Proceedings of the 7th World Congress on Mechanical, Chemical, and Material Engineering (MCM'21)
~~Prague, Czech Republic~~ Virtual Conference – August, 2021
Paper No. ICMIE 130
DOI: 10.11159/icmie21.130

Study of Temperature Fields and Heat Exchange Surfaces of Semiconductor Component.

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Abstract **–** This article focuses on methods of cooling and dissipating thermal energy from electrical components installed in electric vehicles, control centres, information technology, space projects and others. The aim is to research the heat dissipation and the formation of temperature fields of a semiconductor power component installed in closed or tight spaces. The method of cooling the components is based on the method of heat transfer and the cooling technology used. For the design of cooling, it is necessary to know the location and position of the examined component, as well as the possibility of heat dissipation. This introductory part of the heat transfer theory defines the already known methods of heat transfer, on the basis of which the design of the cooling capacity is defined.

Keywords**:** Heat transfer, conduction, convection, radiation, cooling, thermal imaging.

1. Introduction

Heat is generated when current flows through a resistor in an electrical circuit. A semiconductor device can be considered as a type of resistor that generates heat when a current passes in proportion to the ON resistance (internal resistance when current flows through the current).

Heat can adversely affect the semiconductor device itself as well as the electronic system that uses the device. In particular, it can seriously compromise security, performance, and reliability.

Excessive heat caused by poor heat dissipation design can result in smoke or ignition, as well as degraded equipment performance, such as slowing its operating speed and, in the worst case, damage or malfunction. Although the worst case scenario can be avoided, reliability is adversely affected by equipment failure and shorter system life.

To prevent this adverse effect, thermal design is necessary for semiconductor packaging.

2. Ways of Heat Transfer

The theory of energy transfer forms the basis of calculations in the construction, design and operation of thermal equipment. It is a necessary prerequisite for a qualified solution to the tasks of optimizing heat and cold consumption in all thermal engineering equipment.

Heat is propagated by conduction, flow, radiation and the transfer of matter (moisture). These forms of transmission vary considerably, so they are governed by different laws.

According to kinetic theory, heat is the total kinetic energy of the disordered motion of the particles of which a substance is composed. The conversion of mechanical work into heat is explained by kinetic theory as the conversion of the energy of ordered motion into the kinetic energy of disordered motion of particles.

Heat flows from a warmer body to a colder one. In fact, energy flows, which is converted into a disordered movement of the molecules of the substance (in the case of gases) or increases the oscillation of atoms in the crystal lattice (in the case of solids) - thus increasing (or decreasing) its temperature. Heat is thus a measure of the energy that a warmer body transfers to a colder body during heat exchange. When the body receives energy in the form of heat, its internal energy rises [1].

All transitions from one state (evaporation, solidification, melting, condensation, evaporation, sublimation and desublimation) to another are associated with a change in internal energy. During the working cycle of the heat pipe, the liquid state of the working substance changes to gaseous in the evaporator by the action of heat. By flowing the gaseous state through the condensing part, precipitation occurs on the walls of the condenser, the gaseous state of the working substance changes to liquid.

2.1. Heat Transfer by Conduction

Heat transfer by conduction is carried out by molecular energy transfer between substances or their particles that come into contact and have different temperatures; free electrons are involved in metal bodies. It depends quantitatively on the physical and geometric shapes and dimensions of the heat-conducting substances and on the temperature difference between their parts (or surfaces) [2].

The simplest case of heat conduction is a rod with a constant cross-section S and a length L, the ends of which have temperatures T_1 and T_2. Heat of magnitude is then transferred between these two ends in time t:

$$\Delta Q = \frac{\lambda.S.(T2 - T1)}{L}\Delta t \quad (1)$$

Where λ is thermal conductivity, ΔQ heat transfer by conduction (W / m^2). The thermal conductivity values for different substances vary greatly. Metals usually have high thermal conductivity (for example copper 390 $Wm^{-1}K^{-1}$, aluminum 240 $Wm^{-1}K^{-1}$, platinum 70 $Wm^{-1}K^{-1}$, steel 40 $Wm^{-1}K^{-1}$).

