New design of the base (heat dissipation board) in the form of a trapezoidal prism for the power rectifier module, which allows to increase the average forward current.

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To increase the average forward current of a power module without changing its dimensions, it is necessary to: use materials with reduced thermal resistance in the module design; increase the semiconductor chip area to reduce the heat flux density [1]. Using semiconductor chips with a larger area increases the rate of heat transfer, since the density of rate of heat flow depends on the area. But the increase in chip area is limited by the module base area (heat dissipation board). For example, an initial 3D model of a power diode module without a housing was built (Fig.1.1). The heat dissipation board of the module is in the shape of a rectangular parallelepiped.

Fig.1.2

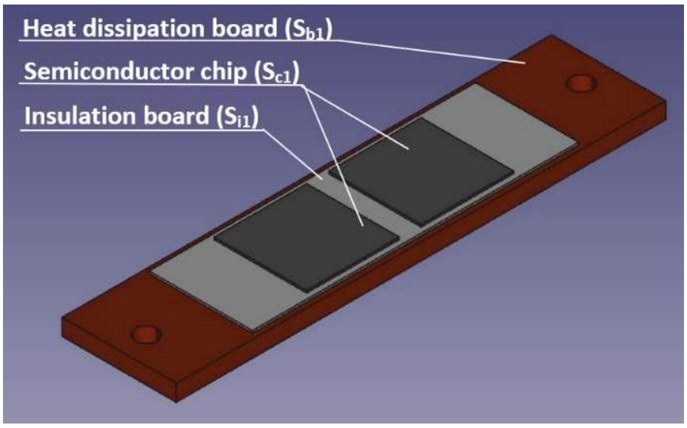

Fig.1.2

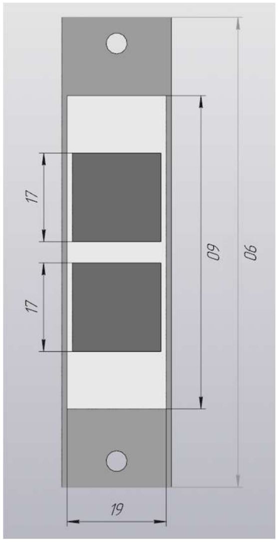

Fig.1.3

Data of the original model (Fig.1.2, Fig.1.3): heat dissipation board height h_{b1} = 3mm, heat dissipation board area S_{b1} = 1890mm^2, insulation board h_{i1} = 0.4mm, insulation board area S_{i1} = 1140mm^2, semiconductor chip height h_{c1} = 0.4mm, semiconductor chip area S_{c1} = 289mm^2. The electrical and thermal indicators necessary for comparison are taken by analogy from the MDD95-16N1B IXYS Corporation module [2]: case temperature T_C = 100°C, junction temperature T_J = 150°C, average forward current $I_{FAV(1)}$ = 120A, power dissipation (per diode) $P_{T(1)}$ (DC) = 120W.

On Fig.2.1 and Fig.2.2 show the temperature distribution of the original model, satisfying the electrophysical and thermal indicators.

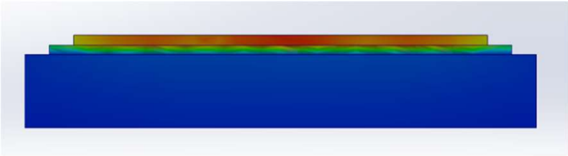

Fig.2.1

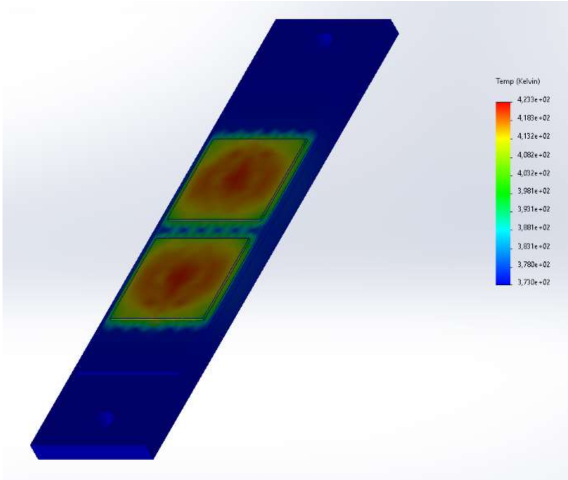

Fig.2.2

The new design of the heat dissipation board (Fig.3.1) allows semiconductor chips to be placed in a larger area, than the original module base allows. The new trapezoidal prism-shaped heat dissipation board increases the area on which semiconductor chips, without increasing the external area of the module. The materials, type of connection of parts, thickness of the chip and insulator in the module of the new model do not change. Thus, the new heat dissipation board allows the use of larger semiconductor chips, which allows the average forward current of the module to be increased.

