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Stability of silver based conductive films on cellulose based substrates

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Introduction

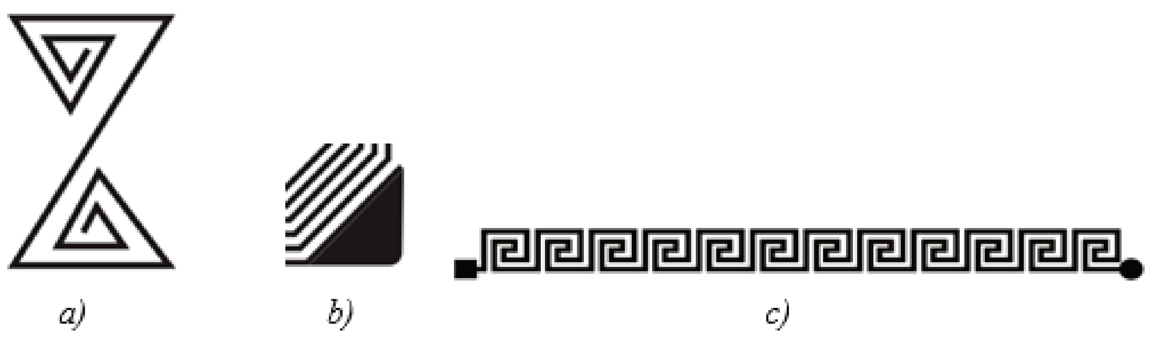
Printed sensors, including capacitive, electrochemical, and RFID tags, benefit from printing technologies due to their low cost, flexibility, and high production volumes. These sensors are essential in industries like healthcare, environmental monitoring, and consumer electronics, where lightweight, compact, and deployable solutions are needed. Printing methods allow integration into smart devices and the Internet of Things.
Various printing techniques, such as flexography, gravure, and inkjet printing, create devices like diodes, transistors, and antennas using conductive, semiconductive, or dielectric inks. Printed thin films on recyclable substrates offer eco-friendly options for electronics, enabling flexible and lightweight components, with applications in environmental monitoring, wearable devices, and education.
Conductive inks on paper lower production costs and speed up prototyping, supporting sustainable electronics development, including smart packaging and health monitoring. Studies show performance variability in paper-based printed antennas due to printing process, ink absorption, and temperature. The goal of this research is to evaluate silver-based conductive films on cellulose substrates, focusing on electrical conductivity, print quality, and mechanical durability, assessing their potential for eco-friendly, durable electronics.

Problem Description

This study examined the possibility of applying conductive silver-based film on cellulose based substrate through the examination of the electric conductivity of silver-based thin films by comparing the quality of prints on two substrates. Additionally, the resistance of printed thin films to double bending and rubbing was investigated.

Materials and Methods

Since the goal is for the antenna to become an integral part of the design, atypical shapes to test their stability were created. The patterns for printing were prepared in Adobe Illustrator (Figure 1).



a) b) c)

