Thermal Cycling Reliability of Gravure Offset Additive Electronics with Water-Based Ink, Biodegradable Substrate and Room-Temperature Curable Adhesives

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Motivation

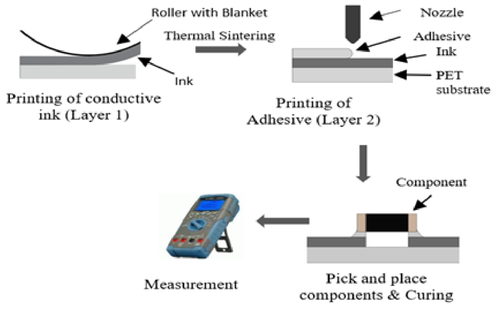
- The growing demand for sustainable and eco-friendly electronics requires alternative manufacturing techniques that minimize environmental impact.
- Conventional electronic manufacturing methods rely on high temperatures and non-biodegradable materials, posing challenges for energy efficiency and waste reduction.
- The use of water-based inks, biodegradable substrates, and room-temperature curable adhesives provides a promising pathway for sustainable electronics.
- Understanding the thermal cycling reliability of such electronics is crucial for ensuring their durability in real-world applications, such as automotive and consumer electronics.
- Bridging the knowledge gap in the behavior of flexible printed circuits under varying environmental conditions supports the advancement of robust and cost-effective electronic solutions.

Objectives

- Attach the components in a circuit printed with water-based ink on a BPET substrate using room-temperature curable adhesive and Gravure Offset printing.
- Evaluate the electrical Performance.
- Compare experimental results with theoretical simulations.
- Examine the reliability of automotive-grade 3 component under thermal cycling in the temperature range of -40C to +85C.
- Develop a reliable and scalable process for producing flexible electronics that meet industry standards for environmental sustainability and durability.

Methodology

Work Flow Diagram



Material Properties:

Water-based Ink Properties	
Color	Silver Grey
Solid Content	85 wt%
Sintering Temperature	80^{o}C for 60 min

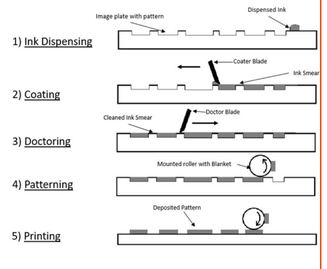
Electrically Conductive Adhesive (ECA)	
Material	Silver Paste
Color	Silver
Reactive solids contents	100%
Sintering Temperature	24 hrs. @ Room Temperature
Resistivity	10^{-4} Ω-cm

Substrate	
Material	BPET
Yield MPa	288
Thickness(mm)	0.02
Elongation at break (%)	100
Tensile Strength at break(kpsi)	31

Printing Technology Used

- Gravure printing is a roll-to-roll printing technique which uses a roller and an etched plate.
- The ink is first dispensed on the plate, and the coater plate spread the ink over the plate while the doctor plate remove the ink smear over the plate.
- The roller, equipped with a mounted blanket, picks up the ink from the plate and deposits it onto the substrate.

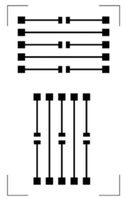
Gravure Offset Printer



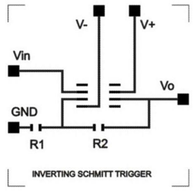
Gravure Offset Printing Schematic

Test Vehicle Design

- Test Vehicle Design 1 is used to study the effect of thermal cycling on traces and SMDs with interconnects.
- Test Vehicle Design 2 is used to understand the effect of thermal cycling on a functional circuit.



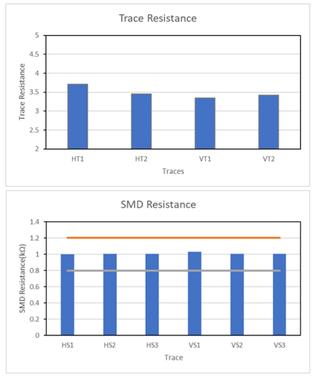
Test Vehicle - 1

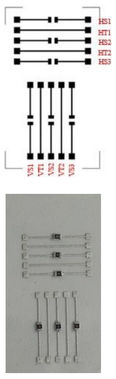


Test Vehicle - 2

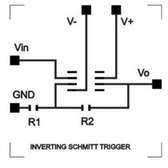
Results

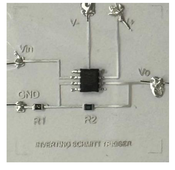
Test Vehicle Design 1 Results

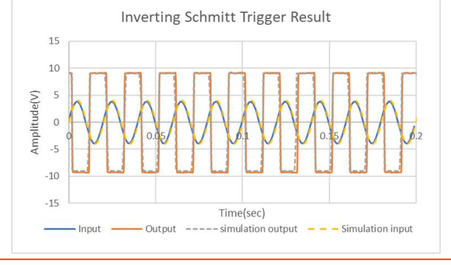


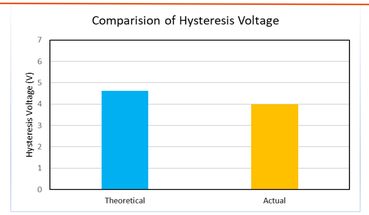


Test Vehicle Design 2 Results

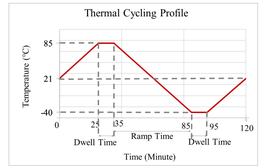


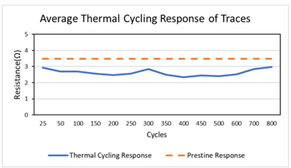


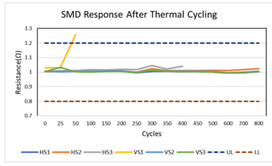


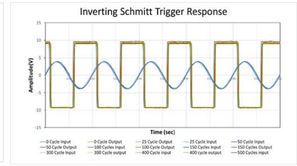


Thermal Cycling Response

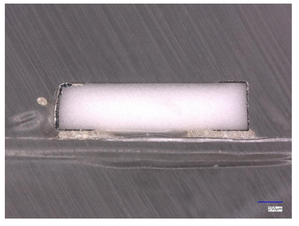




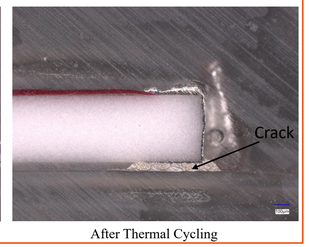




Cross-Sectional View



Before Thermal Cycling



After Thermal Cycling

Conclusions

- There is no significant effect of orientation on the traces.
- The Simulated output of the inverting schmitt trigger closely matches the realized circuit output.
- Post Thermal cycling, the traces did not exceed the pristine condition resistance, and the SMD resistance with interconnect remained well within 20% limit as suggested by the IPC-9071A standard.
- The Schmitt trigger circuit was monitored during thermal cycling, and its output did not exhibit any significant changes.
- During thermal cycling some of the samples were failed due to shear fatigue.

Acknowledgements

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