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ELECTRICAL CONTACT MODELS BASED ON MULTIPOINT CONTACT

The paper presents simulation results of contacts applied in low-current circuits. Various parameters of low-current contact space based on the model consisting of multipoint contingence were analysed. For selected model, the values of current density, power and voltage distributions at operating contact at assumed value of applied voltage were obtained. FLUX 2D software package was used to analyse the contact. This simulation aims at defining how much the number of contact points influences the distribution of current, power and voltage in contact model. The contact made of beryllium bronze with outer layer of gold was taken for the analysis. This enabled to define (electric) phenomena, which occur in operating contact, which cannot be obtained by the application on physical models.

1. Introduction

The paper presents the analysis of various parameters of low-current contact space based on the model, which consists of multipoint contact. For selected model, the values of current density, power and voltage distributions in operating contact at assumed value of applied voltage were obtained. Such distributions for the single and multipoint contacts were then compared at the assumption that the contact surface is the same. This simulation enables to define how much the number of contact points influence current and voltage distributions in the contact. The contact made of beryllium bronze with outer layer of gold was chosen for the analysis. This enabled to define (electric) phenomena, which occur in operating contact, which cannot be obtained by the application on physical models. FLUX2D software package was used for the analysis.

This software enables to define the geometry of designed contact, model configurations and introduce boundary conditions. Modelled space has been divided using finite element mesh. Material data base is used for contact analysis which allows for quick estimation of changes occurring in the contact. Obtained results are presented as tables or diagrams of current intensity distributions, power density and voltages in the connecting area.

2. The influence of exploitation parameters on junction operation

The analysis of the phenomena which occur in electric contact is difficult and it requires a wide range of laboratory tests using professional apparatus. Various phenomena proceed on contact surface which change real surface and thus influence current flow and may result in interruption. It mostly refers to low-current circuits in which the value of voltage does not exceed 5V. The parameters of the junctions are influenced by various exploitation features like mechanical, economical and economic and exploitation ones. The main parameter which decides of junction exploitation is the value of transient resistance that may not exceed 10mΩ.

The value of transient resistance has been influenced by the following factors: pressure force, materials which constitute the contact, type of contact i.e. the shape of contacts that form the junction as well as the state of contact surfaces. Apart from the factors mentioned above, the real contact surface has also been influenced by working environment, type of load and duration of current pulse passing through the contact. These phenomena cause instable operation of the contact and may induce interferences caused by rapid changes of contact resistance. The models that would enable to present investigated contact and obtain results close to experimental ones are in wide demand.

3. Mathematical - physical models used to compute transient resistance of the contact

In previous papers [1, 5–11] several models presenting transient resistance of the contact were analysed. At considerable simplification, contact places have in reality various shapes and dimensions. Thus, it was necessary to create mathematical-physical models of simple geometric shapes. The assumption has been made that this dimension is the mean value of all contact surfaces constituting single contact. Simplifications and assumptions which characterise particular models allow for approximate computations of transient resistance. However, the usage of computations based on considerable simplifications in practice is limited because the models do not take into consideration additional resistance of tarnish films. Further studies on models and their improvement will enable to calculate transient resistance of the contacts more precisely.

4. Computer simulation of contact space model

The paper presents single and multipoint contact model carried out by the application of FLUX 2D software. The objective of the simulation is to show how much the number of contact points influence the distribution of current density and voltage in modelled contact.

To model contact space the following assumptions have been made:

1. for low-current contacts transient resistance shall not exceed the value of 10mΩ,
2. maximum value of current passing through operating contact is 10mA since such value does not generate electric arc phenomenon,
3. for minimum contact surface the value of current density shall not exceed j_{max}=10A/mm^2 which results in surface overheating.

In order to carry out the simulation of the contact, 5μm layer of gold on the sub-layer of beryllium bronze was chosen. Gold is the material commonly applied in low-current contacts. Beryllium bronze assures suitable elasticity. Contact dimensions used for the geometry were selected according to the assumption that the contact was made as the cylinder 20μm long.

The following dimensions of contact model were assumed:

r_s=0,5mm – radius of contact element, S_p – real contact surface, l_s = 0,5mm– length of contact element, l = 20μm – distance between contacts, I=10mA – current passing through the contact.

The assumption was made, that current passes through the surface of the cubicoids that represent transient resistance. The contacts made on the basis of 1 cubicoid and 9 cubicoids at the assumption that the contact surface is constant were compared. The creation of multi-point contact is carried out on the basis of parallel connection of the resistors. At the assumption that the contact surface is the same for each cubicoid it is possible to select the values of the resistance R depending on the number of resistors. Table 1 shows the relation between the number of contact points and the value of the resistance R for single connection at the assumption that transient resistance is R_p=0,42mΩ [8].

$$R = nR_p,$$

n – number of contact points, R – resistance of single connection.

