Development of large flake water-based graphene ink for 3D-printed electronics

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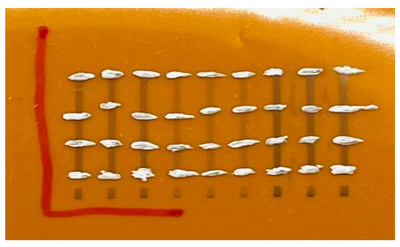
Project Background

In recent years, conductive inks have become vital for flexible electronics, sensors, and other printed devices. These inks, which create electronic circuits through printing and drop casting, rely on factors like formulation, layer count, and curing for optimal conductivity. This project explores how specific additives influence the conductivity of these inks, aiming to enhance their efficiency and performance in various applications. Understanding these relationships is crucial for improving the efficiency and performance of conductive inks in various applications.

Introduction

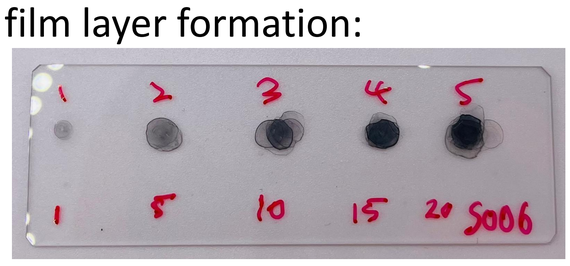


Various printing, drop-casting, and experimental techniques were modified to optimize the printing and drop-casting processes. The project's goal was to evaluate how the addition of an additive influences the overall conductivity of the ink. Two tests were conducted to analyse the impact of the number of layers on sheet resistance and to determine how oven time affects sheet resistance.

Methods and Materials

Firstly, rheology tests were conducted to confirm that the new ink formulation was within the jettable range. Drop casting was performed using the circular drop casting method on microscopic slides with layers of 1, 5, 10, 15, and 20. Electrical measurements were taken, and the following additives were selected based on their improvement in conductivity or film layer formation:

1.Ink B Control
2.Methyl cellulose
3.Ethyl Cellulose
4.Graphene Quantum Dots
5.D-Mannitol
6.Tannic Acid



Example of drop casting

Graphink 1 was chosen for printing due to its highest sheet resistance of 2kΩ/sq during drop-casting. A DIMATIX printer, optimised for consistent jetting, was used to print on Kapton, selected for its heat and chemical resistance. Electrical resistance was measured using the 4-probe technique with silver paste contacts and Keithley 2400 source meters.

Pre-Treatment

Ink B+ Additive	Sheet Resistance
Methyl Cellulose 10 & 20 L	> 10MWΩ/sq
Ink B control 10 L	9kΩ/sq
Ink B control 20 L	**2kΩ/sq**
Tannic Acid 10 L	230kΩ/sq
Tannic Acid 20 L	22kΩ/sq
Graphene Quantum Dots 10 L	500kΩ/sq
Graphene Quantum Dots 20 L	115kΩ/sq
D-mannitol 10 L	33kΩ/sq
D-mannitol 20 L	27kΩ/sq
Ethyl Cellulose 10 L	> 10MWΩ/sq
Ethyl Cellulose 20 L	> 10MWΩ/sq

