Inkjet Printing a Platinum Temperature Sensor

Jones, Thomas; Grant, Tim; Lowe, John; Rothwell, Rosemary; Abdolvand, Amin

Publication date:
2021

Inkjet Printing a Platinum Temperature Sensor

Timothy D. Grant [a*], Thomas D.A. Jones [a], John B. Lowe [b], Rosemary J. Rothwell [b], Amin Abdolvand [a]
[a] University of Dundee, Dundee, UK [b] Ceimig Limited, Dundee, UK * t.grant@dundee.ac.uk

1. Introduction

Inkjet printing is an additive, low-waste and adaptable deposition technique that can be applied to the **manufacture of electronics.** Many conductive inks use nanoparticle suspensions that are susceptible to uneven particle distributions when deposited (the so-called 'coffee-ring effect') and particle agglomeration. An alternative ink type is particle-free inks that theoretically bypass these negatives and form printed films of higher conductivities.

Resistance Temperature Detectors (RTDs) are temperature sensors which typically use platinum owing to its linear resistance-temperature response. Such sensors are commonly called Pt100, indicating a 100Ω resistance at 0°C. To date there are no known publications on platinum-based inkjet-printed temperature sensors.

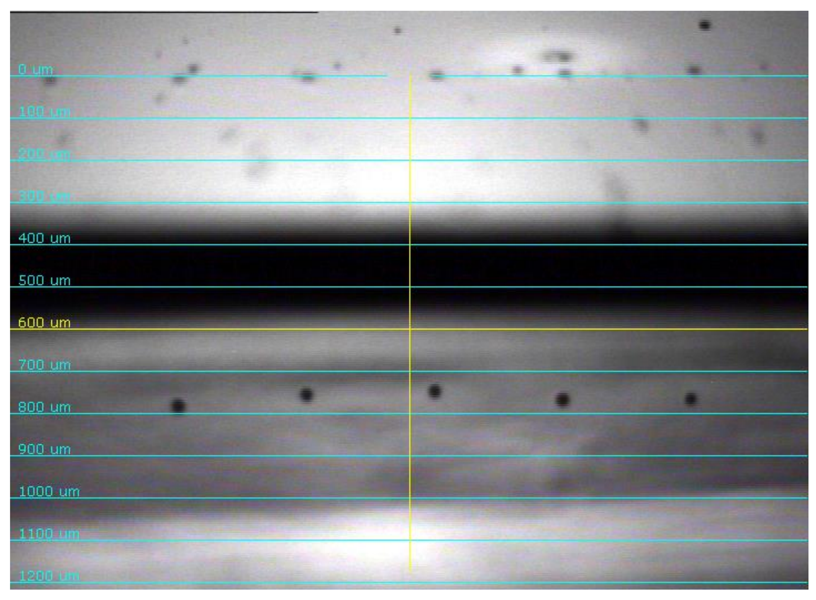
Presented here is a **particle-free platinum ink**, used to print and analyse RTDs. The printed film structure is then imaged using a Scanning Electron Microscope (SEM).

2. Platinum Ink

Solvent comprising of cyclohexanol, cyclopentanone and toluene with dissolved 20wt% $Pt(cod)(Me)_2$ organometallic.

Density: 0.95g/ml
Dynamic Viscosity: 13.5cP
Surface Tension: 30.5mN/m
Inverse Ohnesorge (Z): 1.8

Jetting velocity: 8m/s
Number of printed layers: 3
Drop spacing: 15µm
Cartridge temperature: 40°C


Five nozzles jetting at 7 – 8m/s (100µs strobe delay)

Ink jetted from a Fujifilm Dimatix DMP-2831 materials printer onto glass slide and flexible Kapton HN substrates. Deposited ink cured in a furnace at 320°C for 5 minutes to form the conductive films. Sensors glued to a metal plate before testing.