2.2. Heat Transfer by Convection

Heat transfer by convection takes place only in liquids (liquids and gases) by the effect of displacement and mixing of their unevenly heated particles, the more intense the higher the speed of movement. Because fluid particles with different temperatures come into contact with it, it is then accompanied by heat conduction.

Simultaneous heat transfer through conduction and conduction involves convective heat transfer; it can be natural or forced. Natural (free) convection occurs when a fluid is agitated by the effect of a difference in the density of its particles, e.g. due to the difference in their temperature (when it is heated or cooled). Forced convection occurs when the motion is induced artificially (eg by a fan, pump, etc.) [3].

2.3. Heat Transfer by Natural Convection

Natural convection is a motion that results from the differences between the interaction of gravity and density within a fluid. These differences may result from a gradient in temperature, concentration, or fluid composition. This chapter deals with the heat transfer associated with natural convection excited by a temperature gradient in a Newtonian fluid.

The heat transfer from each of the expanded surfaces (ribbing) shown in Fig. 1 has been analysed so far. Predicting heat transfer requires a solution for complex three-dimensional motion, for which there are several analyses. Experimental data were obtained using air only.

In many practical applications, where there is a significant drop in temperature between the base of the ribs and their apex, natural convection, heat flux and heat transfer are affected. Very little information is available on the connection between the conductivity of the ribbing and the fluid flow, and so our attention is limited to isothermal ribbing. Since the first approximation, the heat transfer coefficient for isothermal ribbing can be used for the case where the ribbing is not isothermal because there is a weak dependence on the temperature difference [4].

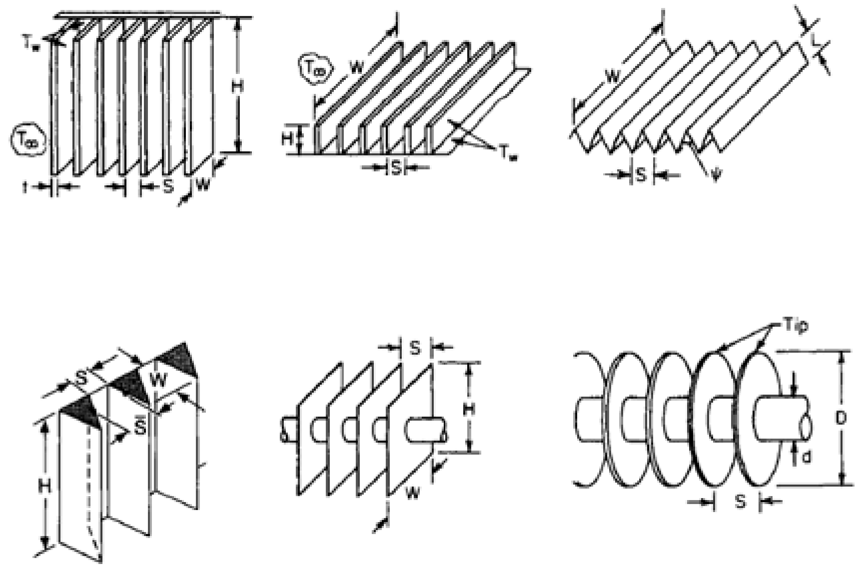

Fig. 1: Type of ribbing of heat exchange surfaces.

2.4. Heat Transfer By Radiation

Thermal radiation is the process by which the internal energy of bodies is propagated to the environment through the emission of thermal radiation from its surface (solid bodies) or from its volume (gaseous bodies). When thermal radiation hits other bodies, it can be absorbed and converted into the internal energy of these bodies (increase in their temperature).

