

# MODELING OF CURRENT DENSITY IN THICK FILM RESISTORS

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## ABSTRACT

This paper describes various methods for setting of desirable value of resistance in thick film resistors. In this ways adjusted resistors are next created and analyzed in view of maximum current density in them. Methods are compared and it is selected the optimal from them.

## 1. INTRODUCTION

Thick film technology is in modern microelectronic perspective technology for industrial scientific and military applications (e.g. satcom). This application must be absolutely reliable, because failure of it can cause serious damage. However, these electronic devices are often at places which are uneasily accessible.

One of factors, which can decrease reliability of electronic system, is heat produced by current passing through conductors and resistors. For thick film technology, a maximum power loss for relevant material is noted in documentation. And in design and in manufacturing process, this restriction must be respected.

## 2. STUDY

Thick film technology is one of most common technologies used in applications, where reliability is foremost (e.g. military, automotive, aerospace). Conductive, dielectric, resistive or special pastes are printed or dispensed on ceramic or organic substrate and cofired. As a part of electric circuit, power is dissipated on resistors, while heat is produced. For example, when we have thick film resistor with voltage  $U$  placed between terminals and current  $I$  passing through this resistor, power  $P$  dissipated in this structure is:

$$P = U * I [W] \quad (1)$$

When shape of our thick film resistor is regular rectangle, there isn't difficult to determine power which is dissipated in particular sections of this structure. Because current density and electrical field is in this case homogenous along whole area of resistor, we can obtain power loss on element of area (as it is mentioned in documentation) from:




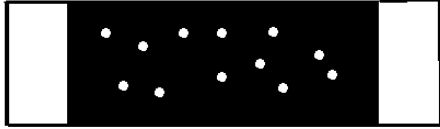
$$P_{element} = (U * I) / A [W/m^2], \quad (2)$$

where  $A$  is area of resistor with width  $W$  and length  $L$ , while these dimensions are designed to setting resistance as it is required. But variability of parameters of manufacturing causes that value of resistance is not accurate. Therefore, parameters  $W$  and  $L$  are designed so that resistance is it is printed were smaller than the desired and after cofire is resistor additionally trimmed, most often by laser.

In resistors, that are modified in this way is current density and electrical field non - homogenous and thereby is also complicated to determine power loss in individual segments of this resistor. Because hot points arise where current density has high value, way to determine power loss in individual segments of our resistor is analyzing of distribution of current density along whole area of the device. For this analyze, computing system ANSYS is available, which can solve and view results of analyze as contour or vector plot or file of values showed in graph.

### 3. PLAN OF EXPERIMENT

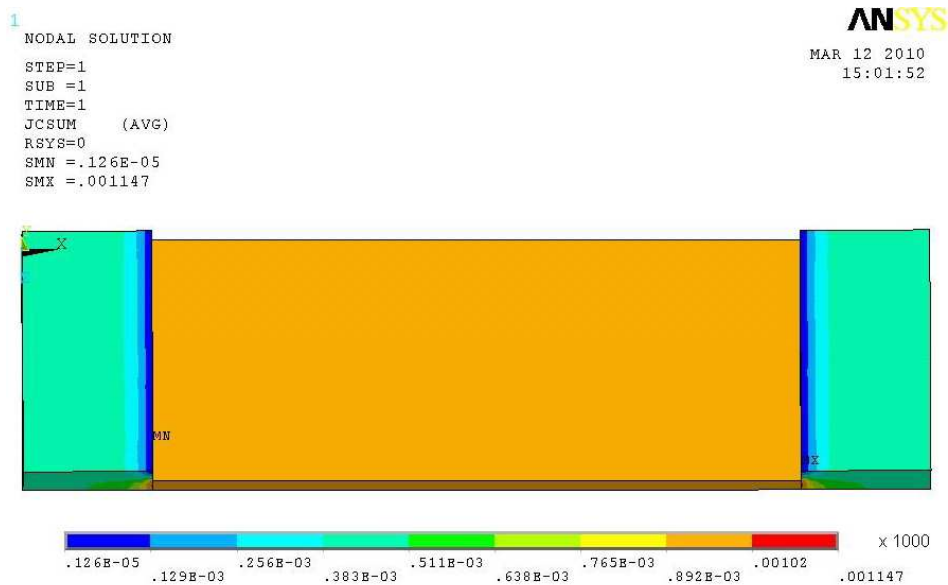
For analyzing, four resistor structures were modelled. Each structures have same dimensions with length of resistive layer 5 mm, width 2 mm and thickness 0,2 mm. Resistivity of paste is 1 k $\Omega$ m. Width of terminal is 2 mm (accordant with width of resistive layer), length 1mm and thickness 0,4 mm. Terminals have width 2 mm, length 1 mm and height 0,4 mm. Their resistivity is 1  $\Omega$ m. Differences consist in design of trimmed notch – three resistors had three various implementation of notch. It was considered I – shaped notch, L – shaped notch, and randomly localised circles. Each simulation was performed at 27°C. Model was meshed with net of tetragonal basic element labelled as SOLID 232 for electrical conductivity analyse. Resistors were compared in consideration of maximum current density that occurs in them.