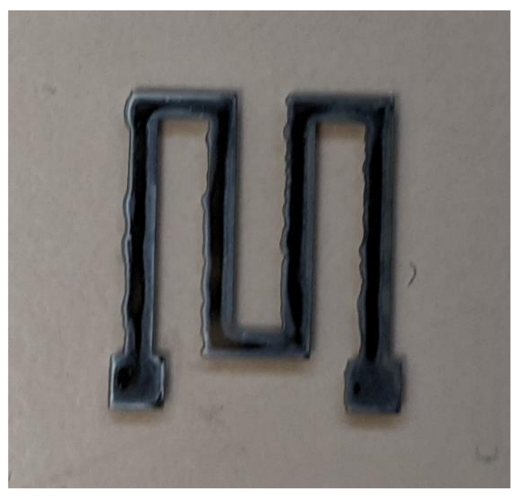
3. Printed Sensors

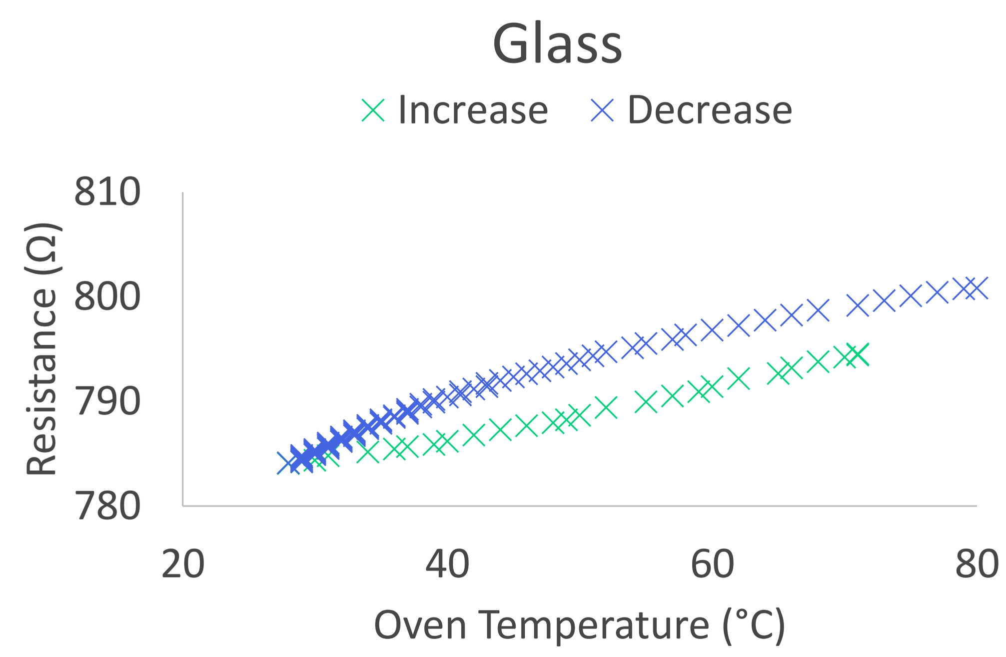
Print pattern modelled on [1] consisting of four 10x1mm lines, three 4x1mm lines and two $4mm^2$ contact pads. Copper wires for resistance measurement were attached to the contact pads with silver epoxy.

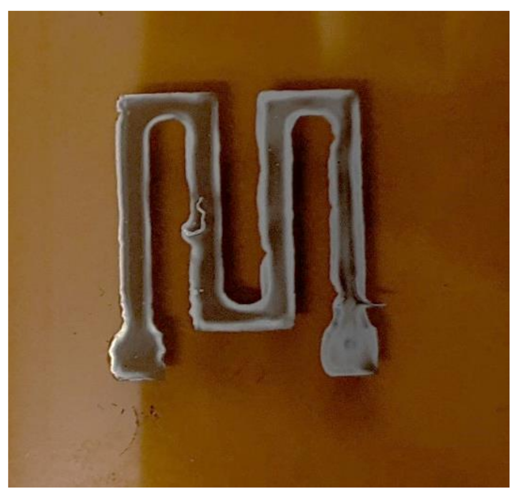
Sensors were placed in a furnace and ramped from 28 – 80°C (increase) then allowed to cool (decrease). Measured resistance across the sensor was recorded every minute.

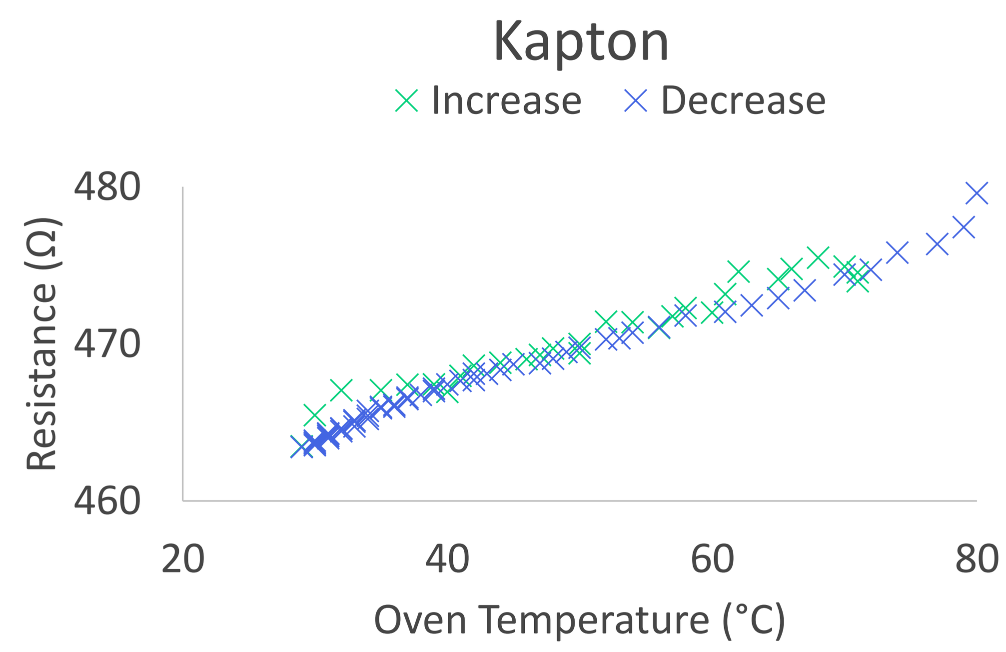
Resistance-temperature response was near linear with an observed offset between the heating and cooling periods.