Fig. 2 shows electrical model of single-point contact.

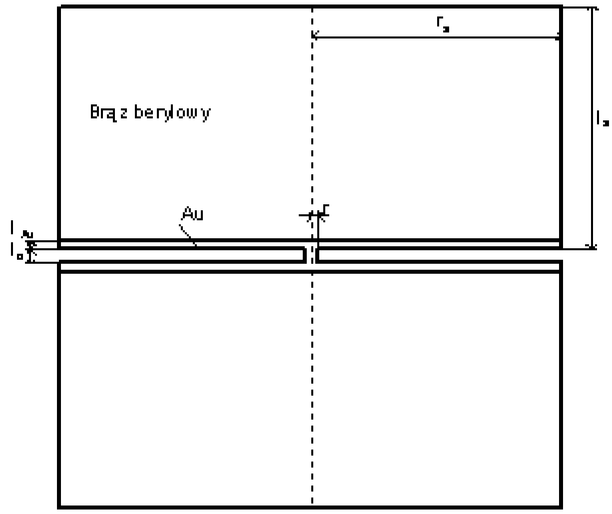

Fig.1. Geometry of modelled contact, planar view

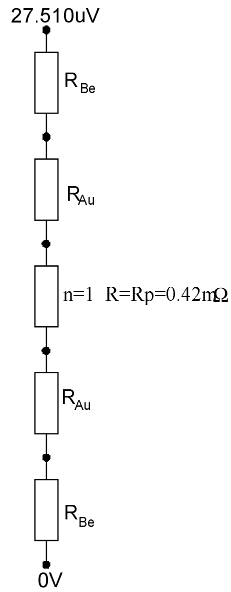

Fig. 2. Electrical model of single-point contact: R –resistance of single connection , R_P – transient resistance of the contact, R_{Au} – resistance of gold layer for single contact, R_{Be} – resistance of the sublayer of beryllium bronze for single contact

Table 1

The relation between the resistance of single connection R depending the number of contact points for constant value of transient resistance of the contact R_p=0.42mΩ

R	mΩ	0.42	4.2	42	420	4200
n	-	1	10	100	1000	10000

4.1. The analysis of single-point contact model

The computations were carried out with the usage of finite element mesh.

The mesh consists of 29 463 nodes and 14 636 triangular elements. Great number of nodes and mesh concentration in the vicinity of the constriction zone assures accurate results. The precision in mesh generation considerably influences the accuracy of the results. For described model the distributions of current density and volume power density were defined.

The highest values of surface current density for the constriction zone of current circuit 28.2A/mm^2 were noticed at the edge of the cubicoid and the contacts. Along the lateral surface of the cubicoids the value of surface current density is 10A/mm^2. This value becomes lower towards the cubicoid's centre. For the sublayer of beryllium bronze maximum value of surface current density is 4.96A/mm^2.

Distribution of volume power density for single-point contact model.

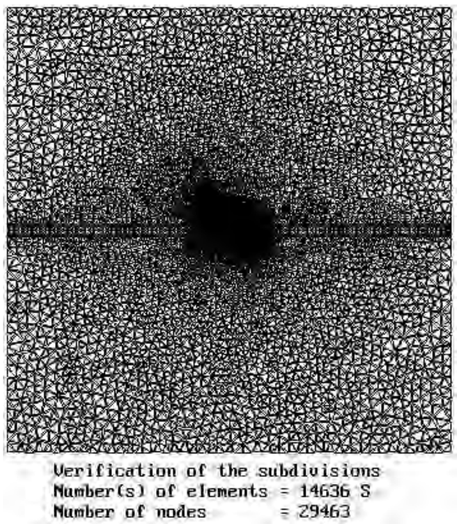

Fig. 3. Finite element mesh for single-point contact model

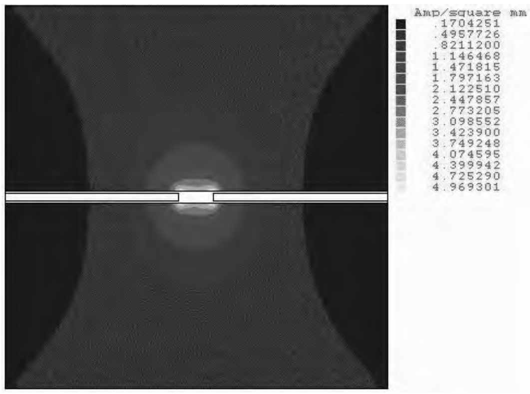

Fig. 4. Distributions of surface current density in single-point contact model for the constriction zone of current circuit

