Ročník 2018 electroscope Číslo I

Influence of Paste´ Viscosity on Precision of Thick Film Printing

S. Zuk, A. Pietrikova, I. Vehec
Department of Technologies in Electronics, Faculty of Electrical Engineering and Informatics, Technical University of Kosice,
Letna 9, 042 00 Kosice, Slovak republic
E-mail: samuel.zuk@tuke.sk, alena.pietrikova@tuke.sk, igor.vehec.2@tuke.sk

Abstract:
In this paper, characterization of thick film structures printed on Kapton PI substrate is presented. By using two different polymer pastes/inks for realisation of planar capacitive comb sensor structures, the influence of paste´ viscosity on precision of thick film printing was investigated. It was found out by doing confocal laser spectral microscopy measurement that there is significant difference not only in the height of the printed structures, but also at every line width dimension printed on the same substrate. Thick film printing of fine planar comb sensor structures using polymer pastes is difficult.

INTRODUCTION

Planar capacitive comb sensor structures are being widely used in different sensing applications [1, 2, 3]. Our previous research [4, 5] showed that sensitivity, repeatability and sensing performance of such a sensing structure is, besides the type of the paste used for printing, in the most cases affected by the homogeneity of the printed layer. For this reason we decided to investigate the influence of paste´ viscosity on the precision of thick film printing process.
Comb sensor structures are very sensitive to repeatability and precision of thick film printing process. Better sensitivity of sensing can be obtained by higher density of comb sensor electrodes. Sensitivity of capacitive comb sensor is also affected by the area of sensor electrodes [4]. It is possible by using standard cermet thick film structures to screen print sensor electrodes with width of 150 µm or less. In our preliminary experiments we found out that thick film printing of polymer pastes using 325 mesh screen is a problem.
In this paper we point out the influence of polymer paste viscosity on precision of thick film technology.

EXPERIMENTAL PROCEDURE

Two different pastes - highly conductive silver colour XZ250 and carbon ink 26-8203 from Britrade with typical viscosity of 30-50 Poise (silver colour) and 70-80 Poise (carbon ink) at 25°C printed on polyimide film foil DuPont Kapton HN of 125 µm thickness were used for this study. For precise characterization of printed structures we printed capacitive comb sensor structures with 200 µm trace width and 290 µm spacing between traces and totally of 40 comb pairs. Such a demanding structure will give us the opportunity to verify the required parameters to a sufficient extent. Design of planar capacitive comb sensor structure used for realisation of this study is presented in Fig. 1. Pads at the bottom of the motive serve as connection to measurement electronic circuit.

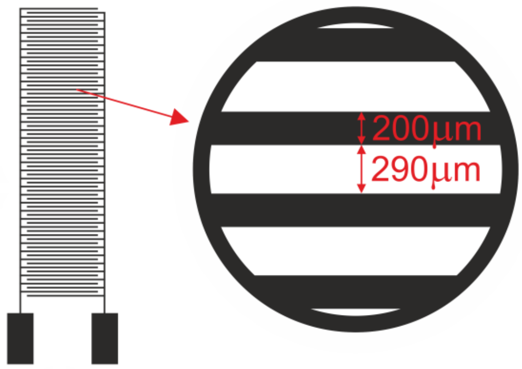

Fig. 1: Realized capacitive comb sensor structure for characterization of printed structures (line width and spacing dimensions for screen printing process)

During screen printing process we used the same screen of 325 mesh for printing process of both pastes, so it was possible to analyse (compare) the influence of paste´s viscosity on the precision of realized structures. Using screen of 325 mesh for constructing of comb structure for lines width 200 µm and spacing between lines 290 µm is in the thick film technology considered as standard and manufacturer of these pastes recommends such a value of mesh. After screen printing process, both pastes were dried for 30 minutes at 120°C according the requirements of manufacturer of the pastes. Tab. 1 shows selected properties of polymer pastes used in this study.

Tab. 1: Selected properties of polymer pastes used for this study [6, 7]

Parameter	*XZ250*	*26-8203*
Resistivity [mΩ/□]	35	<70
Viscosity [Poise] at 25°C	30-50	70-80

For our experiment we used two different conductive polymer pastes of whose viscosity values differs two times, as can be seen in Tab. 1.

Roughness of PI substrates surfaces is 0.044 µm [8]. Thick film printing of structures with line width of 200 µm and with thickness of about 18 µm because of that is not a problem and roughness of surface can be ignored.

In our preliminary experiments when designing comb sensor electrode structure we applied the electrode width of 150 µm. We tried to change many printing process parameters trying to obtain better printing results, however, line width of 150 µm cannot be used when using screen of 325 mesh, because of electrode´s lines contained empty unfilled places. For the design process we changed the design of comb sensor electrodes with the width of electrode of 200 µm as can be seen in Fig. 1.

