

Deposition of Thick Film Fine Line Patterns by Direct Writing

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Abstract

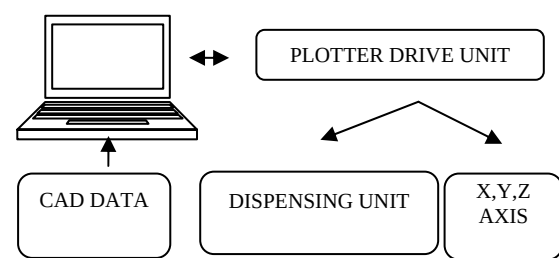
The process of the direct deposition of thick film materials (somewhere known as direct writing) on ceramic and silicon substrates was investigated. Some newly achieved findings and results are described in this paper. Such approach was chosen as a low cost and prompt alternative for deposition of thick film pastes, especially by low volume batches. The use is for hybrid IC's, as well as for a wide range of non-conventional applications (for example for front side of solar cells, antennas, CSP interposers etc.). This relatively new technique offers significant cost and time benefits across a wide spectrum of applications because it eliminates expensive masks and tools. Developed at Brno University of Technology is reasonable and no expensive equipment for direct writing deposition with basic characteristics somewhere between the dispensing and the jetting technique. This equipment consists of a plotter drive unit with dispensing head (with z axis motion) which is situated beyond the x, y axis table, and a control unit with software capable to process CAD data. The substantial part of the head is the z axis holder with syringe and dispensing nozzle. The paste is extruded through a hollow needle, working as a non contact dispense nozzle. Z axis motion is required when the head moves down to the paste transfer position and after pattern completion moves up to the starting position. Paste viscosity including temperature conditions, pressure in the cartridge, speed of the nozzle and distance between the nozzle and substrate are the most important parameters for achieve the optimal setting and resulting paste transfer reproducibility. That is the reason why we investigate in more detail the paste transfer which depends essentially on paste viscosity. Obviously constant pressure, optional heating of the cartridge and constant movement of either the needle or the substrate also have a significant impact on the uniform and homogeneous paste transfer. Various materials under various process conditions are applied to achieve favourable results with good quality and reproducibility. Subsequently, the shape of the deposited layer has been observed, measured and evaluated. Also electrical properties of the deposited conductor materials were evaluated.

Introduction

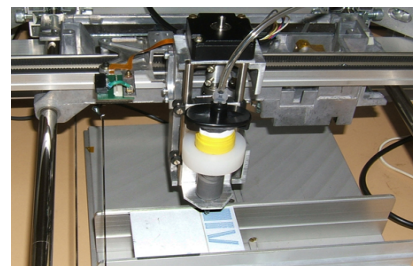
The direct write approach of thick film paste may be utilized to deposit a single layer of pattern or to sequentially stack layers of material to produce a multilayer pattern as well. To achieve a reproducible and reliable transfer of thick film paste on the substrate it is necessary to define in advance some technological parameters of this process on the base of defined paste transfer. The volume of paste transferred through nozzle, speed of nozzle, distance of nozzle from substrate and others are technological factors to define and to optimize, in order to achieve the requested reproducibility and reliability. But most of these parameters are related to viscosity. The construction of the equipment is also very important for the quality of deposition.

The realized prototype equipment uses a computer automated device to achieve precision printing of thick film materials. Rather than being screen printed or etched, patterns are drawn on a substrate with non-contact nozzle. The printing device consists of a plotter drive unit based on the XY axis table, Z axis holder of syringe with dispensing nozzle and control unit. The control unit

with software capable process CAD data is used to control the deposition process.



a)



b)

Fig. 1: Writing equipment a) block diagram
b) detail of the dispense nozzle

The paste is extruded with compressed air of the micro dosing unit through a hollow needle, working as a dispense nozzle. Constant pressure and constant movement of either the needle or the ceramics substrate enables a uniform and homogeneous paste application. The block diagram of this equipment shown on Figure 1a gives a good idea about the basic principle of this equipment and its basic arrangement. Detail of the dispense nozzle is shown on Figure 1b.

