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Thick Film Structure – Influence of Pattern Geometry

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Anotace:
Článek je zaměřen na problematiku tlustovrstvých struktur vytvářených sítotiskem. Práce analyzuje vliv různých typů polymerních past a technologie přípravy vrstev na geometrii nanesených motivů. Vzorky testovacích struktur byly natištěny na podložky z korundové keramiky. Měřenými parametry byly elektrický odpor a rozměry nanesených vrstev. Byly vyhodnocovány a porovnávány také odchylky od teoretické šířky vrstvy. Natištěné motivy se měřily optickým mikroskopem a tloušťka vrstev hrotovou metodou.

The article concern with the topic of thick-film structures prepared by screen printing. Work is focused on analysis the influence of different types of polymer paste and preparation technology of layer on the pattern geometry. Set of samples of test structure with different sizes and shapes were printed on ceramics substrates. Measured parameters were the electrical resistance and the dimensions of the layers. Deviations from the theoretical width values for each type of paste were analyzed and compared. The path width was measured by optical microscope and the thickness of the layers by the stylus method.

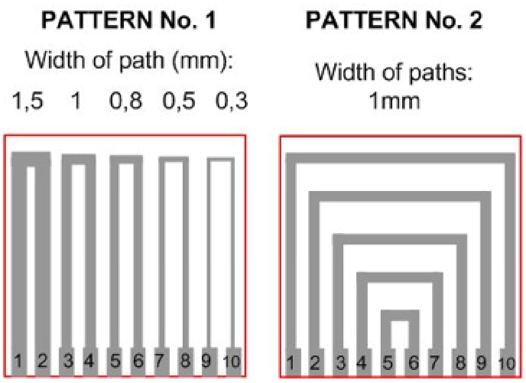
INTRODUCTION

Thick film technologies for the preparation of organic and inorganic layers are widely used in electronic production. The advantage of polymeric thick layers is their low cost production. Using these technologies, it is possible to build up an electric component with the required properties [1]. The printed polymer layers can be integrated into PCBs. In some cases, they can replace SMD discrete components [2]. It is important, among other things, to ensure that the required dimensions are met. This applies especially for structures where it is necessary to set certain parameters such as conductivity, resp. resistance [3].

The ideal printed and cured film has a rectangular shape in cross section. The dimensions of the rectangle are given by the mesh size on the screen. The deposited real film exhibit a certain shape deformation. The resulting thick film structure pattern depends on the properties of the paste, the printing process and the curing conditions. Spreading of patterns and roughness of the film depend on the viscosity of the paste, the solid content of the functional phase, etc. Structure inaccuracies also affect printing parameters such as print speed, distance between mesh and substrate, slope of squeegee etc.

THE SAMPLES AND THEIR PARAMETERS

Structures of different width, length and shape of the path were designed for analysis of polymer layers deposited by screen printing. Layout of tested structures are shown in Figure 1.



Pattern No. 1		Pattern No. 2	
Contacts of paths	Length of paths (mm)	Contacts of paths	Length of paths (mm)
1-2	41	1-10	63
3-4	41	2-9	50
5-6	41	3-8	36
7-8	41	4-7	23
9-10	41	5-6	11

Obr. 1: Tested structure of polymer thick film layers with dimensions of path

Four polymer screen paste for screen printing of two types (silver and carbon black) from producer Chang Sung were used [4]. Two pastes CSP 3110D and Paron 910 with silver solid content and two paste CSP 3225 and Paron 920 with carbon black solid content were used.

The electrical resistance, width and thickness of the layers were measured. The path width was measured by optical microscope and the thickness of the layers by the stylus method on device "Form Talysurf Intra" from the company Taylor Hobson. The principle of method and description of the device can be found in the [5]. Samples with large deviations of the measured parameters were excluded from the evaluation. Values significantly different from the average values were measured on the paths where screen printing errors occurred. These errors were confirmed by visual inspection under a microscope.

RESULT DISCUSSION

Comparison of values of sheet resistance and path dimension

The table 1 shows the measured and calculated values for all analyzed pastes. For comparison, some available data from the producer are added to the table.

Tab. 1: Parameters of tested structures for all used pastes

	CSP 3110D	**Paron 910**	**CSP 3225**	**Paron 920**
Data from producer				
Solid content (wt%)	75 ± 2	not in datasheet	42 ± 2	not in datasheet
Resistivity (Ω·cm)	$< 5\cdot10^{-5}$	not in datasheet	< 0.1	not in datasheet
Resistance (mΩ/square/mil)	not in datasheet	15 - 50	not in datasheet	40 000
Measured a evaluated values				
Width (mm)	0.987	1.03	1.01	1.03
Thickness (µm)	13.2	7.65	7.20	7.88
Sheet resistance (Ω/square)	$55.4\cdot10^{-3}$	$62.3\cdot10^{-3}$	78.7	62.4
Resistivity (Ω·cm)	$7.3\cdot10^{-5}$	$4.8\cdot10^{-5}$	$5{,}7\cdot10^{-2}$	$4.9\cdot10^{-2}$

