THERMAL SIMULATIONS OF FAST FUSES FOR POWER SEMICONDUCTOR DEVICES PROTECTION

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Abstract: One of the most important problem as regard fuses operating and especially fast fuses operating is their thermal behaviour during steady-state or transient operating conditions. That because a good corelation between fast fuses and power semiconductors to be protected means also besides electrical parameters corelation and an adequate thermal behaviour from both sides.

This paper takes into account the thermal aspects of fast fuses within transient operating conditions, and the analysis is done using a FEM method to simulate the complex thermal behaviour. There are shown the thermal field into different parts of fuse body and also the temperature distribution at a momentary time.

Keywords: fast fuses, power semiconductors, thermal simulations

1. Introduction

Power electronics is often said to have brought in the second electronics revolution. The first electronics revolution made the modern microelectronics integrated circuits available. At the root of the both revolutions was the historic invention of the transistor by Bardeen, Brattain and Shockley in 1948. During the recent years, we have seen widespread application of power electronics in industrial, commercial, residential aerospace and military applications. As the size and cost of power electronics decrease along with the improvement of performance and reliability, power electronics applications will spread practically everywhere.

Power semiconductor device is the heart of modern power electronics because it is indeed the most complex, delicate and "fragile" element in a converter.

It can observe a continuously expansion of power electronics and converters which include power semiconductors into a lot of applications, but also results important conclusions as regards special operating conditions, such as: using a lot of components in parallel branches, intermittent load currents, failure currents which can reach hundreds of kA, special climatic and mechanical stresses. All these unfavorable operating conditions lead to special protection means for power converters and their components, especially to overcurrents.

The power semiconductor devices working into steady state or transitory operating conditions, lead to heating of device because of power dissipation. For a good operating and to avoid thermal run away, it is necessary to assure the heating evacuation from semiconductor structure. The thermal equilibrium condition, which means the same values for generated energy and evacuated energy from semiconductor device, is reached at a silicon temperature structure below 125^0C. Over this temperature there is an important degradation of specific proprieties of power semiconductor.

These devices have very limited overload capacities and, as they were expensive, the fuse manufactures attempted to produce fuses which are more sensitive to overloads and which would operate more quickly than their conventional designs.

2. Fuses for power semiconductors

Fuses are among the best known of electrical devices because most of us have quite large numbers of them in our homes and, unless we are extremely fortunate, we are made aware of their presence from time to time when one must be replaced because it has blown, or to use the official term, operated. They are basically simple and relatively cheap devices, although their behavior is somewhat more complex than may be generally realized.

The underlying principle associated with fuses is that a relatively short piece of conducting material, with cross-sectional area insufficient to carry currents quite as high as those which may be permitted to flow in the protected circuit, is sacrificed, when necessary, to prevent healthy parts of the circuit being damaged and to limit the damage to faulty sections or items to the lowest possible level.

Fuses incorporate one or more current-carrying elements, depending on their current ratings, and melting of these, followed by arcing, occurs when excessive overcurrents flow through them. They can be designed to safely interrupt the very highest fault currents that may be encountered in service, and, because of the rapidity of their operation in these circumstances, they limit the energy dissipated during fault periods. This enables the fuses to be of relatively small overall dimensions and may also lead to economies in the cost and size of the protected equipment.

Because of the above advantageous features, fuses have been and are used in a wide variety of applications, and it appears that the demand for them will continue at a high level in the future. They were undoubtedly incorporated in the earliest electric circuits in which the source power and value of the equipment were significant.

From power semiconductor overcurrent protection point of view a special fuses were made, so called fast fuses.

Taking into account the thermal phenomena complexity, especially for transitory operating conditions, as regards fast fuses heating; it was done a thermal field simulation for a fast fuse with rated current, 100A, using FLUX2D software. The current test was by 300A and the thermal field is shown at time t = 26.04s. Because of simmetry, the simulation was done only for a half of fuse, the thermal field being the same on the other half of fuse. The environment temperature was 20^{0}C.

The next pictures show the thermal field at the whole fuse, main component parts, and also the temperature distribution along the component parts.