Factors influencing dispensing process

There are diverse factors influencing transfer of paste through the nozzle on the substrate. These factors are internal (dispensing unit and x,y,z axis motion) and external (paste and substrate). The basic parameters that are decisive for assurance of quality deposition are shown in the Ishikawa diagram (Figure 2).

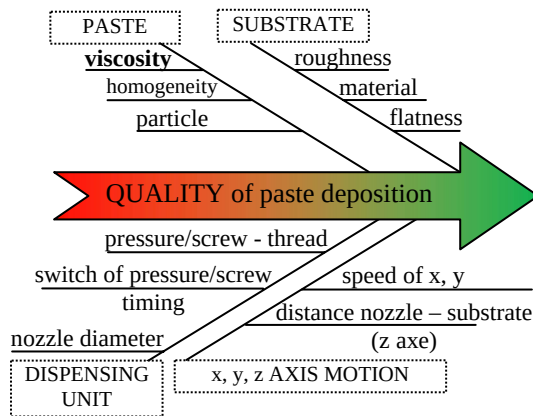


Fig. 2: Ishikawa diagram for direct writing process

The most significant parameters were established after a couple of experiments. Paste viscosity, pressure in the cartridge, speed of the nozzle and distance between the nozzle and substrate are substantial parameters that can assure good paste deposition and the desired reproducibility of the whole process. These results of correlation are summarized in Figure 3.

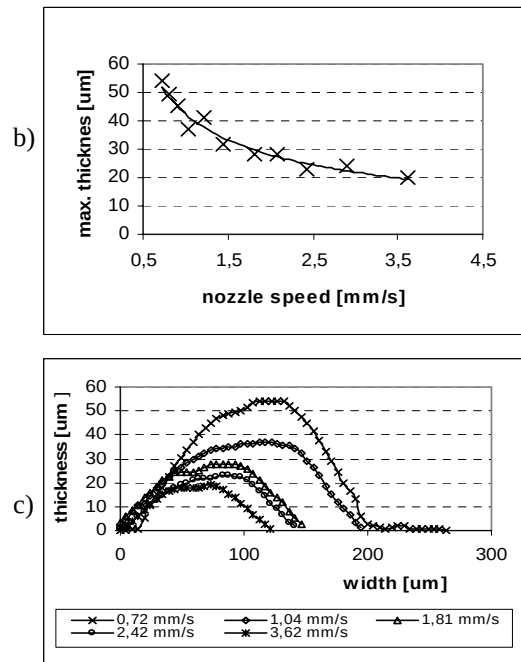
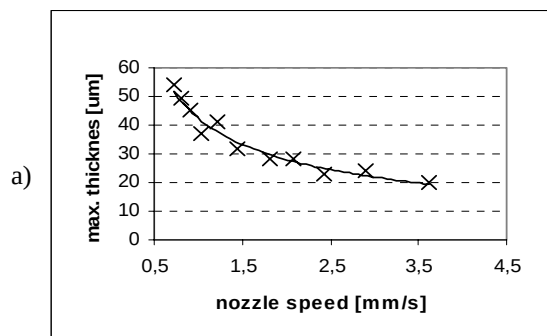


Fig. 3: Relationship between a) nozzle-substrate gap and line width b) deposited layer thickness and nozzle speed c) deposited profiles obtained by different speed

Paste transfer and viscosity

Paste transfer proceeds from the syringe to substrate through the nozzle, which is terminated by a needle with a defined diameter. Paste behaviour during the transfer from the syringe to the deposition on the substrate can be considered on the base of the character of a non-Newton liquid. As well as each paste transfer technique requires certain viscosity to assure a good quality and reproducible results, viscosity is important for direct writing, especially when the resolution moves to lower values, which means to 100 microns and less.

