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Influence of Screen Printing Mesh Count on Deposition of Graphite-Starch Conductive Ink onto Cardboards

ABSTRACT

Due to the increasing need for flexible and lightweight electronic components, the market for printed electronics is continuously growing and is to reach almost 40 billion USD in 2030. Therefore developing a more sustainable conductive inks is highly important. The aim of this paper is to propose conductive ink with graphite as a conductive component, dispersed in starch paste for the application on cardboard using screen printing technique. For the purpose of this research printed samples were prepared on two types of cardboard (coated and uncoated) by printing with various screen printing mess thread count. The samples were evaluated by measuring optical density, visual inspection and by measuring electrical resistance. The results of the evaluation showed that both cardboard surface finish and screen printing mesh count is significantly influencing ink film formation. Additionally, only samples printed with 32 lpcm screen printing mesh count achieved electrical resistance lower than 2 kΩ. It can be concluded that graphite-starch conductive ink has the potential for use in printed electronics, but due to the high electrical resistance and relatively bad ink film forming on coated cardboard, it should be improved. The future work will be focused on increasing conductivity and improving wetting on smooth, coated surfaces.

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KEY WORDS
Screen printing, conductive ink, graphite, starch

1. Introduction

The need for flexible and lightweight electronic components is growing across various industries. That fact is driving the market of the printed electronics with the CAGR of 15.4% from 2025 – 2030, i.e. almost doubling the global market size from 19.46 billion USD in 2025. to 39.85 billion USD in 2030 (Printed Electronics Market Size, Share, Latest Trends & Growth Analysis, 2025-2030, n.d.) . For the successful printed electronics there are two main influencing factors – the functional printing ink and the printing process. Printed electronics include various traditional, master based printing techniques, but inkjet as well (Wiklund et al., 2021) . One of the often used printing processes is screen printing due to the possibility of deploying thick ink layers on the printing substrate. With the growth of environmental concern and a number of electronics applications the research effort was put into development of the sustainable ins for printed electronics. The inks are often composed of metal particles (silver or copper) which are dispersed in some organic solvent (Sanchez-Duenas et al., 2023). In addition, many of the functional inks in printed electronics are solvent based and use thermal energy for curing ("Functional Inks for Printed Electronics- Demystified," 2026).

Graphite offers conductivity and as a relatively cheap material it was investigated as a base for the producing affordable conductive ink with various binders: nail polish (Oliveira & Pereira, 2021) and corn starch (Dey et al., 2025) applied on the substrate by a brush and chitosan (Marchianò et al., 2024) applied by stencil printing. These papers showed that there is high potential in graphite based conductive inks.

Having these results in mind, aim of this paper was to prepare a graphite-starch conductive

ink and apply it on a cardboard substrate using screen printing technique to determine its usability as a screen printing conductive ink.

2. Materials and methods

For the purpose of this paper a conductive printing ink was prepared by mixing graphite powder (particle size 20 µm, Sigma Aldrich) into tapioca starch solution. Composition of the conductive ink can be seen in Table 1.

Table 1
Components of the conductive ink

Component	Amount
Tapioca powder (Nutrigold)	5 g
Graphite powder (Sigma Aldrich)	5 g
Glycerol (pro analysi, Gram.mol d.o.o.)	2.5 g
Distilled water (INA d.d.)	50 ml

The conductive ink preparation was performed by weighing tapioca powder and glycerol using Mettler Toledo XS205DU. The components were put into a glass container and water was added and mixed with the glass stick at room temperature. After achieving even mixture, graphite powder was added to solution and mixed using magnetic stirrer (Tehtnica rotamix). The prepared solution was mixed at 500 rpm and with increasing temperature up to 65 oC by increasing temperature by 2 oC pro minute on average. After achieving defined temperature, printing ink was left to cool down to room temperature.

The procedure was set after a few trials in which increasing temperature to the ones found in literature (Lukavski et al., 2025; Żołek-Tryznowska & Kałuża, 2021) made prepared ink difficult to print. By using the described procedure prepared ink was printable paste.

The printing form used for the purpose of this research was prepared using capillary film with thickness of 25 µm (CDF vision 25, ULANO). Used screen printing meshes were all made of polyester with white threads. The mesh count of the used printing forms is shown in Table 2.