- whole fuse body

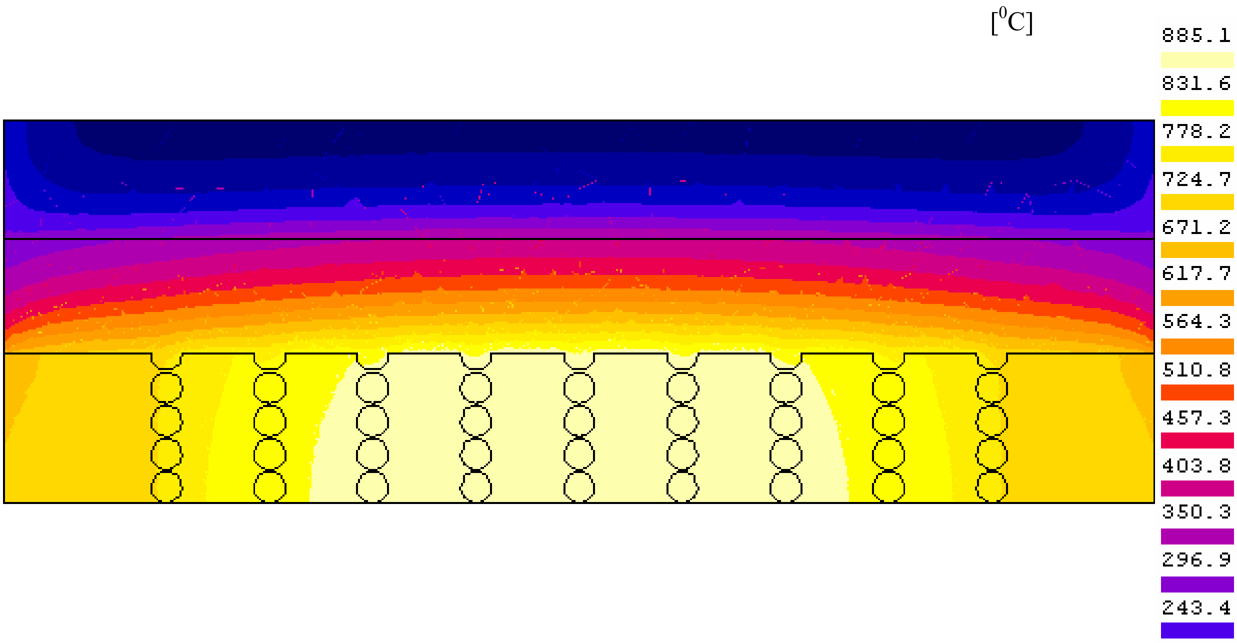

Fig.1 Thermal field in whole fuse body at t = 26.04 seconds

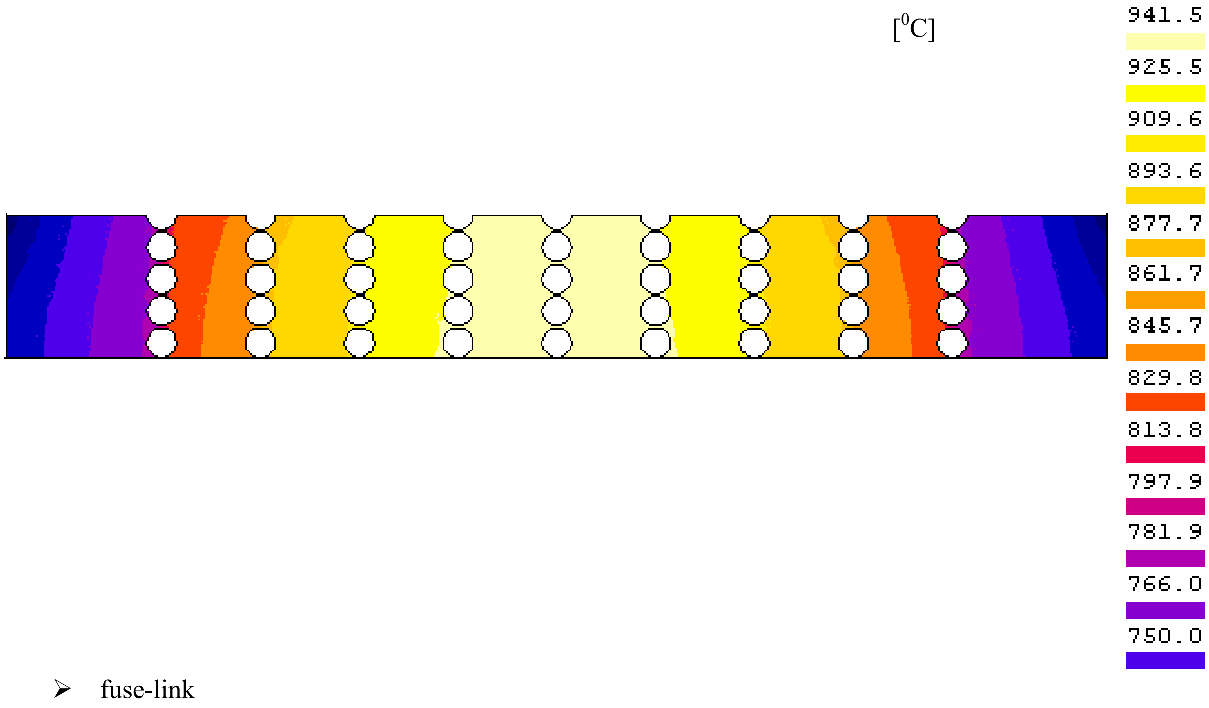

Fig.2 Thermal field along fuse-link at moment t = 28.75 seconds

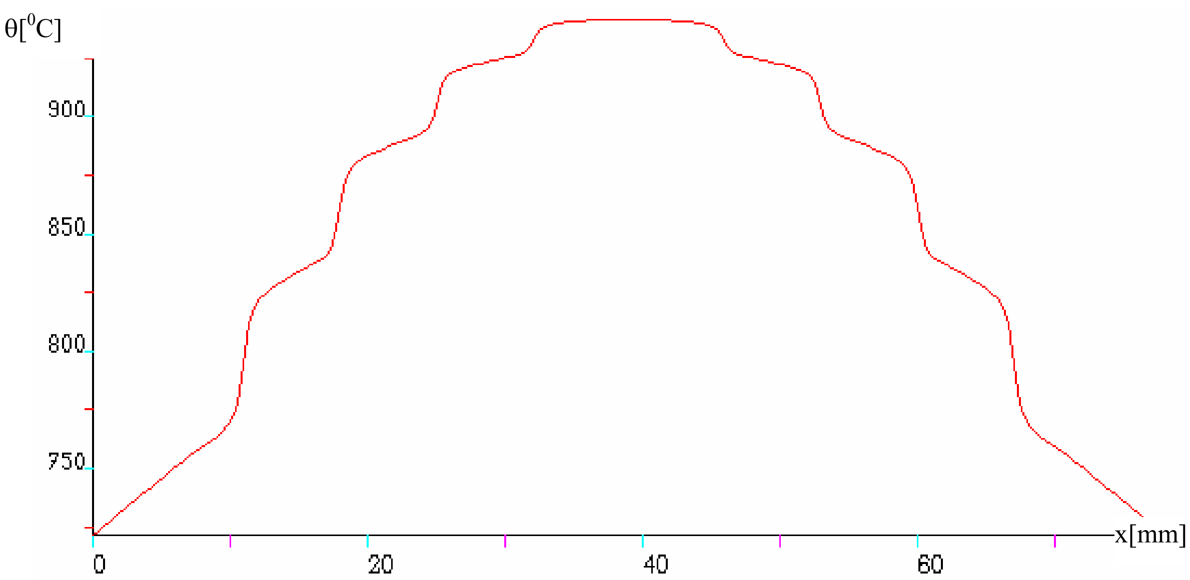

Fig.3 Temperature distribution along fuse-link at moment t = 28.75 seconds

➢ silica sand

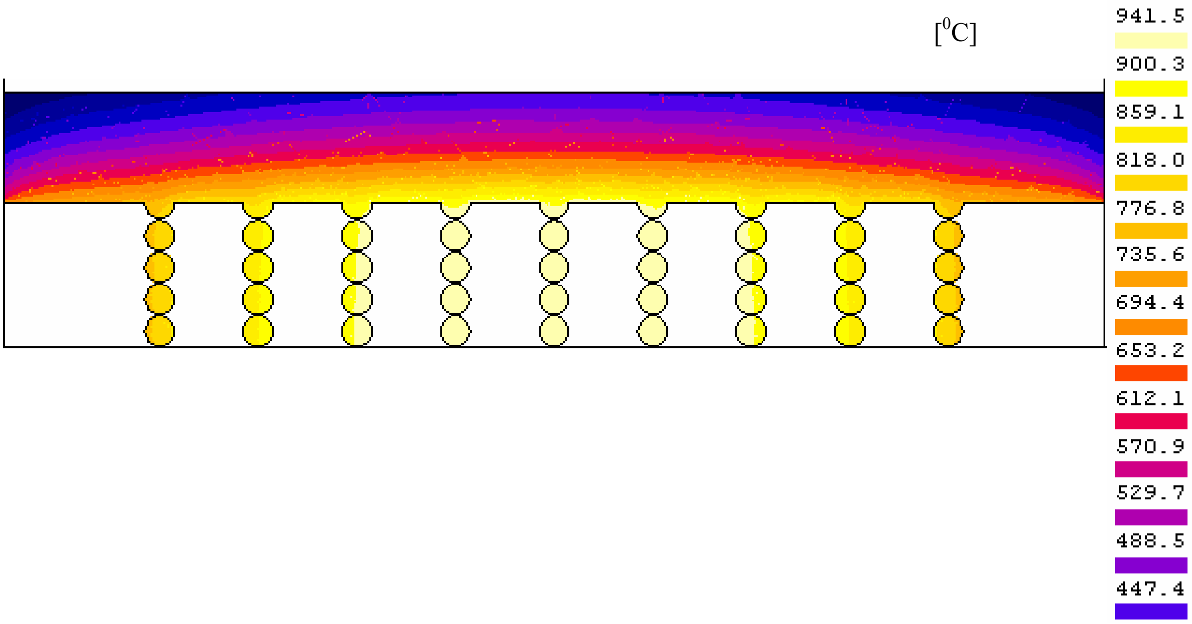

Fig.4 Thermal field into silica sand at moment t = 28.75 seconds

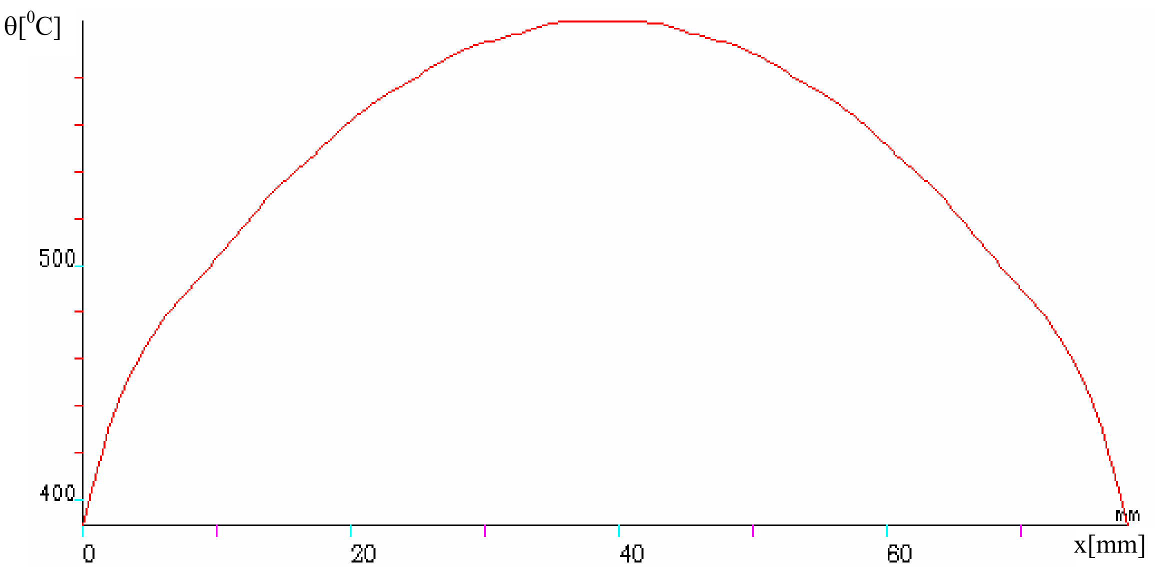