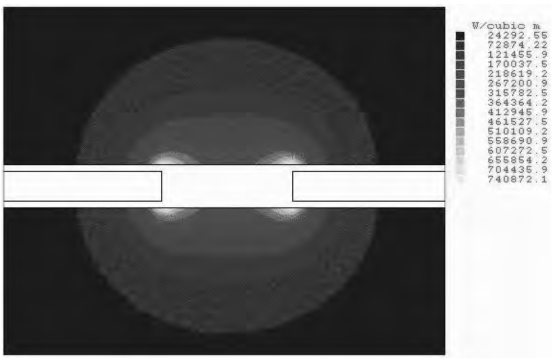

Fig. 5. Distributions of volume power density of single-point contact model for the constriction zone of current circuit

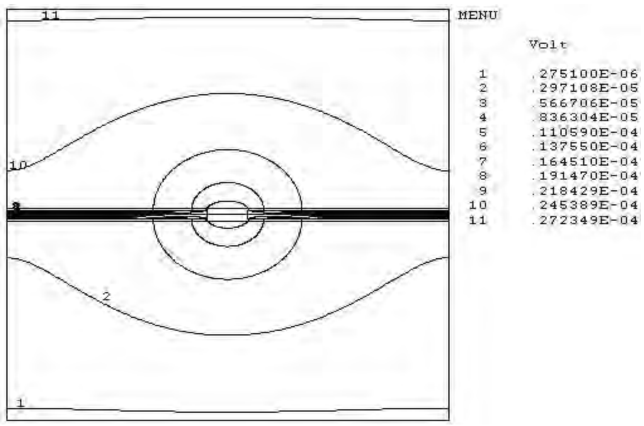

Fig. 6. Distribution of equipotential lines for single-point contact model

At contact edges of cubicoid's base with the contacts, the value of volume power density is 0.0192W/mm^3. However, the region where this value occurs is very small thus it is not dangerous for the contacts. For the sublayer of beryllium bronze, maximum value of volume power density - 0.0007W/mm^3 occurs close to the constriction zone and is safe i.e. allowable temperatures for beryllium bronze will not be exceeded. For modelled contact the distributions of equipotential lines are shown in Fig. 6.

For the reason that the real contact is not considered but only it's part, transient resistance has the same value as the resistance of each contact element. Potential distribution in the contact is uniform. For the real model, the value of transient resistance is considerably higher that the resistance of contact elements.

4.2. Multipoint contact model with 9 equal contact surfaces

Assuming that the mean value of surface current density is 10A/mm^2, maximum value o 16.8A/mm^2 was obtained, which results from 9 contact surfaces. The number of contact points assures equal distribution of surface current density inside the contact. For single-point contact model, maximum values of surface current density - 28.2 A/mm^2 were obtained. The contact has higher strength along with the increased number of contact points since current passage is more uniform and there are lower values of surface current density. The distribution of volume power density in the contact model with 9 equal contact surfaces is shown in Fig. 9. The application of 9 contact surfaces resulted in lower values of volume power density. For the model with single contact surface P_{Vmax}=0.0192W/mm^3, for the model with 9 contact surfaces P_{Vmax}= 0.0068W/mm^3, thus the value is three times lower. The value of volume power density in beryllium bronze sublayer was changed into 0.0005W/mm3, for the contact with one contact surface it amounted 0.0007W/mm3.

Distribution of current density of the model with 9 identical contact surfaces.

The distribution of equipotential lines of the contact model with equal contact surfaces.

Equipotential lines are perpendicular to the direction of the current passing through the contact. Along with approaching the cubicoid inside the contact, the value of the potential is lower.

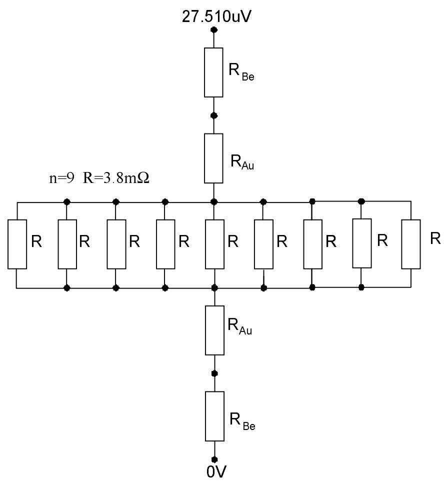

Fig. 7. Electrical model of the contact – 9-points contact of the same contact surfaces. R –resistance of single connection, R_P – transient resistance of the contact, R_{Au} – resistance of the gold layer for single contact, R_{Be} – resistance of the sublayer of beryllium bronze for single contact

