Mapping of Temperature Dependent Heat Transfer Coefficient Values in Power Hybrid Electronic Circuits Cooled by Natural Convection

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EXTENDED ABSTRACT

Thermal analysis of electronic circuits is now an essential part the design process since thermal issues are the major cause of failures. The temperature field is modeled by the Fourier heat equation. For its solution, problem geometry, material properties and boundary conditions have to be specified. Some of these quantities, such as the heat transfer coefficient, depend on temperature and the change of their values should be taken into account. Otherwise, obtained simulation results might bear significant errors. This problem is disused in detail here based on thermal simulation results carried out for a test structure.

The test structure analyzed in thermal simulations presented in this paper resembles a power module manufactured in the insulated metal substrate hybrid technology. This structure has the dimensions of 10 cm x 10 cm x 1.5 mm and its base is made of the 1.5 mm thick aluminum plate covered by a 100 µm resin layer. It contains a single, centrally located, square heat source of variable size. The power dissipated in the source is taken into account in the circuit thermal model by a heat flux flowing through the structure top surface and the heat transfer to the ambient is modelled by the heat exchange coefficient having variable value dependent on temperature.

The heat transfer coefficient value represents two different physical phenomena participating in circuit cooling: radiation and convection. Since both cooling mechanisms mostly occur simultaneously, they are usually represented in thermal models by a single value of the total heat transfer coefficient h_t, which is the sum of the radiation heat transfer coefficient h_r and the convection heat transfer coefficient h_c. The values of the total heat transfer coefficient and its components determined based on the assumed model for two different ambient temperature values of are plotted in Fig. 1. These results prove that in the temperature range close to the ambient temperature the value of heat transfer coefficient varies rapidly due to the appearance of convection.

The temperature rise values were computed assuming the power dissipation of 20 W in the heat source occupying from 1% to 100% of circuit area. The resulting minimal, maximal and mean temperature rise values are shown in Fig. 2. As can be seen, when the source dimensions decrease, its temperature grows whereas the minimal circuit temperature decreases, but at the same time the mean temperature rise value is virtually insensitive to the heat source size.

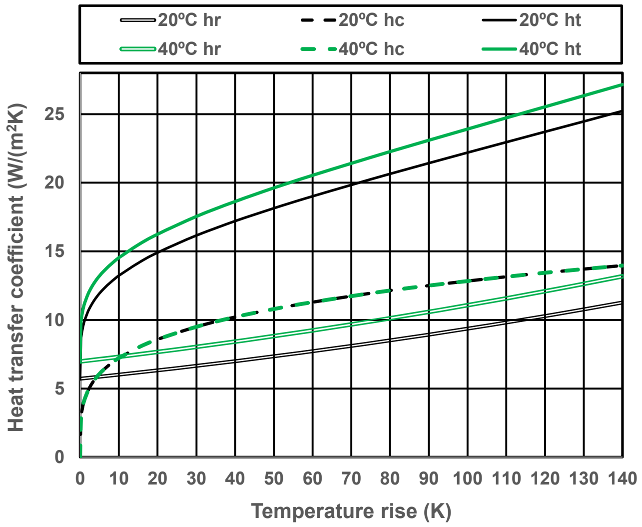

Fig. 1. Modeled heat transfer coefficient values for the ambient temperature equal to 20 °C and 40 °C.

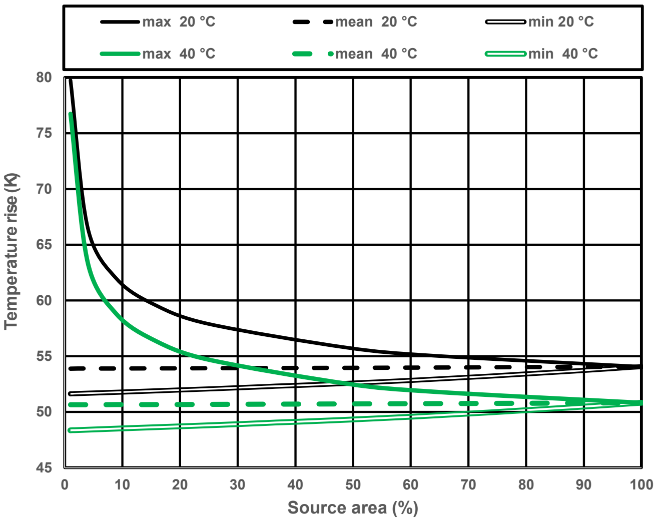

Fig. 2. Simulated maximal, mean and minimal temperature rise values for the ambient temperature equal to 20 °C and 40 °C.