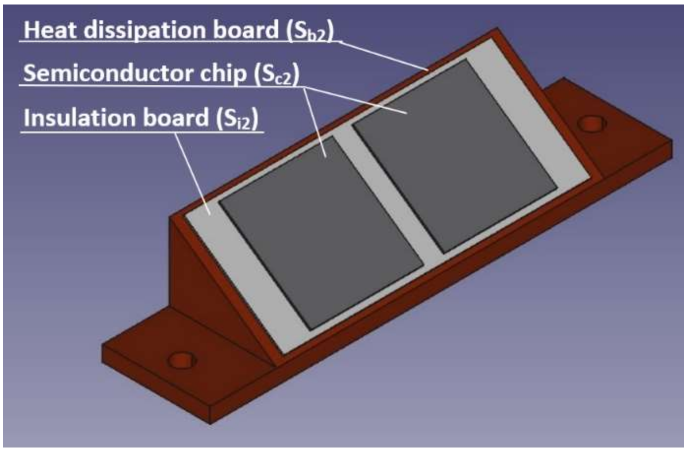

Fig.3.1

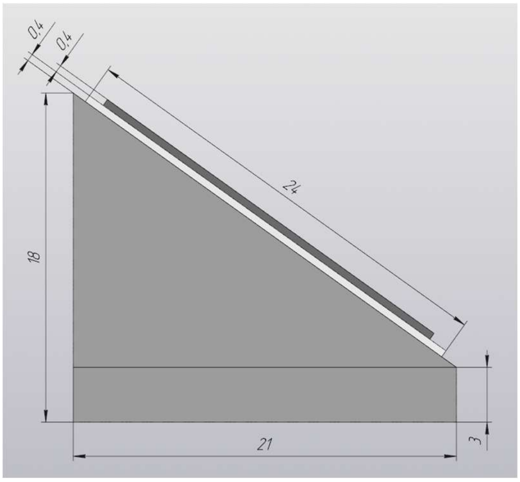

Fig.3.2

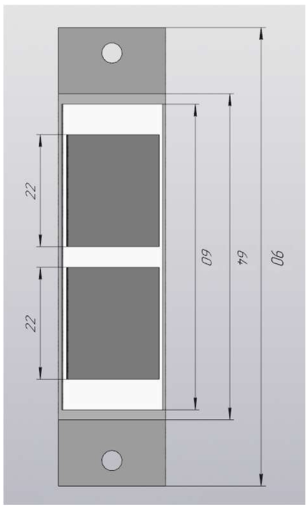

Fig.3.3

Data of the new model (Fig.3.2, Fig. 3.3): heat dissipation board angle α = 35º, minimum heat dissipation board height $h_{b(min)2}$ = 3mm, maximum heat dissipation board height $h_{b(max)2}$ = 18mm, insulation board height h_{i2} = 0.4mm, insulation board area S_{i2} = 1440mm2, semiconductor chip height h_{i2} = 0.4mm, semiconductor chip area S_{c2} = 484 mm2, T_C = 100°C, T_J = 150°C.

The heat flux density in a plane parallel to the external base of the module for the new model q_2 is approximately equal to the heat flux density for the original model q_1, for temperature conditions: T_C = 100°C, T_J = 150°C.