The evaluated parameters were sheet resistance, width and thickness of layer and resistivity. Sheet resistance R_{sq} can be calculated from given and measured values of resistance R, width w and length l as

$$R_{sq} = R \cdot \frac{w}{l} \qquad (1)$$

where we take the measured width in the calculation. The value width is given by measurements of path on pattern No. 2, where paths are equally wide. Width of the paths is defined by the mask of the screen, and in this case it should be theoretically 1 mm.
Values of resistance ρ in table 1 are calculated from sheet resistance R_{sq} and thickness t with equation

$$\rho = R_{sq} \cdot t \qquad (2)$$

All pastes were printed under the same conditions, i.e. through the same mesh screen. The measured thicknesses differ slightly for most samples. Values range from 7 to 8 µm. The significant difference is only for paths deposited with paste CSP 3110D. There is an average thickness of 13.5 mm. In this case, the paste spread out less than the others. This is confirmed by the measured path width values (see Table 1 and 2). Table 1 shows that for paste CSP 3110D is width less than 1mm, while for other pastes the width is greater than 1 mm. Higher layer thickness may be due to higher paste viscosity. The percentage of the solid content in the paste can also influence the spread out and hence the thickness. But they do not indicate the calculated resistivity values. If we compare both silver pastes, we can see that the resistivity is lower for the paste Paron 910. A major role here can also be played by the expiration time of the CSP paste. In terms of resistivity, both carbon black pastes CSP 3225 and Paron 920 are comparable. Solid content of paste is given only for CSP 3225, but since both pastes are designed for the same application, it will also be similar to Paron 920. Both pastes are low resistive and are designed for membrane touch switches and flexible circuits

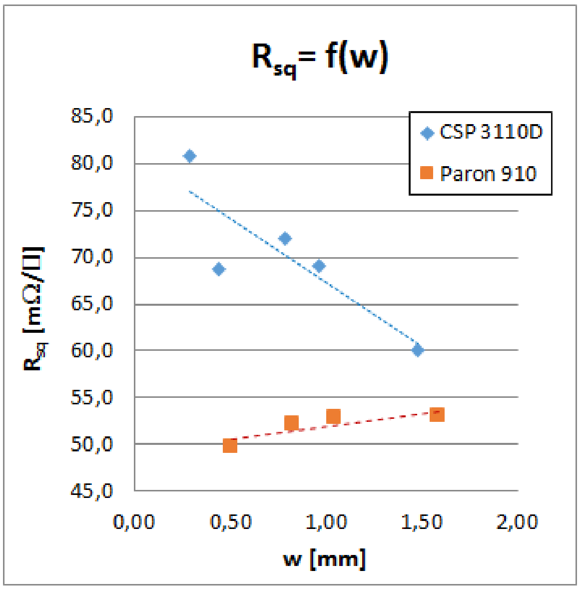
Influence of width a length on sheet resistance

To verify the assumption that the sheet resistance should be independent of the width of the path, structure No. 1 (see fig. 1) was used. There are paths of varying width on this sample. The average measured path widths for pattern 1 are shown in tab. 2.

Tab. 2: Theoretical and measured values of widths for paths of Pattern No. 1

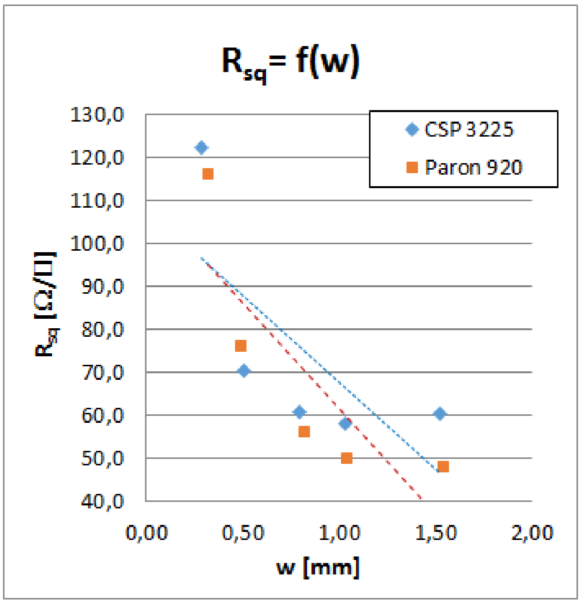
	Width of path (mm)				
Theoretical value	1,5	1	0,8	0,5	0,3
CSP 3110D	1,48	0,968	0,785	0,443	0,291
Paron 910	1,59	1,05	0,826	0,507	0,321
CSP 3225	1,52	1,04	0,798	0,509	0,288
Paron 920	1,55	1,04	0,821	0,488	0,317

Graph for silver structure on fig. 2 and graph for carbon black structure on fig 3 show the sheet resistance values of individual paths, calculated from the measured actual width depending on the path width. Sheet resistance Rsq can be calculated from equation 1.