Radiation is the result of changes in the microstructure of bodies, in its electron, resp. ionic composition and, accordingly, electromagnetic waves are generated by which this energy propagates [5]. E.g. the oscillation of ions corresponds to low wave frequencies, but changes in the electron composition are high. The radiation has both a wave and a corpuscular character. The relationship between wave and corpuscular radiation is given by Planck, according to which bodies radiate or absorb energy only in certain quantities, the energy of which is proportional to the frequency of the waves:

$$Q = h.v = h\frac{c}{\lambda} \tag{2}$$

Where h = 6,626.10-34 (Js) is the Planck constant, v - frequency (1 / s), λ - wavelength (m), c = 2,999.108 (m / s), speed of light in vacuum, Q - heat transmitted by radiation (J).

3. Aim of Experiment

The aim of a simple experiment was to measure an electric semiconductor power component that is used in active electric vehicle systems, information technology control centres, space projects. During the measurement of the component tax at different supplied electrical power, the thermal changes of the component surface and the temperature fields were monitored. The measurement was performed using thermal imaging equipment.

From the individual images (Fig. 2. – Fig. 6.) taken with the help of thermovision, it can be stated that with a short power load of the semiconductor component, temperature fields were formed on the component in which heat transfer took place by conduction. At higher power loads (Fig. 3. – Fig. 6.), it is possible to observe heat transfer from the component to the non-flammable insulating pad.

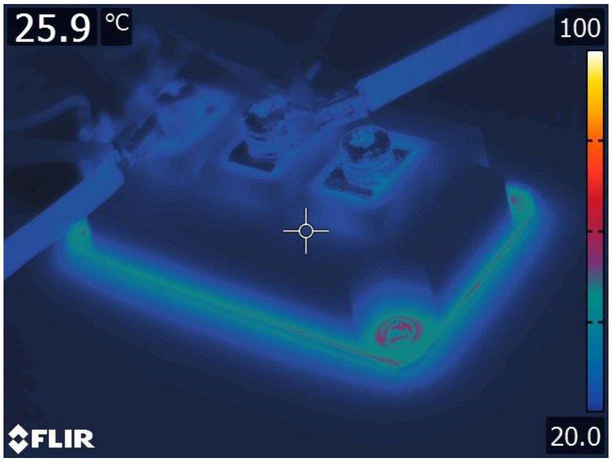

Fig. 2: Thermal analysis at the initiation of transistors in a semiconductor device.

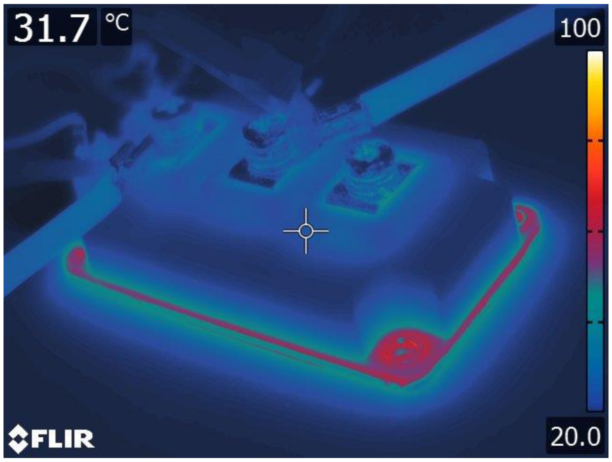

Fig. 3: Thermal analysis of a semiconductor component at an electrical power of 20W.

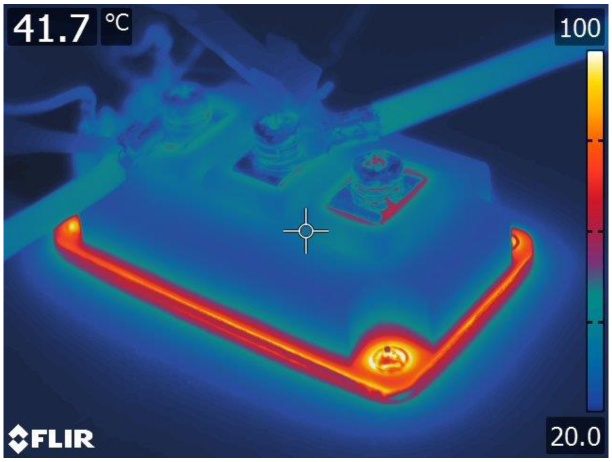

Fig. 4: Thermal analysis of a semiconductor component at an electrical power of 35W.