Calculation of heat flow without taking into account dissipation:

$$q_1 = q_2 \tag{1}$$

$$q_1 = \frac{P_{T\,(1)}}{S_{c1}} \tag{2}$$

$$q_2 = \frac{P_{T\,(2)}}{S_{c2}\cos\alpha} \tag{3}$$

$$P_{T\,(2)} = \frac{P_{T\,(1)} \cdot S_{c2}\cos\alpha}{S_{c1}} \tag{4}$$

The calculated value according to formula 4 of the power dissipation (per diode) for the new trapezoidal heat dissipation board of the power rectifier module has increased by 37% and is $P_{T(2)}$ (DC) = 164.6W.

On Fig.4.1 and Fig.4.2 show the temperature distribution of the new model, satisfying the electrophysical and thermal indicators, with the same R_{thch} = 0.2K/W (thermal resistance case to heatsink) [2]. According to 3D modeling of the new model, the power dissipation and average forward current increased by 25%: average forward current $I_{FAV(2)}$ = 150A, power dissipation (per diode) $P_{T(2)}$ (DC) =150W.

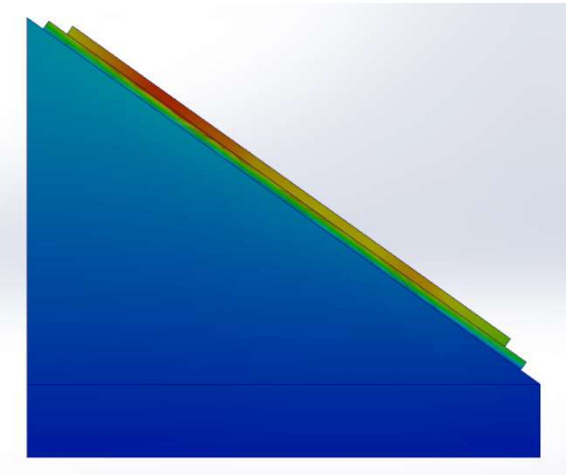

Fig.4.1

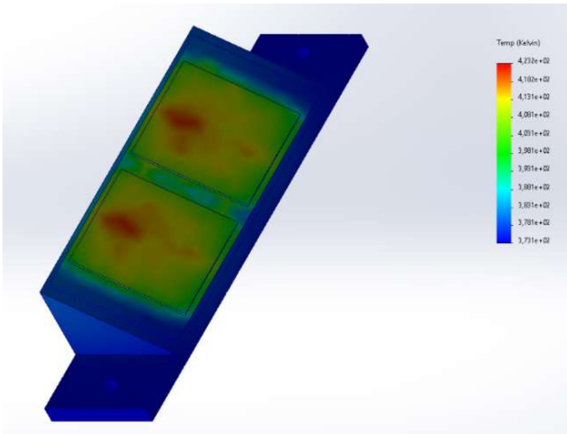

Fig.4.2

After truncating the top of the new heat dissipation board by angle 3º, and moving the insulation board with semiconductor chips to the upper edge of the base, a second new model of the module was built (Fig.5.1 and Fig.5.2). According to 3D modeling of the new model, the power dissipation and average forward current increased by 33%: average forward current $I_{FAV(3)}$ = 160A, power dissipation (per diode) $P_{T(3)}$ (DC) = 160W. In Fig.5.1 and Fig.5.2 show the temperature distribution of the new model, satisfying the electrophysical and thermal indicators.