Table 2
Screen printing mesh count used

Screen mesh count	Thread diameter (µm)
32	100
61	64
100	40

The printing substrates were typical cardboards with two surface finishes, one coated with gloss finish (UPM Finesse white gloss) with a grammage of 305 g/m^2 and the other was uncoated (Sappi Tauro) with a grammage of 300 gm^2.

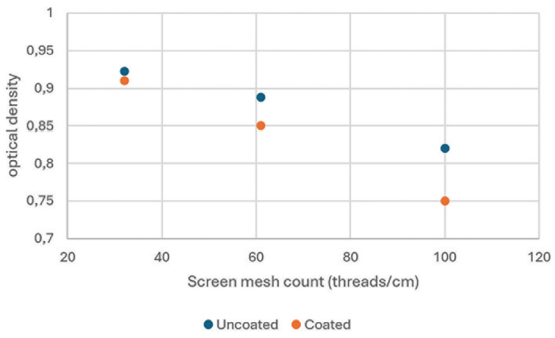
The printing process was performed manually with handheld squeegee and a vacuum table used to hold cardboard fixed during printing.

After printing, prepared prints were dried at room temperature and additionally processed by exposing them to hot air at 100 oC for 20 min by using Memmert UNB400 heating chamber.

The prepared samples were analyzed by measuring optical density of the printed ink film (Techkon SpectroDens), visual inspection of microscopic images obtained using Olympus BX-51 and finally by measuring electrical resistance using Milli-Ohm metar Viei VC480 C+.

3. Results and discussion

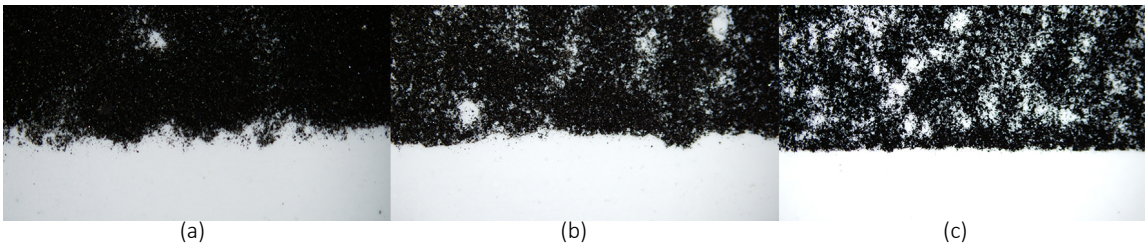
The optical density indicates the ink transfer and indirectly the thickness of the formed ink film on the printing substrate. In Figure 1 one can see the value of achieved optical density printed with different screen printing mesh count. It is visible that higher values of optical density are achieved on the uncoated cardboard compared to the coated cardboard. These results were not expected as prior research like (Cigula et al., 2019; Seymour, 2021) showed that on coated papers optical density is higher than on the uncoated ones.



» **Figure 1:** *Optical density on prepared prints*

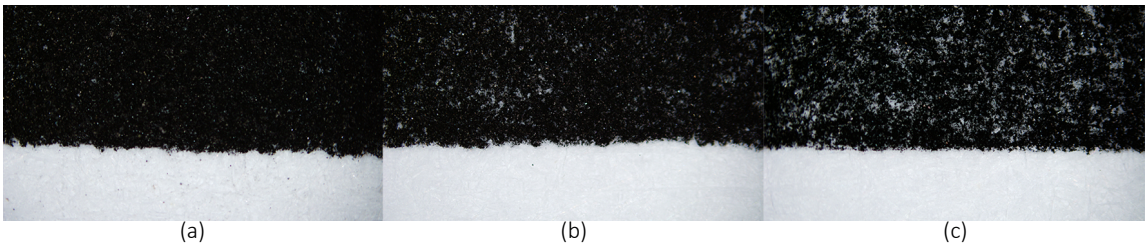
The results of the optical density indicate that the ink film thickness on the coated cardboard is lower than on the uncoated cardboard.