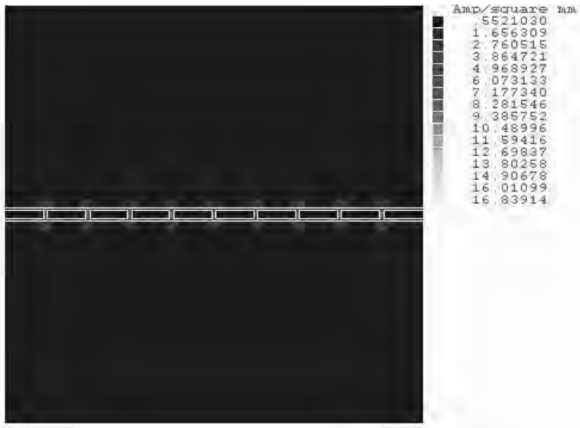

Fig. 8. Distribution of surface current density for contact model with 9 equal contact surfaces

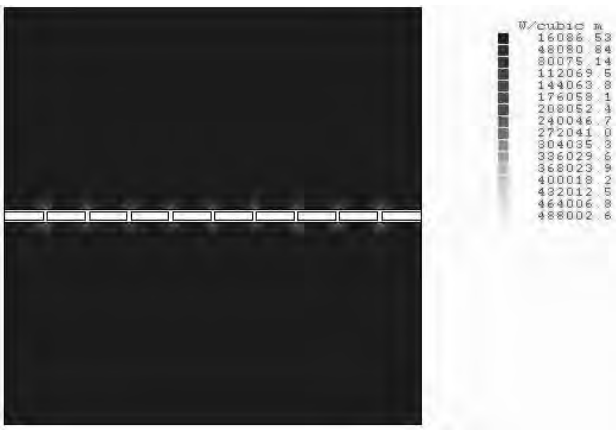

Fig. 9. Distributions of power volume density of the contact model with 9 equal contact surfaces

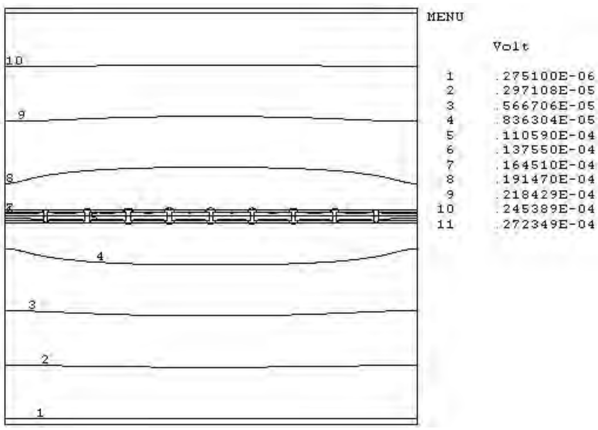

Fig. 10. Distribution of equipotential lines of the contact model with 9 equal contact surfaces

Conclusions

Two mathematical-physical models of the contacts were compared in the paper by the application of FLUX 2D package. The models consist of the layer of gold 5μm on beryllium bronze. Carrying out computer simulations does not require high financial contribution and it enables to analyse the phenomena occurring in the contact. Well-prepared simulation assures the obtainment of real value distributions. Without the software, the designers may calculate mean values which occur in the materials however, the maximum values revealed by computer simulations are of great importance.

Real contacts operate on the principle of multipoint contact. By the application of FLUX 2D package, the model can be made in planar system. Contact model was used to consider single-point and multi-point system of equal contact surfaces. The model made on single-point contact has been treated as the reference model. Designed models were considered in planar system, the same boundary conditions $U=25.510\mu V$ $R_p=0.42m\Omega$ were assumed.

Significantly, **in multipoint contact model** the highest values of surface current density $j=28.2A/mm^2$ and volume power density $0.0192W/mm^3$ were reached. These values occur at the edges of the cubicoid's base on very little surfaces. Along the line drawn through the centre of the contact, the value of surface current density increases as the distance from the centre of the octopus is higher, near the wall it amounts $6.6\ A/mm^2$, in the centre $3.4\ A/mm^2$, thus the edges of the cubicoid are more subject to damage than the centre. For this model, there is very little probability that permissible temperatures will be exceeded in the cubicoid representing transient resistance of the contact.

In 9-point contact model with equal contact surfaces, significantly lower values of current surface density $j= 16.8A/mm^2$ and volume power density $P_V=0.0062W/mm^3$ were obtained. The distribution of current surface density along the line drawn through the contact centre shows, that the highest vales of surface current density are present on the surface in higher distance from the centre $9.2A/mm^2$, in the centre $7.5A/mm^2$. Such values increase the probability of damage of conductivity points due to the exceed of permissible temperatures.

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