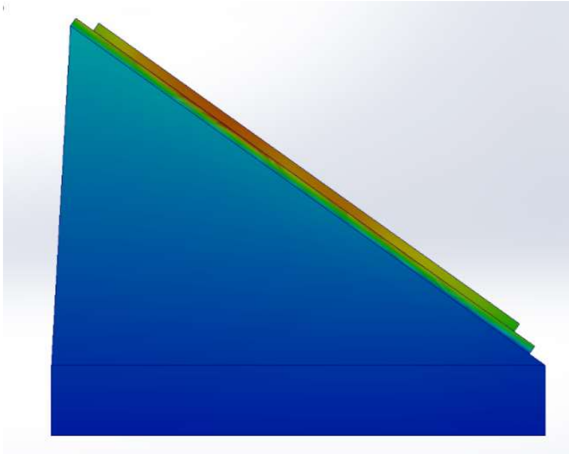

Fig.5.1

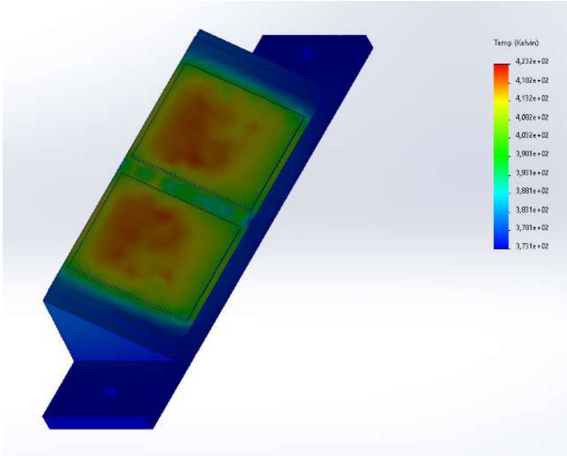

Fig.5.2

The trapezoidal prism shaped heat dissipation board design can be applied to other modules. For example, a model of a three-phase bridge (power modules) was created Fig.6. Model data: heat dissipation board height h_{b4} = 3mm, heat dissipation board area S_{b4} = 3150mm^2, insulation board height h_{i4} = 0.4mm, insulation board area S_{i4} = 1860mm^2, semiconductor chip height hc4 = 0.4mm, semiconductor chip area S_{c4} = 182.25mm^2. The electrical and thermal indicators necessary for comparison are taken by analogy with the VS-160MT160KPBF Vishay Intertechnology module [3]: case temperature T_C = 85°C, maximum junction temperature T_J = 150°C, maximum DC output current $I_{D(4)}$ = 160A, maximum total power loss $P_{T(4)}$ = 420W. In Fig.7.1 and Fig.7.2 show the temperature distribution of the new model that satisfies the electrophysical and thermal parameters.

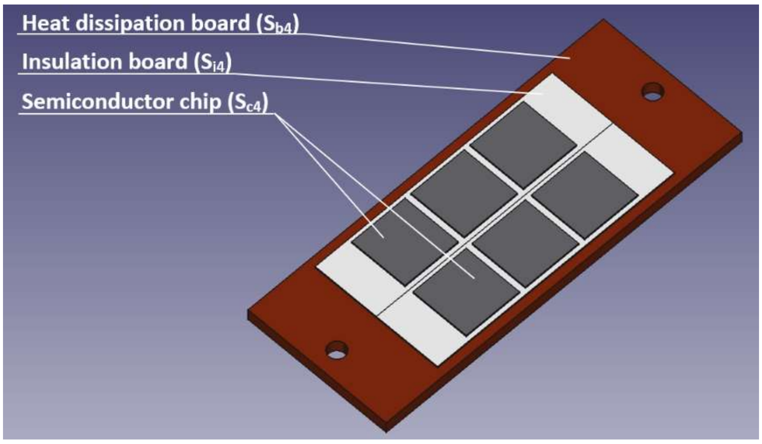

Fig.6

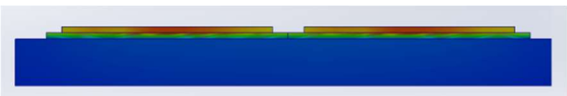

Fig.7.1

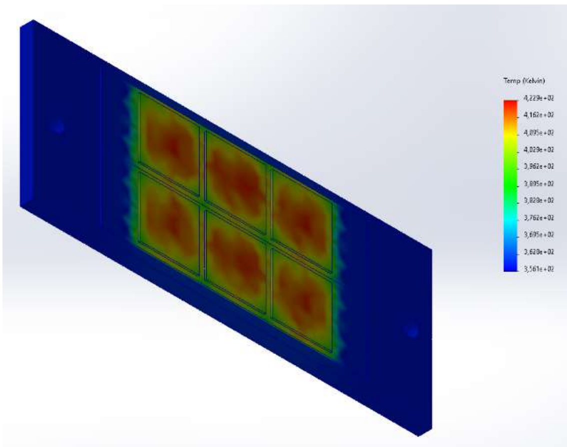

Fig.7.2

After changing the design of the new base in the form of a trapezoidal prism with an angle $\alpha = 35°$, a new model of a three-phase bridge was built. Fig.8. Data of the new model: minimum heat dissipation board height $h_{b(min)5}$ = 3mm, maximum heat dissipation board height $h_{b(max)5}$ = 12.5mm, external heat dissipation board area S_{b5} = 3150mm^2, insulation board height h_{i5} = 0.4mm, area insulation board S_{i5} = 2280mm^2, semiconductor chip height h_{c5} = 0.4mm, semiconductor chip area S_{c5} = 289mm^2. Calculated value according to formula 4: maximum total power loss $P_{T(5)}$ = 545.6W.