The adjustment of the viscosity of the paste to an optimal value depends on a couple of factors. The most important are the pressure in the cartridge (defines the speed of paste transfer) and the needle diameter. But the viscosity is closely connected with temperature too. Our experimental work has shown significant dependence of paste transfer quality and reproducibility on rheology behavior. Especially the temperature has to be controlled if we want to achieve a resolution less than 100 microns. That is why we investigate the paste behavior in more detail by paste transfer simulation, to obtain optimal paste transfer conditions (see Fig. 4). The force reacting reversibly inside the fluid towards the movement of the elementary paste particles is excited by viscosity. However, the

flowing in the centre of the dispensing needle has the maximum speed. The lowest flow speed is in the boundary layer.

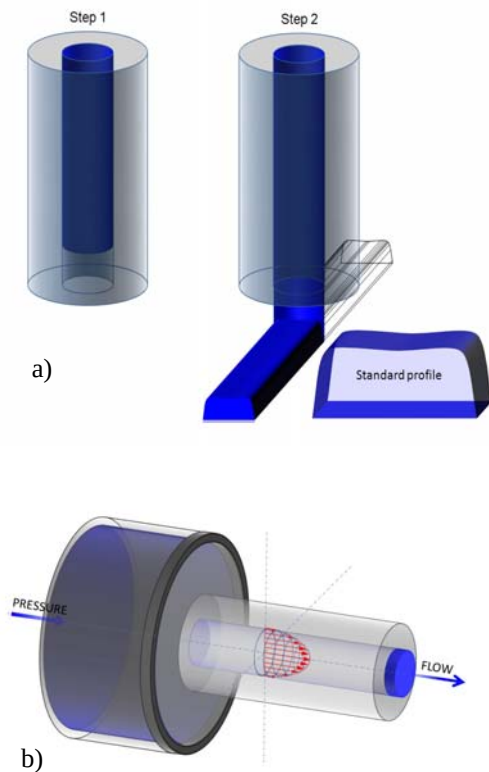


Fig. 4: Simulation of paste transfer a) through needle on substrate b) in needle aperture

To achieve a steady paste flow, invariable viscosity of paste in the transfer point has to be achieved when the paste is transferred from the needle on the substrate. This can be realized when we are able to set in the optimal values foremost:

- viscosity range,
- speed of paste transfer,
- type of nozzle.

It is obvious that the paste viscosity is a fundamental parameter, and for very precise deposition it would be optimal to monitor it consecutively immediately in the syringe. Whereas the viscosity for screen printing moves around 1400 Pa.s, for direct writing it is usually lower, between 400 and 1200 Pa.s. However, there is one important topic leading to process optimization: the relevance between the paste viscosity and the optimal device settings for concrete types of materials, especially if a resolution less than 100 μm is required.

Some experimental results

Various materials under various process conditions were applied to verify the possibilities of this technique for achieving reproducible results.

Subsequently, the shape of the deposited layer (see Fig. 1) was measured and evaluated, and also electrical properties of the deposited conductor materials.

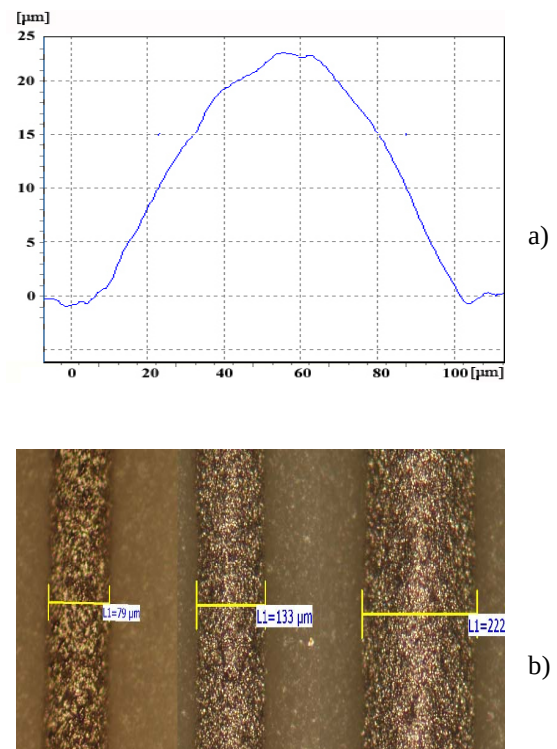


Fig. 5: ESL8844G Au paste deposition
a) the shape b) conductive lines of various width

