nanoCOPS: Analytical Approach for Estimating the Heating of Bond-wires.

Abstract

An analytic model to estimate the heating of bond-wires within a package is described. The formula involves the essential parameters that define a package. This work has been carried out within the FP7 nanoCOPS project.

Introduction

Bond-wires are commonly used to connect the chip and the pins during device assembling. These wires are heated up due to Joule effects and their temperature. Fig. 1 shows a diagram of a classic IC lead-frame package.

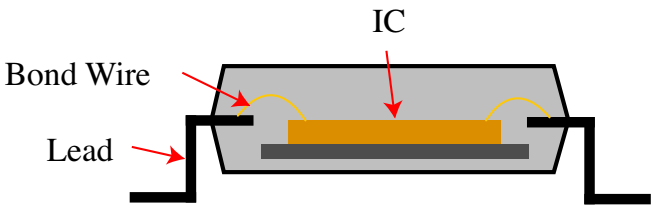

Figure 1: *Classic IC lead-frame package.*

Since wire melting is a potential source of failure in IC devices, one would like to estimate, in a expedient manner, the current amplitude and duration that could cause such a failure. Ideally, the sought formula should involve the most important physical parameters that define the package. In this letter, we briefly describe an analytic bond-wire heating model, offspring of a collaboration between TU-Darmstadt and ON Semiconductor within nanoCOPS, that extends the one in [2].

Analytic Bond-Wire Heating Model

Fig. 2 depicts the simplified thermal problem upon which the model is built.

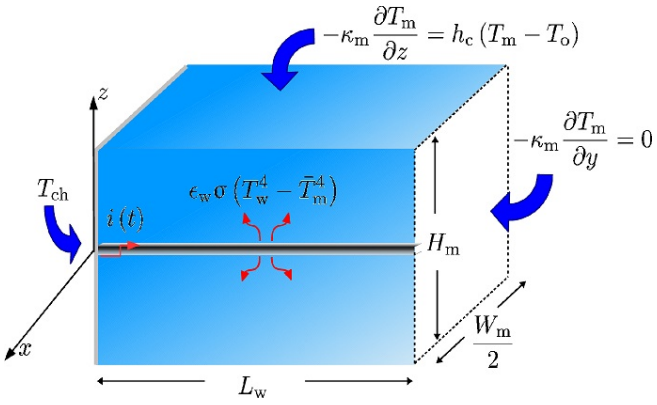

Figure 2: *Bond-wire heat transfer problem.*

The rectangular shape of the package compound is retained and suitable boundary conditions (BCs) are used;

1. adiabatic on the rightmost wall except on the wire portion. This facilitates the inclusion of the lead into the model;
2. iso-thermal on the leftmost and bottom walls amounting to the chip and die-attach temperatures;
3. convective on lateral and upper walls;
4. thermal radiation on the wire surface.

The temperature dependence of the wire thermal and electrical conductivities is also included. The heat equation is solved by means of an *ad-hoc* linearisation which involves the compound heat equation and its heat kernel [1], viz.

$$T_w(y,t) \cong T_o + \frac{\sqrt{2\alpha_\kappa \tilde{\theta}_w(y,t) + 1}}{\alpha_\kappa} - \frac{1}{\alpha_\kappa}. \qquad (1)$$

Above, T_w is the wire temperature, T_o is the reference (ambient) temperature, α_κ is the temperature coefficient of the wire thermal conductivity, and $\tilde{\theta}_w$ is an auxiliary variable.

Numerical Results

Several numerical tests for wires of Gold, Copper, and Aluminium have been performed with data provided by ON Semiconductor. Numerical verification has been carried out with CST Multiphysics Studio™, and a good agreement has been corroborated.

Fig. 3 shows the estimated current capacity (temperature vs current amplitude) for a gold wire after 50 ms.

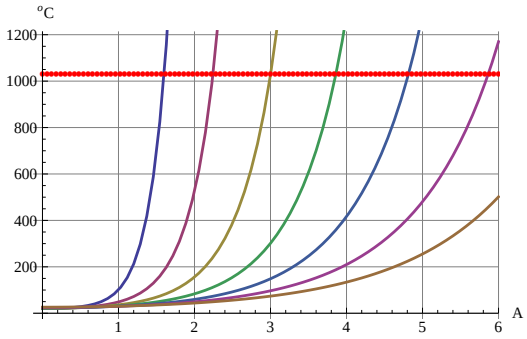

Figure 3: Au-*wire current capacities for diameters* $D_w = \{0.8, 1.0, \ldots, 1.8, 2.0\}$ *mil and* $L_w = 2.5$ mm. *The plotted temperature is at the wire mid-point, where the hottest point is expected.*

Conclusions and Further Actions

A transient and fully analytic model for the estimation of the heating of bond-wires within a package has been developed. The model resorts to simple mathematical functions, and retains the most important geometric and physical parameters of the package. The model readily permits to estimate

the wire melting current and the mould deterioration current. Currently, an *in-house* numerical implementation is underway at TU Darmstadt, and a measurement setup is in preparation by Brno University of Technology and in collaboration with ON Semiconductor, to supply experimental data, which will permit to further enhance the capabilities of the model.

References

[1] D. Duque, S. Schöps, and A. Wieers. An extended analytical approach for the estimation of the heating of bondwires. In *18th European Conference on Mathematics for Industry (ECMI)*, Taormina, Sicily, Jun. 2014. European Cosortium for Mathematics in Industry.

[2] G.T. Nöbauer and H. Moser. Analytical approach to temperature evaluation in bonding wires and calculation of allowable current. *Advanced Packaging, IEEE Transactions on*, 23(3):426–435, Aug 2000.

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