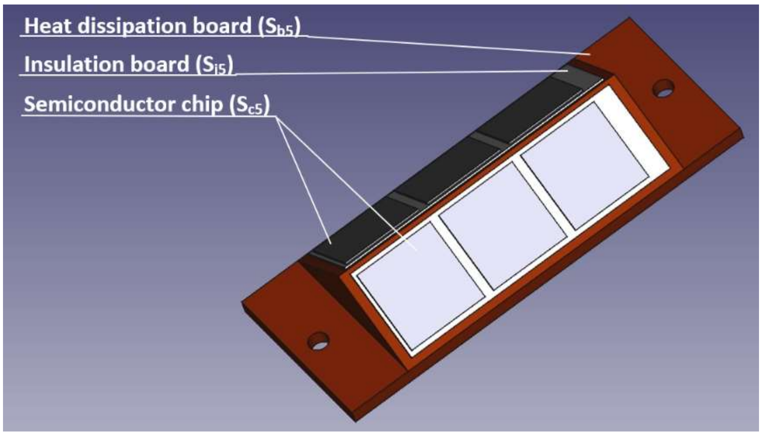

Fig.8

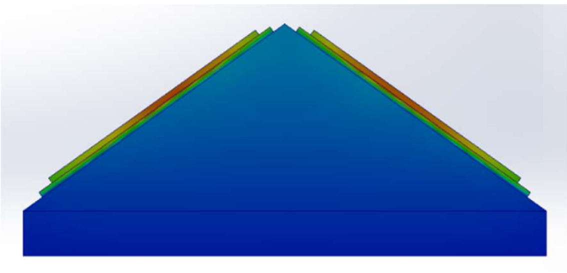

Fig.9.1

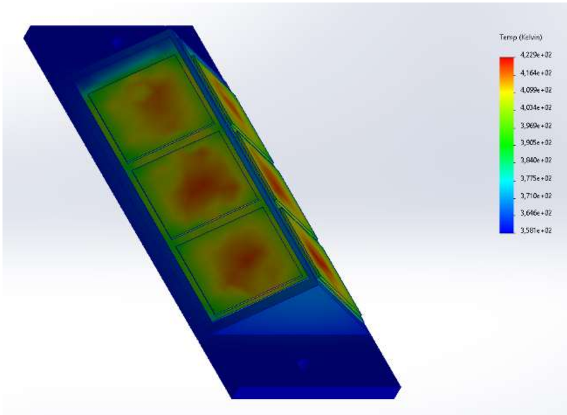

Fig.9.2

On Fig.9.1 and Fig.9.2 show the temperature distribution of the new model, satisfying the electrophysical and thermal indicators. According to 3D modeling of the new heat dissipation board, the dissipated thermal power and average current increased by 26%: maximum DC output current $I_{D(5)}$ = 200A, maximum total power loss $P_{T(5)}$ = 529W.

Conclusions:

1. The use of a heat removal board in the form of a trapezoidal prism for the power rectifier module allows you to place a larger area semiconductor crystal in the same module design, which will increase the average value of the average forward current;
2. The new design of the power module must be modified taking into account the manufacturing technology and the need to change other parts: housing, terminal lead, terminal wire;
3. The new model is more difficult to manufacture and more expensive;
4. The advantage of using the new model is space saving;
5. This design is applicable to all types of devices based on semiconductor structures.

Information sources:

1. William W. Sheng, Ronald P. Colino Power Electronic Modules: Design and Manufacture CRC Press, 2004. – 296c.
2. MDD95-16N1B IXYS Corporation, Milpitas, California, USA - www.ixys.com
3. VS-160MT160KPBF Vishay Intertechnology, Malvern, Pennsylvania, USA - www.vishay.com