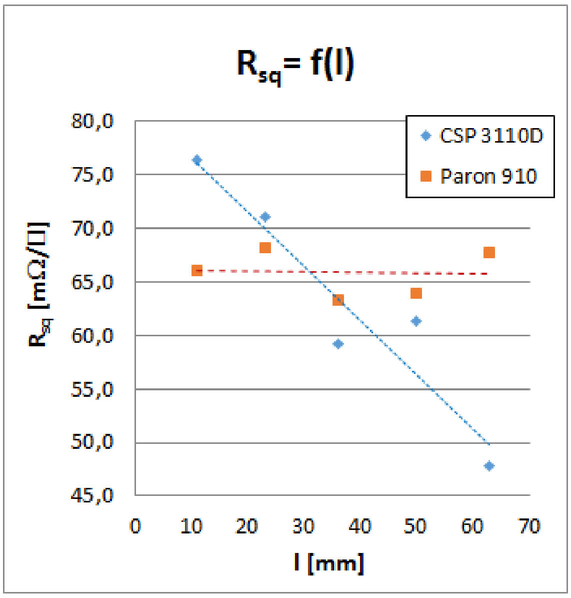
Obr. 2: Dependence of sheet resistance on width of paths for silver pastes

It can be seen from the graphs on fig. 2 and 3 that the value of the sheet resistance is highest for narrow path. For wider paths the resistance on the square with the change in the width of the paths is decreasing. This can be caused by non-constant thickness and width of layer and inhomogeneities, which are most apparent in the narrowest paths. From the path width measurement (see tab. 2), it follows that the path is on average about 0.03 mm wider regardless of the assumed path width. Thus the percentage change in the real width compared to the theoretical width of the path is the largest in the narrowest paths. An exception to such course of behavior of sheet resistance is the dependency for paste Paron 910. This anomaly could be caused by some measurement inaccuracies. Dependence of sheet resistance on width will probably be constant. This may mean, for example, a small amount of print defects and thus small influence on resistance value.

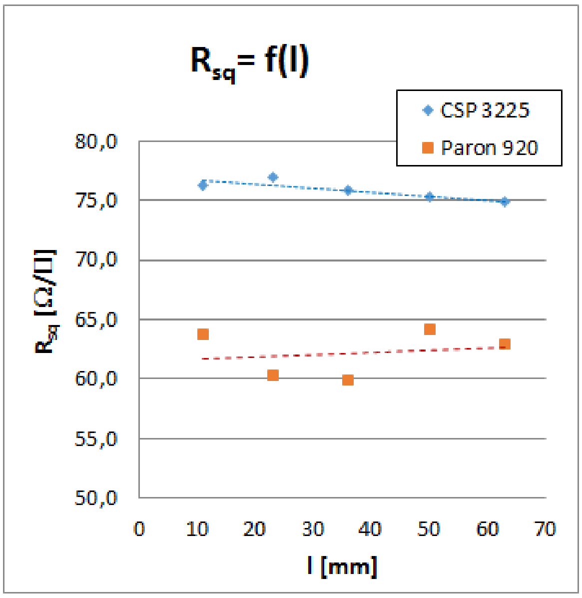


Obr. 3: Dependence of sheet resistance on width of paths for carbon black pastes

For the analysis of dependence sheet resistance on the length the values measured on the paths of pattern No. 2 were used, where are paths with same width. Dependence for the tested pastes is shown the graphs in Fig 4 and 5.



Obr. 4: Dependence of sheet resistance on length of paths for silver pastes



Obr. 5: Dependence of sheet resistance on length of paths for carbon black pastes

The value of sheet resistance with the length of the path is almost unchanged for most samples. For samples deposited by paste CSP 3110D we can see dependence decreasing. There the measured value of resistance is influenced by contact resistance. The measured value resistance includes a contact resistance that appears on the sample contacts with the measuring equipment. This can be assumed to be constant for all paths regardless of their length. When we calculate sheet resistance from measured resistance this phenomenon is most likely to occur on short paths. It can be seen from the graphs that the contact resistance of the carbon paths deposited by pastes CSP 3225 and Paron 920 is negligible due to the size resistance.

CONCLUSION

The measured and analyzed data is influenced by the quality of the samples. Due to the use of a manual screen printing machine, the quality of the samples was affected. In the case of the dependence of the sheet resistance on the width of the layer it was found that with the exception of the narrowest paths of the samples prepared by the CSP 3110D paste, the resistances with the layer width almost did not change. In the case of the narrowest paths, the difference in square resistance from other larger width paths can be explained by the difference between the actual and theoretical width and the inhomogeneities of the layer, which is most evident in the narrowest paths.
When measuring the thickness of the layers using the profile meter, it was also found that the surface of the carbon black structures have lower roughness than in the case of silver pastes, which was probably due to higher solid content and higher viscosity of silver pastes.

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