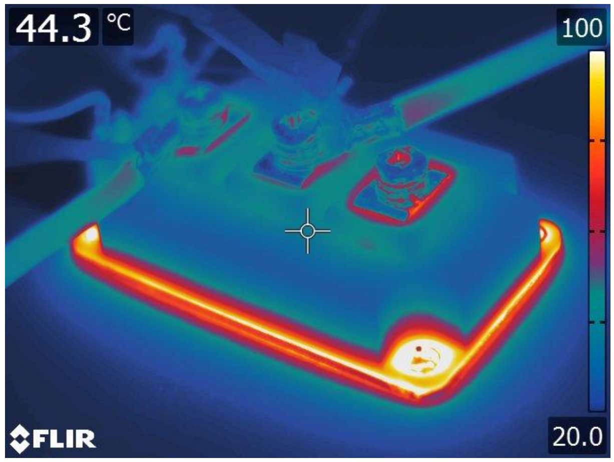

Fig. 5: Thermal analysis of a semiconductor component at an electrical power of 70W.

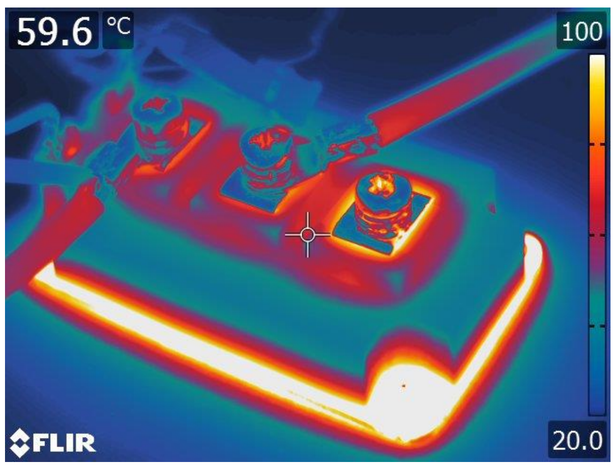

Fig. 6: Thermal analysis of a semiconductor component at an electrical power of 80W.

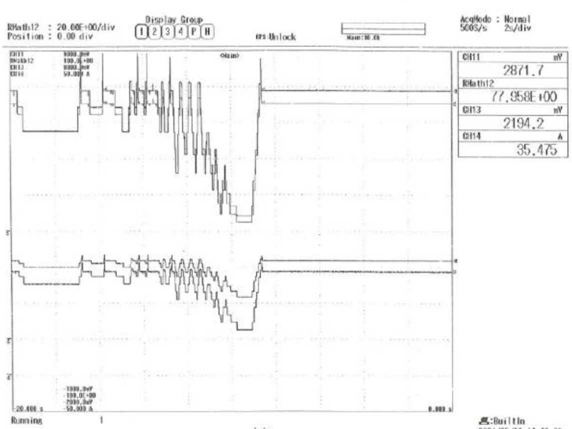

Fig. 7: Recording diagram of the behaviour of a semiconductor component at stabilization of electrical power.

In Figure 7 it is possible to see the steady power consumption by means of a semiconductor component. Due to the high heat production, it is possible to state the low working efficiency of the device.

4. Conclusion

During the measurement of the semiconductor component, the temperature fields arising during the operating cycle the power component were detected by means of a thermal imaging system. Based on the measurement, more detailed analyzes of the heat exchange surfaces of the component will be performed, which will show us the efficient heat transfer and a suitable topic for the design of the cooling system.

Acknowledgements

"This publication was realized with support of Operational Program Integrated Infrastructure 2014 - 2020 of the project: Innovative Solutions for Propulsion, Power and Safety Components of Transport Vehicles, code ITMS 313011V334, co-financed by the European Regional Development Fund" and this work was supported by Grant System of University of Zilina No. 8021. 1/2020.

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