Fig.5 Temperature distribution along silica sand at moment t = 28.75 seconds

- ceramic body

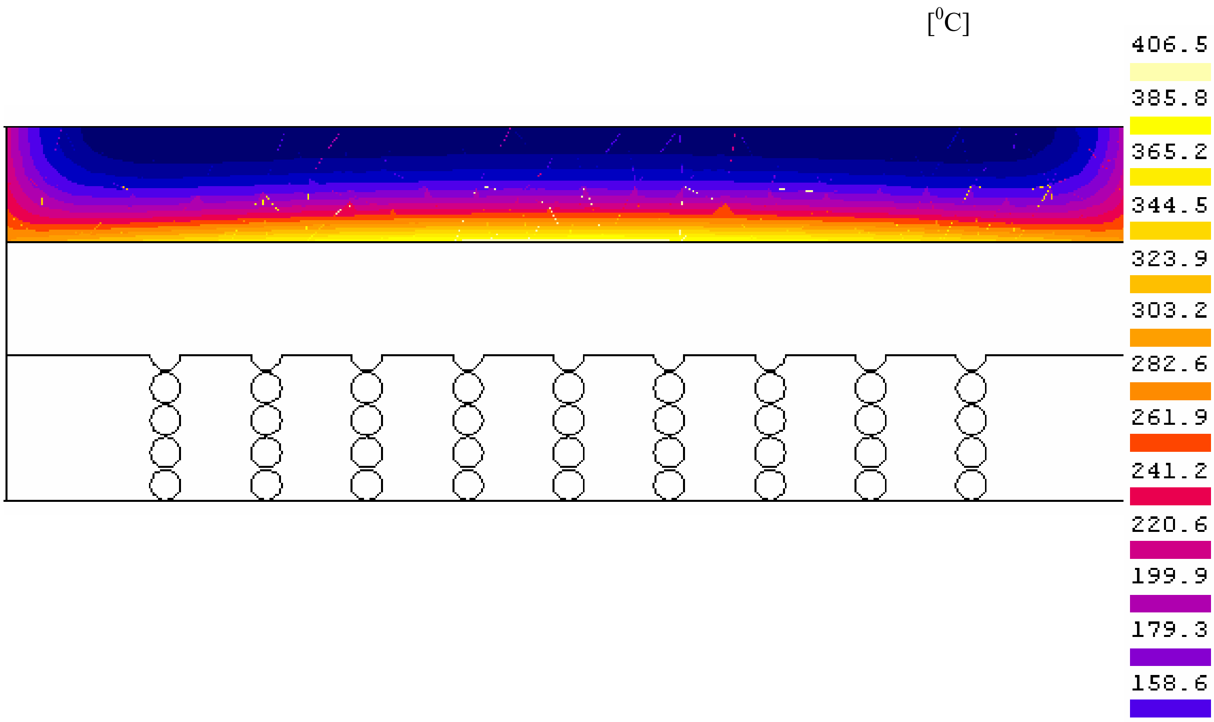

Fig.6 Thermal field into ceramic body at moment t = 28.75 seconds

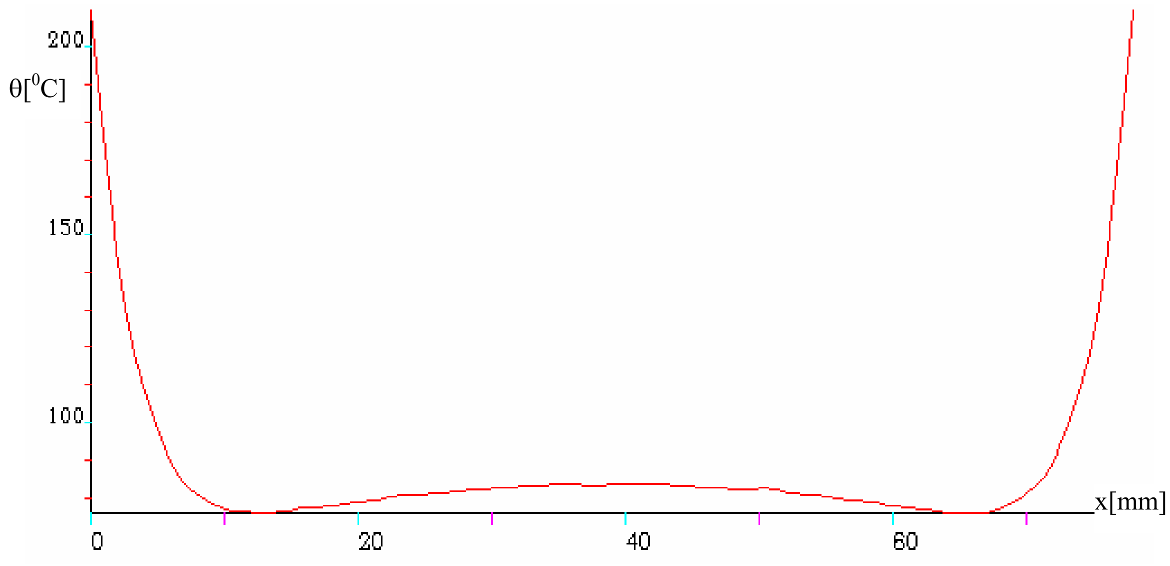

Fig.7 Temperature distribution along ceramic body at moment t = 28.75 seconds

3. Conclusions

Further on, are presented the main conclusions of this simulation study as regards thermal field and temperature distribution at fuses for power semiconductors protection.

- because of very complex thermal phenomenon the analysis of fast fuses thermal field can be done using the simulation software FLUX2D, in this way it can be calculated the temperature of fuse anywhere at any time moment;
- in any cases that were analysed it can observe a maximum temperature in the middle of component part and the minimum values at the ends;
- in the case of temperature distribution along the fuse-link it can observ the notches influence because of the specific fuse-link geometry;
- temperature distribution along ceramic body underline the influence of contacts, and so the maximum temperature values are at the ends because of higher thermal conductivity, 60.6[W/m^{0}C], and only 1.5[W/m^{0}C], for ceramic fuse body;
- using the simulation software it can improve the fast fuse designing that implies a better protection for power semiconductors and also new solutions.

References

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