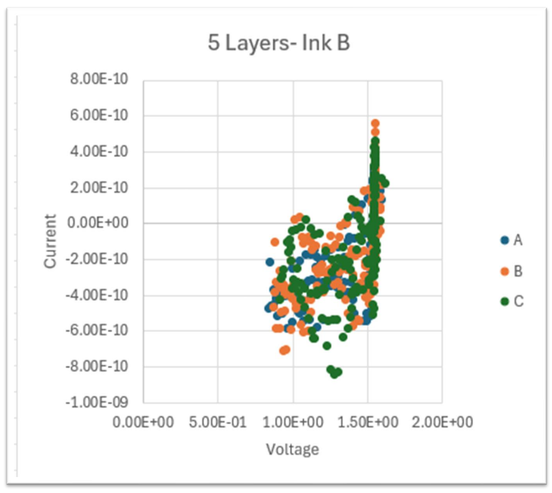
Post-Treatment

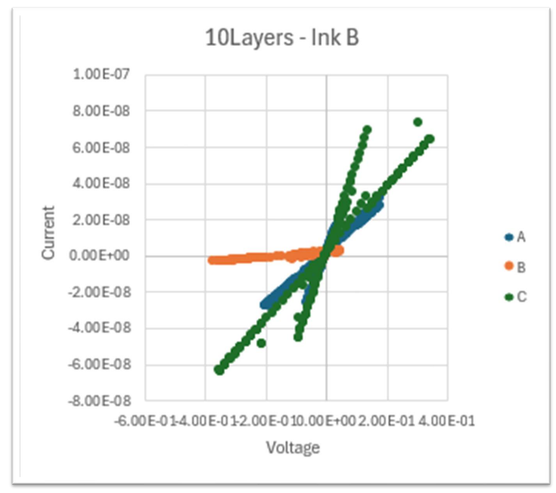
Ink B+ Additive	Sheet Resistance
Methyl Cellulose 10 &20L	> 10MWΩ/sq
Ink B control 10 L	2kΩ/sq
Ink B control 20 L	**700Ω/sq**
Tannic Acid 10 L	37kΩ/sq
Tannic Acid 20 L	5kΩ/sq
Graphene Quantum Dots 10 L	55kΩ/sq
Graphene Quantum Dots 20 L	8kΩ/sq
D-mannitol 10 L	3kΩ/sq
D-mannitol 20 L	5kΩ/sq
Ethyl Cellulose 10 L	900kΩ/sq
Ethyl Cellulose 20 L	5MWΩ/sq

Results

Printing Results

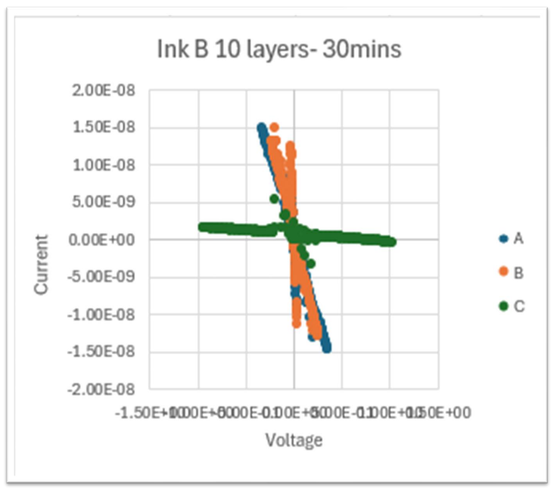
Number of Layers vs Sheet Resistance

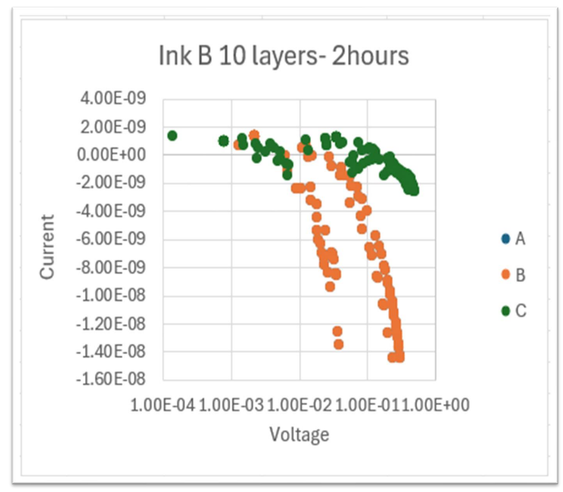




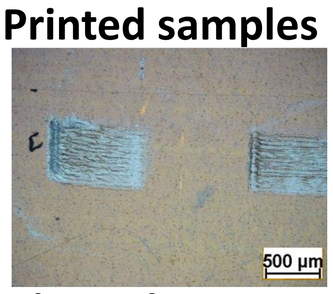
Printing Results

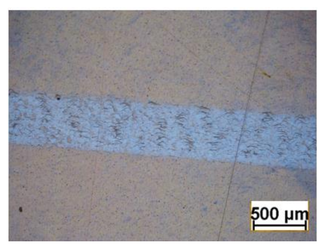
Oven Time vs Sheet Resistance





Printed samples





Discussion

Printed samples showed a good film layer but the electrical measurements indicated that their conductivity was lower than that achieved through drop casting with the majority of values in the megaohms range. This discrepancy may be due to:

- nature of drop casting, where human error and the tape technique used could introduce more variability.
- Drop casting often results in super-concentrated areas
- drop-cast ink contained butanol, whereas the printed ink did not, further influencing the results

Conclusion

These factors may have influenced the physical properties of the graphene, leading to the unexpected differences between the drop-cast and printed samples. Further research on the original Graphink 1 and its composition is necessary to determine its conductivity without additives and to identify the causes of the instability in the ink's performance.

References

Austin, J.S. *et al.* (2024) 'Developing colloidal nanoparticles for inkjet printing of devices with optical properties tuneable from the UV to the Nir', *Journal of Materials Chemistry C*, 12(29), pp. 10992–11000. doi:10.1039/d4tc01917b.
Bastola, A. *et al.* (2023) 'Formulation of functional materials for inkjet printing: A pathway towards fully 3D printed electronics', *Materials Today Electronics*, 6, p. 100058. doi:10.1016/j.mtelec.2023.100058.