The printed ink is composed of starch and graphite with water as a solvent. Although in the form of paste, it is still a thick liquid and the surface properties of the printing substrate significantly influences the ink transfer. The most paper/cardboard coatings used today are polymer based and therefore have low polar component of the surface free energy leading to lower adsorption of the water based printing ink. On the other hand, uncoated paper/cardboard has rough



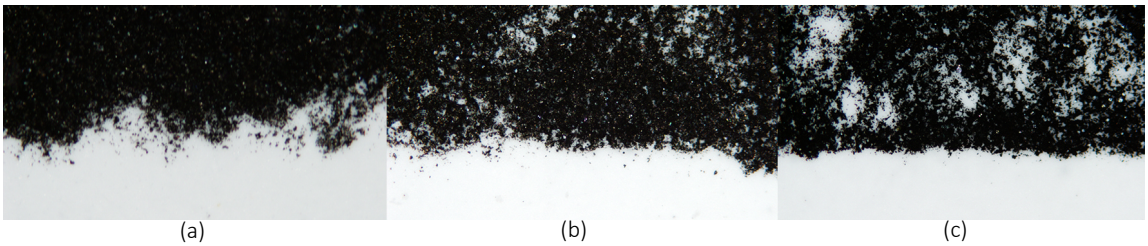
(a) (b) (c)

» **Figure 2:** *Micrographs (50×) of prints on coated cardboard: a) 32 lpcm, b) 61 lpcm, c) 100 lpcm*



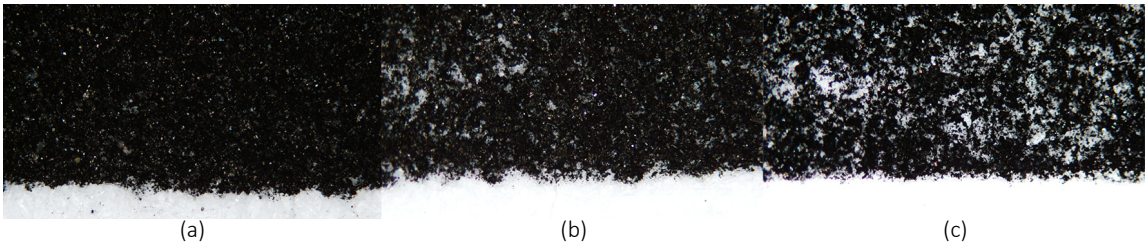
(a) (b) (c)

» **Figure 3:** *Micrographs (50×) of prints on uncoated cardboard: a) 32 lpcm, b) 61 lpcm, c) 100 lpcm*



(a) (b) (c)

» **Figure 4:** *Micrographs (100×) of prints on coated cardboard: a) 32 lpcm, b) 61 lpcm, c) 100 lpcm*



(a) (b) (c)

» **Figure 5:** *Micrographs (100×) of prints on uncoated cardboard: a) 32 lpcm, b) 61 lpcm, c) 100 lpcm*

surface with pores in the structure which enables adsorption of the ink during the printing process. In this case enabled formation of thicker film of ink despite ink's absorption into the paper/cardboard structure.

The above mentioned behaviour of the ink is visible in Figures 2 and 3 where one can observe uneven ink film layer with visible white areas, where ink is not present. These white areas are more present on coated cardboard and when printed with higher screen printing mesh count.

On the other hand, although prints on the coated paper should have sharper edge, observing Figures 4 and 5 one could se the opposite, i.e. the line edge on the uncoated paper is a bit smoother than the prints on coated paper.

In the final step of evaluation, electrical resistance on prepared samples was measured and the results are presented in Table 3. The electrical resistance is very high. The measuring range of the used unit was up to 2 kΩ and the only two samples had electrical resistance lower than the measuring range- samples printed with the screen printing mesh count of 32 lpcm.

The unevenness of the ink film and visible areas where ink is not visible (Figure 2 and Figure 3) are decreasing the conductivity of the printed lines.

Table 3
Electrical resistance on the prepared samples

Screen printing mesh count	Electrical resistance (kΩ)	
	Coated cardboard	Uncoated cardboard
32	1.77	1.51
61	> 2	> 2
100	> 2	> 2

4. Conclusions

The aim of this paper is to propose conductive ink with graphite as a conductive component, dispersed in starch paste for the application on cardboard using screen printing technique. For the purpose of this research printed samples were prepared on two types of cardboard (coated and uncoated) by printing with various screen printing mesh count. The samples were evaluated by measuring optical density, visual inspection and by measuring electrical resistance.

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To conclude, graphite-starch conductive ink has the potential for use in printed electronics, but due to the high electrical resistance and relatively bad ink film forming on coated cardboard, it should be improved. The future work will be focused on increasing conductivity and improving wetting on smooth, coated surfaces.

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