RESULTS

Sensor structures were screen printed by using screen of 325 mesh. The dimensions of lines and spacing between lines were 200 µm and 290 µm respectively, as can be seen in Fig.1. All samples were characterized by two types of measurement – confocal laser spectral microscopy to obtain thickness profile of realized structures and line width and spacing measurement to obtain real dimensions of printed structures. Measured 3D comb sensor structures of the capacitive sensors realized by silver colour and carbon ink are shown at Fig. 2 and Fig. 4, respectively. Measured thickness profiles of the capacitive comb sensor structures realized by silver colour and carbon ink are shown at Fig. 3 and Fig. 5, respectively.

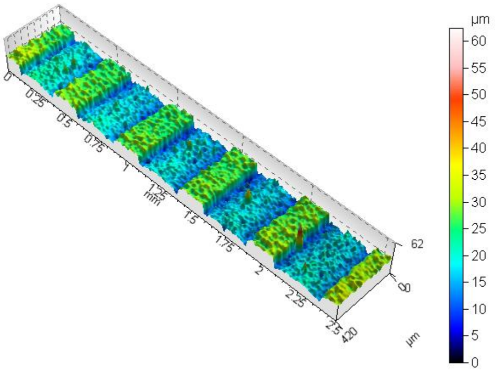

Fig. 2: Measured 3D structure of the capacitive comb sensor structure realized by silver colour

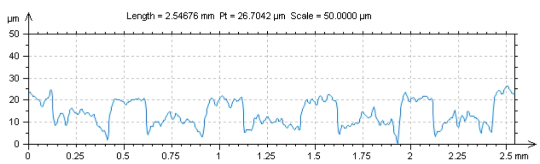

Fig. 3: Measured thickness profile of the capacitive comb sensor structure realized by silver colour

As it can be seen at Fig. 3 and Fig. 5, respectively, measured average thickness of the sensor lines realized by silver colour is about 20 µm, but the same sensor structure realized by carbon ink has the thickness of only about 17 µm.

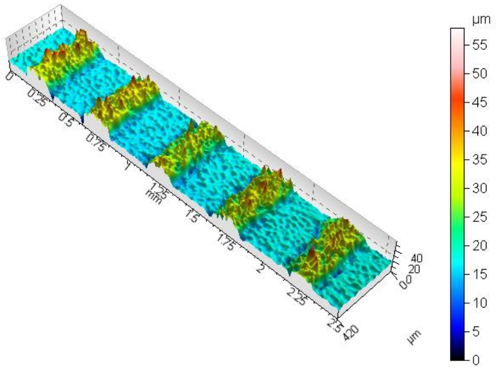

Fig. 4: Measured 3D structure of the capacitive comb sensor structure realized by carbon ink

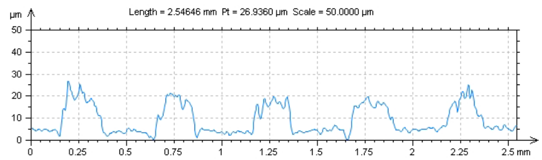

Fig. 5: Measured thickness profile of the capacitive comb sensor structure realized by carbon ink

It was measured that sensor´s traces width is not constant (also the distance between sensor lines of comb structure is changing), but it varies not only by using of different pastes, but also in the sensor structures printed with the same paste. Measured lines and spaces dimensions of the capacitive comb sensor structure printed by Ag colour and carbon ink are presented on Fig. 6 and Fig. 7, respectively.

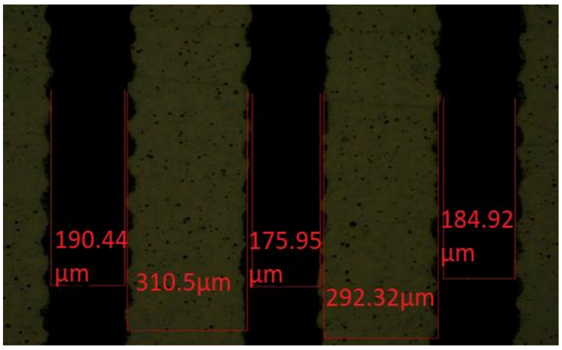

Fig. 6: Measured lines and spaces dimensions on the capacitive comb sensor structure printed by Ag colour

As can be seen in Fig. 6 and Fig. 7, there is up to 20 µm difference of printed line´s width, no matter which paste was used for screen printing process. These variations of line´s widths can be seen not only on one sample structure, but it varies with every of the samples printed with the same paste.