Sensor	Sensitivity (Ω/°C)	Resistance at 0°C (Ω)
Glass	0.295 ±15.3%	776.30 ±0.05%
Kapton	0.255 ±5.9%	457.1 ±0.20%
Pt100 [2]	0.385	100 ±0.12%


Sensor printed on glass



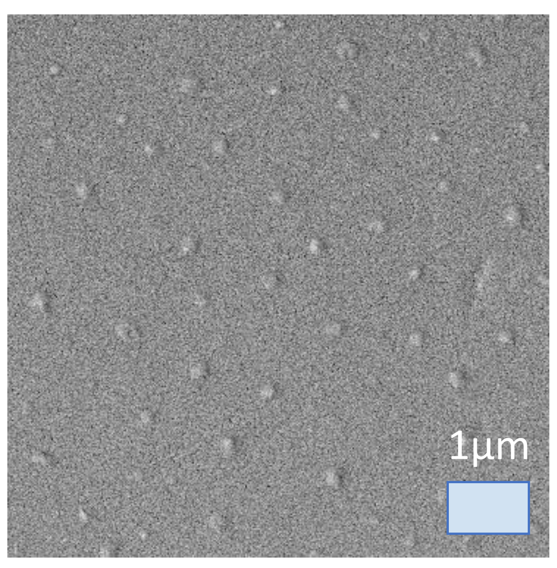

Sensor printed on Kapton



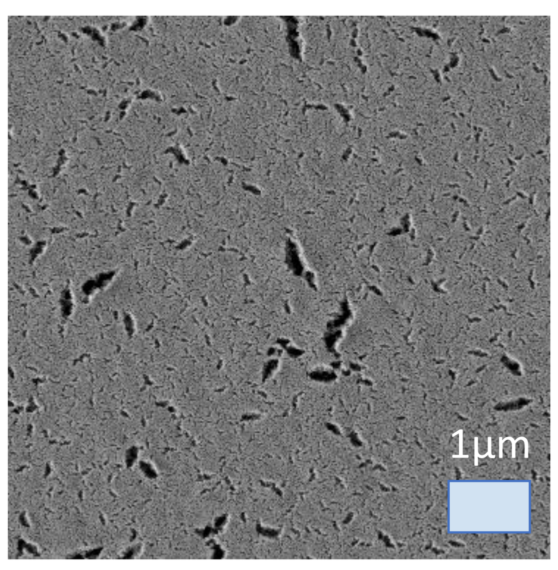
4. Film Structure

Thickness of the printed films was found to increase over 400% at the edges. SEM images indicated the presence of nodules <0.2µm diameter at the film edges versus none at the centre. The ink was passed through 0.2µm filters before jetting, thus indicating a coffee-ring effect possibly from dust particles or other particulate matter in the ink.

Rupturing was more prevalent towards the centre of the film, potentially due to volatiles escaping as the ink dried. Largest observed void was $0.31µm^2$. The changing morphology can be attributed to different drying regimes at the edge versus centre of the films [3].



Closer to edge



Closer to centre

5. Summary

Jetting with a novel particle-free platinum ink to form high definition films on glass and Kapton substrates.

Positive and near linear resistance-temperature response observed from 28 – 80°C.

Identified inconsistencies in the printed films forming potential future investigations.

6. References

[1] Y. Sui, L. P. Kreider, K. M. Bogie, and C. A. Zorman, "Fabrication of a Silver-Based Thermistor on Flexible, Temperature-Sensitive Substrates Using a Low-Temperature Inkjet Printing Technique," IEEE Sensors Lett., vol. 3, no. 2, pp. 1–4, 2019, doi: 10.1109/lsens.2019.2893741.

[2] Pt100 IEC 751 (1995) Class B Standard.

[3] R. D. Deegan, O. Bakajin, and T. F. Dupont, "Capillary flow as the cause of ring stains from dried liquid drops," Nature, vol. 389, pp. 827–829, 1997, doi: 10.1038/39827.