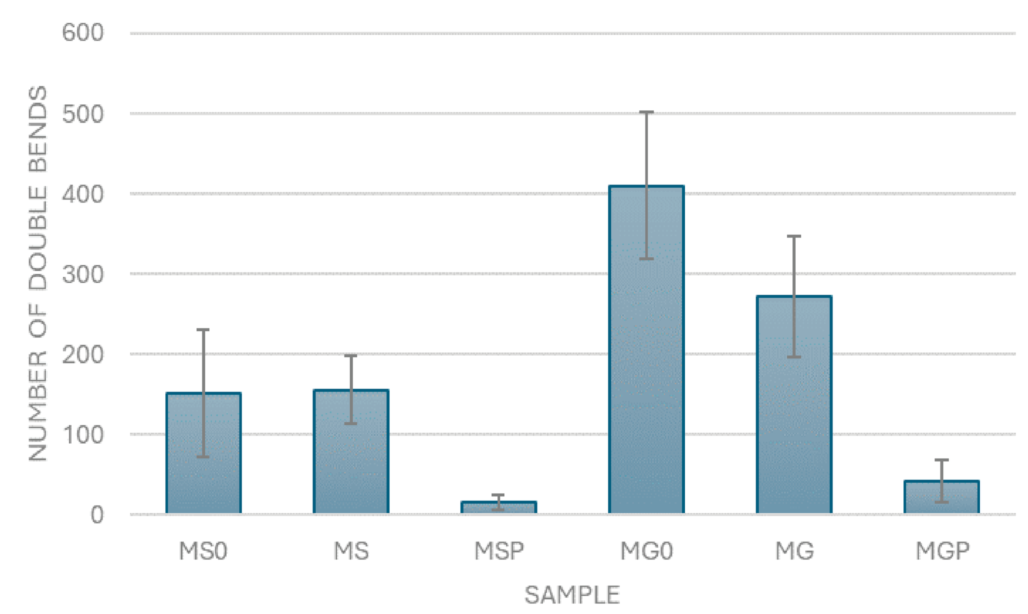
Figure 1

Patterns for printing (a-sample for resistance measurement, sample for rub test, sample for double folding test).

The screen-printing technique was used for printing, utilizing a capillary photosensitive film with a mesh count of 140 lines per cm, and the base material is polyester, specifically poly(ethylene terephthalate). In this study, Saral HSCSilver 600 high-conductivity ink.

Results and discussion

The double folds for unprinted satin paper (MS0) range from 65 to 281, averaging 151. After exposure to 70°C for 10 minutes, the average remains 156. In contrast, printed satin paper (MSP) drops significantly, averaging 16 folds. Unprinted coated paper (MG0) averages 410 folds, and exposure to 70°C reduces this to 273. Printed coated paper (MGP), after exposure, averages 42 folds. Graph1 illustrates that printed papers (MSP, MGP) have significantly lower mechanical resistance to double folds than unprinted papers (MS0, MS, MG0, MG).



Graph 1

Comparison of the results of double folds for coated papers (MG0 - original paper, MG - paper exposed in the oven, MGP - printed thin film exposed in the oven) and satin papers (MS0 - original paper, MS - paper exposed in the oven, MSP - printed thin film exposed in the oven).

Figure 2

Abrasion on the prints after rub resistance tests with the frequency of 30, 40 and 50 rotations with weights .

As for rub resistance tests, the visual assessment of coated paper is notably better. In comparison to satin paper, abrasion is less prominent across multiple samples (Table 1). When comparing the results for rub resistance on satin and coated paper, it is clear that less ink transfers from prints made on coated paper, making these prints more durable.

Sample	Grade	Sample	Grade
MS-1	2	MG-1	2
MS-2	2	MG-2	1
MS-3	3	MG-3	4
MS-4	4	MG-4	3
MS-5	4	MG-5	2
MS-6	2	MG-6	3
MS-7	3	MG-7	4
MS-8	3	MG-8	3
MS-9	4	MG-9	4
MS-10	5	MG-10	3

Table 1

Evaluations of the visual assessment of prints on coated papers (MG 1-10) and satin papers (MS 1-10).

Figure 2 shows abrasion on the prints after rub resistance tests with the frequency of 30, 40 and 50 rotations with weights .
he average electrical resistance of the selected line on the coated paper measures 135 ohms, in contrast to 51 ohms for the satin paper. The standard deviation is significantly greater than any individual measurement, indicating inconsistency in the obtained prints. The values obtained from measuring the resistance of lines printed on paper can be highly unbalanced due to several factors. Firstly, the inherent variability in the printing process itself can lead to inconsistent ink deposition, resulting in uneven conductivity along the printed line. Additionally, the properties of the paper substrate, such as its texture and moisture content, can affect how the ink adheres and interacts with the surface, further contributing to variations in resistance. Lastly, environmental factors, such as temperature and humidity, can also impact the electrical properties of both the ink and the paper, leading to fluctuating resistance measurements.-such as its texture and moisture content, can affect how the ink adheres and interacts with the surface, further contributing to variations in resistance. Lastly, environmental factors, such as temperature and humidity, can also impact the electrical properties of both the ink and the paper, leading to fluctuating resistance measurements.

Conclusions

The research results show that conductive thin films based on silver printed using screen printing on fibrous substrates exhibit variable properties in response to various external factors, such as mechanical bending, abrasion, and exposure to high temperatures. Thin conductive films printed on coated papers demonstrated greater resistance and stability compared to those on satin papers, highlighting the importance of selecting an appropriate substrate for applications in smart packaging solutions. However, challenges such as reduced mechanical resistance after printing and heat exposure indicate a need for further research and optimization of the process.

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