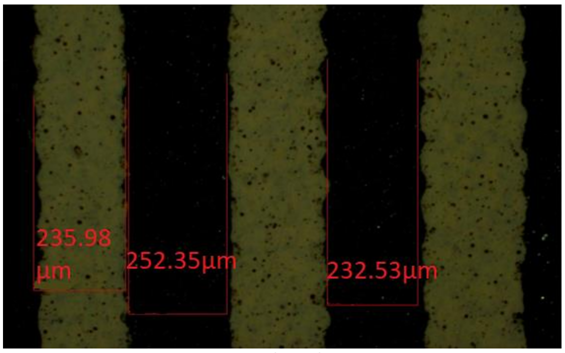

Fig. 7: Measured thickness profile of the capacitive comb sensor structure realized by carbon ink

As it can be seen from the measurements, when using the same screen (325 mesh) and by applying materials of different viscosity, different line widths are printed. For carbon ink (viscosity of 80 Poise), the line width is approximately 18% higher compared to the original printing motive. For Ag colour, where the viscosity is 50% lower (50 Poise), the width of the lines increases by about 50% over the original mesh pattern. In addition, it was observed that even within the only sample, dimensions of lines and distances between lines differ. This fact significantly affected subsequently the resulting values of the measured capacities of these planar capacitive sensors.

Although the mesh size in the 325 mesh screen is generally considered to be suitable for conventional line widths (not less than 200 µm), it can be stated that the viscosity significantly affects the width of these lines as well as the reproducibility of the printing process. Despite the fact that the manufacturer recommends using these materials in the standard screen printing process, such behaviour of the used materials suggests that they are not pseudo plastic or thixotropic fluids. In the case of Ag colour and carbon ink, we recommend to make an entry screen printing test prior to using them in the thick film technology process to avoid confusion in production.

For our experiments, we used materials whose viscosity is much lower (about 100 times) compared to conventional solder pastes. The use of polymer pastes, inks, paints, therefore, requires increased attention when applied. Precise printing of these materials is complicated.

Presented capacitive comb sensor structure will serve for capacitive sensing application as a possible replacement of standard automotive rain sensor. Measured results of performance of these structures are presented in [4].

CONCLUSIONS

This article points out that, when applying the same line width at the screen motive and using materials with different viscosities, paste with higher viscosity value, carbon ink (70-80 Poise) copies the motive of the line with the difference only about 18%. When applying material with lower viscosity value (Ag colour of 30-50 Poise), the width of the line compared to the screen motive is changed about 50%. Before using Ag colour and carbon ink in the thick film technology process we recommend to make an entry screen printing test prior to avoid confusion in production. At such low viscosity this liquids lose the character of thixotropic and pseudo-plastic fluids.

Using polymer pastes, inks and colours is because of their low viscosity values for using precise printing motives problematic, especially for carbon ink, and before screen printing process in spite of producer recommendation it is necessary to make testing screen printing in the relation to the width of lines. Printing fine motives that occupy large areas with mentioned polymer pastes is challenging task.

ACKNOWLEDGEMENTS

This paper was developed with support of the Project "Centrum excelentnosti integrovaného výskumu a využitia progresívnych materiálov a technológií v oblasti automobilovej elektroniky" (Centre of Excellence of Integrated Research and Exploitation the Advanced materials and Technologies in the Automotive Electronics), ITMS 26220120055, that is co-financed from Structural Funds EU ERDF within Operational Program Research and Development OPVaV-2009/2.1/03-SORO and preferred axis 2 Support of Research and Development.

This work was supported by APVV project No. APVV-14-0085: Development of New Generation Joints of Power Electronics Using Nonstandard Sn-Based Alloys.

This work was supported by KEGA project under the contract No. 021TUKE-4/2017: Promotion of modern teaching methods at the Laboratory of automotive electronics.

This work was supported by VEGA project under the contract No. 1/0141/18: Experimental and theoretical behaviour study of newly developed miniature touch capacitive and inductive sensors realized by film technologies.

LITERATURA

[1] X. Hu, "Planar capacitive sensors – designs and applications," Sensor Review, vol. 30, no. 1, pp. 24-39, 2010.

[2] Wilson, J.S. *Sensor Technology Handbook*. Oxford: Elsevier, 2005, 702 s. ISBN 0-7506-7729-5.

[3] B. Goj, H. Bartsch, U. Brokmann and J. Müller, "Thin-film capable ceramics for humidity and temperature sensing applications," in 58th Ilmenau Scientific Colloquium, Germany – Ilmenau, September 2014.

[4] S. Zuk, A. Pietrikova and I. Vehec, "Possibilities of planar rain sensor manufacturing by thick film technology," Acta Electrotechnica et Informatica, will be published.

[5] S. Zuk, A. Pietrikova and I. Vehec, "Capacitive touch sensor," Microelectronics International, vol. 35, no. 3, pp. 153 – 157, 2018.

[6] BRITRADE SLOVAKIA: XZ250 Highly Conductive Silver Colour, Technical Datasheet, Available at: <http://www.britrade.sk/storage/file/strieborna-pasta.pdf>.

[7] BRITRADE SLOVAKIA: Conductive Carbon Paste 26-8203, Technical Datasheet, Available at: <http://www.britrade.sk/storage/file/pasta-flexy.pdf>.

[8] A. Pietrikova, P. Lukacs at al, "Surface analysis of polymeric substrates used for inkjet printing technology," Circuit World, vol. 42, no. 1, pp. 9-16, 2016.