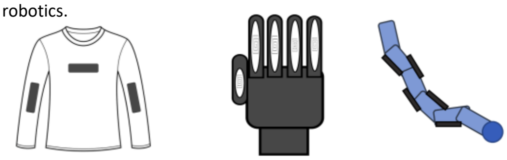
Towards 3D Printed Graphite-PDMS Composites for Soft Stretchable Sensors

Elabd, D.[1], Hu, M.[2], Keshavarz, M.[2], Kassanos, P.[2], Burdet, E.[1]
[1]*Department of Bioengineering, Imperial College London, UK*
[2]*The Hamlyn Centre, Institute of Global Health Innovation, Imperial College London, UK*

HAMLYN SYMPOSIUM ON MEDICAL ROBOTICS 2021

1. Introduction

Stretchable sensors are vital for physiological monitoring and soft robotics.



Wearable sensors: Bioimpedance, ECG, EMG, temperature, sweat analysis

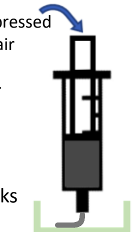
Robotic hand finger pressure sensors

Snake-like robots with sensing skin

Printing techniques:

- Stencil printing → Requires masks and contact – Closed surfaces cannot be printed
- Screen printing → Requires masks and contact
- Inkjet printing → Unsuitable for high viscosity inks

Solution: Extrusion-based printing → Contactless, suitable for high viscosity

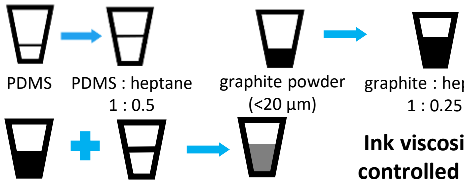


Extrusion-based printing

- **Aim:** use of an elastomer (PDMS) with carbon or silver fillers as inks for printing sensors for physiological monitoring and force sensing for wearables and surgical soft robots.

2. Methods

Ink fabrication



Ink viscosity controlled by heptane, based on nozzle size

Extruding nozzle profiles

Straight **Tapered**

Tapered nozzles → less extruding pressure→ finer printing

Nozzle inner diameter: 27 AWG (⌀ 210 μm)

Printing

27 AWG nozzle.
Optimized Print Parameters:

Min. pressure = ~6.5 psi
Print speed = 15 mm/s
Layer height = 0.08 mm

Printing on fully cured PDMS

Print files: G-code scripts, allow finer control of the print process.

Allevi 2 3D Bioprinter

3. Results

Prints

Cured at 70 °C for 2 hours

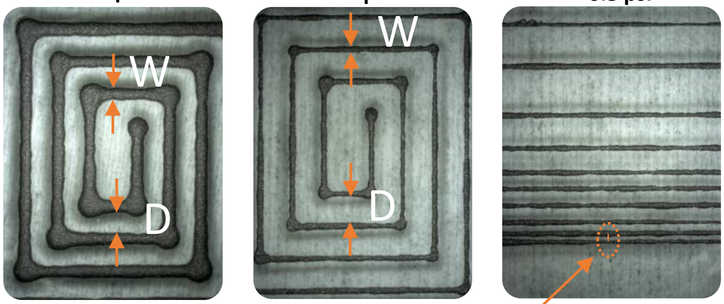
Rectangular spiral (inductor pattern) 8.5 psi (left) and 6.7 psi (right)

Meander

Strong adhesion between PDMS and printed ink after curing.

Lines for resolution assessment
Min. defined separation in G-code = 0.7 mm

Microscope images



8.5 psi: W = 665 μm, $\sigma_w = \pm 48$ μm; D = 1138 μm, $\sigma_y = \pm 23$ μm

6.7 psi: W = 315 μm, $\sigma_w = \pm 35$ μm; D = 1537 μm, $\sigma_y = \pm 56$ μm

6.5 psi: W = 228 μm, $\sigma_w = \pm 47$ μm; D_{min} = 234 μm, $\sigma_y = \pm 28$ μm

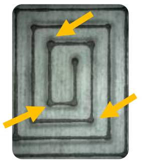
4. Discussion

Resolution

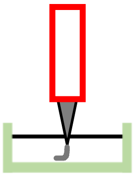
Average min. track separation = 234 μm
Average min. track width = 228 μm
Goal → 100 μm (commercial PCB resolution)

Future work

Optimization for 30 and 32 AWG nozzles for smaller resolution



Optimizing print paths by modifying G-code to achieve finer corner prints



Embedded printing in uncured PDMS for multilayer prints

- Heaters
- Temperature
- ECG/EMG
- Chemicals
- Bioimpedance
- Force

Develop a stretchable multiparameter sensing system for wearables/soft robotics

→ Ink and process optimization for Ag-PDMS composites

References

[1] Tavakoli, M., Rocha, R., Osorio, L. et al (2017) Carbon doped PDMS: conductance stability over time and implications for additive manufacturing of stretchable electronics. *Journal of Micromechanics and Microengineering.* 27 (035010).
[2] Larmagnac, A., Eggenberger, S., Janossy, H. and Vörös, J. (2014) Stretchable electronics based on Ag-PDMS composites. *Scientific Reports. 1 (7254).*
[3] Kassanos, P., Seichepine, F., Wales, D., Yang, G-Z. (2019) Towards a Flexible/Stretchable Multiparametric Sensing Device for Surgical and Wearable Applications. *2019 IEEE Biomedical Circuits and Systems Conference.* 1-4.