is desirable to use an insulator with a high breakdown voltage.

3.5 Thermal pad thermal property

Thermal Resistance is defined as the temperature drop from the packaged chip to its primary heat sink per watt of power dissipated in the package. The primary heat sink may be the ambient air, the PWB itself, or a heat sink that is mounted on the package. Thermal resistance is denoted by the symbol $\Theta_{Jx}$ (or Theta-Jx) where ‘x’ denotes the external reference point where the temperature is measured.

- qJA is junction-to-ambient air thermal resistance
- qJC is junction-to-case thermal resistance
- qJP is junction-to-pad thermal resistance
- qJB is junction-to-board thermal resistance

Gap Pad is a thermally conductive material that acts as a thermal interface between a heat sink and an electronic device. The conformable nature of Gap Pad allows the pad to fill-in air gaps between PC boards and heat sinks or a metal chassis.

Gap Pad is available in a variety of styles with various levels of softness and in thicknesses ranging from 0.020” to 0.200”

3.6 Typical properties of any thermal pad
3.7 Silicon pad Usage Recommendations

Silicone-based gap fillers typically can withstand continuous use at temperatures from –60°C to 200°C for extended periods of time. In specific applications, however, it can be wise to study the performance and behaviour of the materials at both the low and high end of the temperature spectrum to ensure suitability for the conditions.

Two-part materials must be mixed in a 1-to-1 ratio by volume. As an aid to mixing, without requiring complicated measuring equipment, disposable plastic static mixing nozzles are available. These nozzles can be attached to the ends of cartridges or mounted on automated dispensing equipment and automatically mix the two parts together at the desired ratio.

Bergquist recommends purging newly tapped containers through the static mixer until a uniform colour is achieved. This will ensure a proper 1-to-1 mix ratio. Unless otherwise indicated, mixing nozzles with a minimum of 21 mixing elements are recommended to achieve proper mixing. To ensure consistent material characteristics and performance, Bergquist two-part systems always should be used with matching lot numbers for both parts.

Thermal resistance measurement

Thermal Resistance

TSP Method (temperature sensitive parameter)
Meets military specifications

Use forward voltage drop of calibrated diode to measure change in \( T_j \) due to known power dissipation

**Thermal resistance calculation**

Recall formula for junction temperature:

\[
T_j = (P_D \times q_{JA}) + T_A
\]

Rearranging equation, thermal resistance calculated by:

\[
q_{JA} = \frac{DT_j}{P_D} = \frac{T_j - T_A}{P_D}
\]

where \( T_j \) is junction temp, \( T_A \) is ambient temp and \( P_D \) is power dissipation

TSP diode calibrated in constant temperature oil bath, measured to ±0.1°C

Calibration current low to minimise self-heating

Normally performed at 25°C and 75°C

**Temperature coefficient for calculation**

Temperature coefficient known as K-factor

Calculated using

\[
K = \frac{T_2 - T_1}{V_{F2} - V_{F1}}\]

at constant \( I_F \) where:

\[
K = \text{Temperature coefficient (°C/mV)}
\]

\( T_{1,2} = \text{lower and higher test temperatures (°C)} \)

\( V_{F1,2} = \text{Forward voltage at } I_F \text{ and } T_{1,2} \)

\( I_F = \text{Constant forward voltage measurement current} \)

Heat conduction in copper-clad PCB dominated by in-plane transfer

Trace layers have only a small contribution to total conduction

FR4 is a good insulator.
Thermal pad Design

Fig 5: 3D view of the new proposed design

4. Thermal Analysis

Steps – coupled field analysis and optimization

Ansys Workbench

Thermal Analysis

Geometry

Material: Silicon Pad
Density: 2.1 g/cc
Thermal conductivity: 1.5 W/m-K
Young's modulus : 45 Psi

Mesh

Type : Fine Mesh

Thermal Load and Boundary condition

Ambient temperature : 22degc

Heat Flow : 5W
Temperature Distribution

Fig. 6. Images of Single LED bulb with different existing heat sinks

Structural Analysis – Boundary condition and Loading

Imported Body Temperature
Result of Static Analysis

Equivalent Stress

![Equivalent Stress Diagram]

References

2. CERN, Rough calculation of the temperatures of the electronic components of the digital mezzanine for LTDB, by considering that the space between boards is filled with "gap-pad" Bergquist or other thermal conductive material.
4. Roger Stout, Thermal Considerations for a 4x4 mm QFN.