|   |   |   |  |
|---|---|---|--|
| 1 | Resistor without trimming   | 3 | Resistor with L – shaped notch   |
|   |  |   |  |
| 2 | Resistor with I – shaped notch  | 4 | Resistor with randomly placed circles  |
|   |  |   |  |

**Table 1:** List of structures that were liable to analyze

#### 4. RESULTS

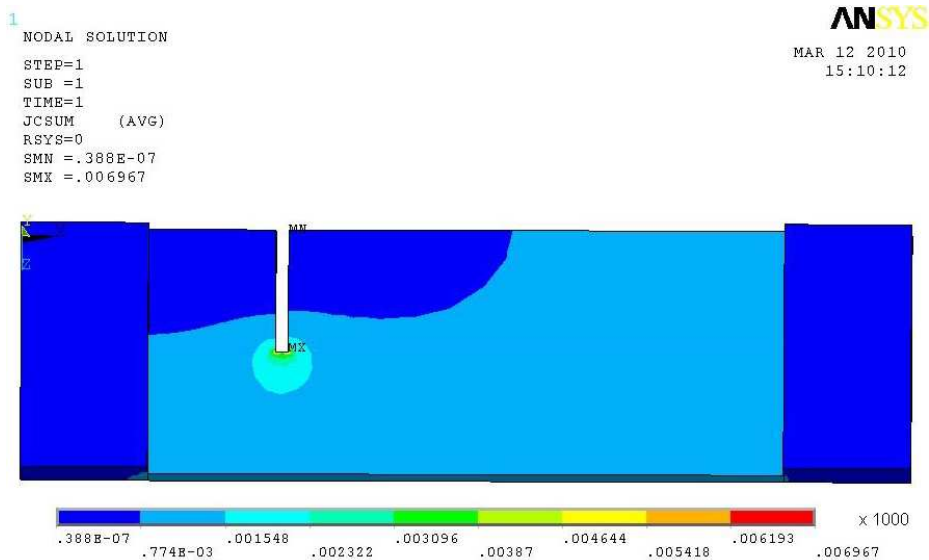
As a first was analyzed resistor as it is printed, without trimming. It is possible to anticipate that current density is strictly homogenous in whole plane of resistor. In a Figure 1 we can see result of this analyse.



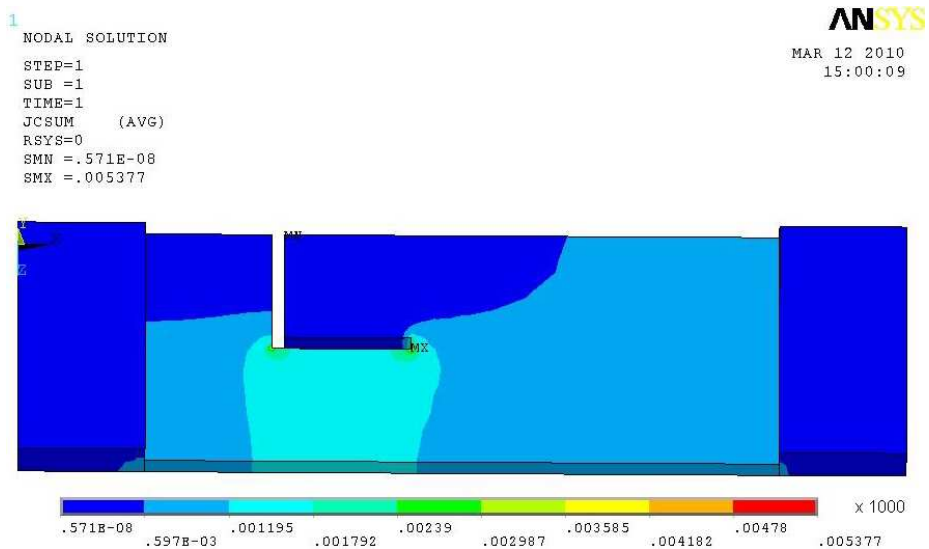
**Figure 1:** Current density in non – trimmed resistor