In Fig. 5a the profile of the deposited conductor line is shown, and in Fig. 5b are some details of conductor lines of various widths (220 microns, 133 microns and 79 microns) deposited by the conductive paste ESL 8844G. It should be mentioned that good reproducibility results were achieved by applying these line widths.

As we demonstrated before [4],[5],[6], the direct write technique is capable to produce circuits on various substrate surfaces. One example realized on the inorganic alumina substrate is shown in Fig.6. There is an interconnection module board for TQFN-EP package as an example of rapid prototyping.

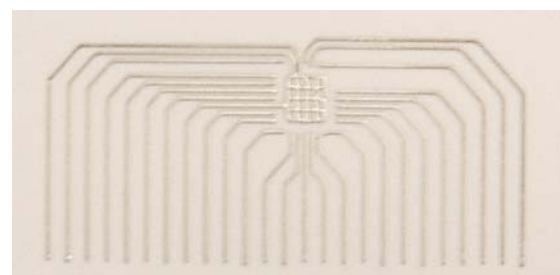


Figure 6: 28 TQFN-EP package expansion board

Another example of a component produced by direct writing is shown in Figure 7. There is example of a coil deposited by AgPd thick film conductive paste (ESL 9635-HG). Topology modification is rather easy because it can be done by a simple software arrangement.

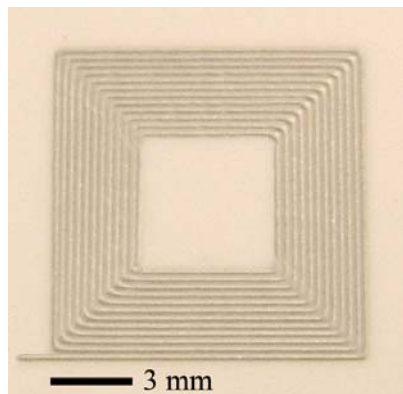


Figure 7: The test coil realized by direct writing technique

Conclusion

This work has presented the possibility to use the deposition of common thick film materials by direct writing technique. In this way can be deposited various types of pastes, conductive as well as dielectric and insulating. The deposition of resistor paste will be investigated. However, there are more parameters that influence significantly paste transfer by direct writing. Two of them are fundamental and have to be defined precisely paste viscosity and equipment adjustment. Both of them are more significant if the resolution of deposited layers is smaller lower, which means that the resolution value is 100 microns and less. Then it is necessary to control paste viscosity and to define the optimal device settings (pressure, nozzle diameter, speed of transfer) for concrete type of application (deposited material, substrate etc).

The simple usage and user-friendly interface (guaranteed by using a computer with comprehensible software) predestines the direct writing workplace for the production of prototypes and small series of thick film circuits and non conventional applications such as sensors, solar cells etc. Our investigation has presented the possibility to use common thick film materials for deposition on inorganic substrates by direct writing, only the viscosity needs to be matched. Then various types of pastes can be deposited, such as conductive, dielectric and insulating ones. The possible use of resistive materials is examined.

Results have shown that this process constitutes the flexible, reconfigurable and user-friendly technique to create various patterns without long

set-up time. The direct write approach may be utilized to deposit conventional thick film materials in the single layer of pattern or to sequentially stack layers of material to produce multilayer patterns. To achieve the desired deposition process reproducibility with low cost is the main aim of this work. But obviously, an interim way is the solution for each concrete process.

Our further research may be directed to deposition on organic substrates. We suppose that this method can be used for solder paste deposition as well, and for various materials with defined viscosity, such as adhesives etc. Generally, this process represents a flexible, reconfigurable and user-friendly tool for production of various patterns with the use of direct writing technique without long set-up times.

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