As we can see, current density in resistive layer is homogenous. In terminals, current density is lower here because of higher thickness (and larger area of cross section) than resistive layer, while current is the same. Maximum of current density is  $1,1 \text{ A/m}^2$ .

Next, it was considered resistor with I – shaped notch. In this case, notch is 1 mm long, 0,1 mm wide and is localised 1 mm from left terminal. We can see here that density of current passing through resistor is approximately  $1 \text{ A/m}^2$  near of right terminal, but in region around notch is density higher five times. This can be problem if we need to manufacture resistor with higher value of resistance – notch will be longer and current density will dangerously grow.



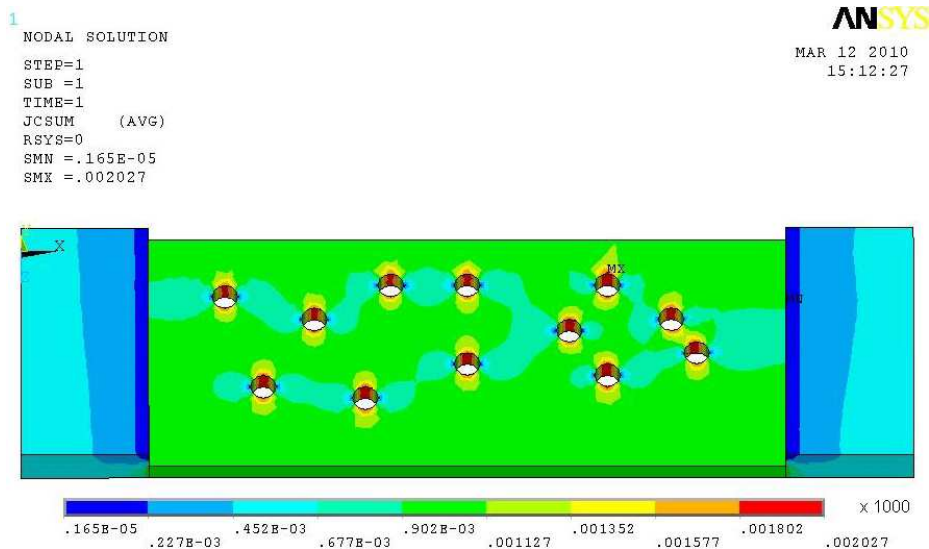
**Figure 2:** Resistor with I – shaped notch



**Figure 3:** Resistor with L – shaped notch

Disadvantage of I - shaped notch resistor can partially solve next type – L – shaped notch resistor. There is again one notch, but now it is rebated and partially guided along direction of current. This solution reduces the maximum current density. Next reduction can provide resistor with notches in shape of randomly localised circles. Thanks to random character of

localisation of individual circles, this solution leads to greater dispersal of places with higher current density along whole plane of resistor and danger of hot point creation is lower here.



**Figure 4:** Randomly localised circles trimmed resistor

## 5. CONCLUSION

Various methods of resistor trimming were considered and trimmed resistors were modelled. Analyse shows, that method with I – shaped notch isn't the best choice if we need to have certainty, that there won't be hot point in resistor layer. So better choice is here L - shaped notch resistor because there are no individual places with high current density, but places with higher current density are spread in larger area. Randomly localised circles concept leads to dispersal of places with higher current density along whole area of resistor – maximum current density isn't too high as in case of I - shaped resistor.

## ACKNOWLEDGEMENT

This research is supported by Research Plan MSM 0021630503 MIKROSYN „New Trends in Microelectronic Systems and Nanotechnologies”

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