



HAL
open science

Innovative Strategie for Eco-Friendly Printed Circuit Board Design

Nouh Zeggai, Morgan Almanza, Denis Labrousse, Laurent Dupont

► **To cite this version:**

Nouh Zeggai, Morgan Almanza, Denis Labrousse, Laurent Dupont. Innovative Strategie for Eco-Friendly Printed Circuit Board Design. POLYMER BLENDS / EUROFILLERS 2025, Jan 2025, Lyon, France. hal-04930104

HAL Id: hal-04930104

<https://hal.science/hal-04930104v1>

Submitted on 5 Feb 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

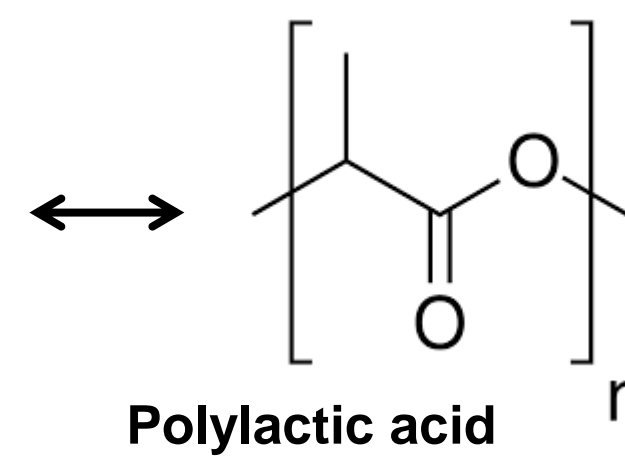
(a) Université Paris-Saclay, ENS Paris-Saclay, CNRS, SATIE, 91190 Gif-sur-Yvette, France, nouh.zeggai@universite-paris-saclay.fr

(b) Le Cnam, F-75003 Paris, France, HESAM Université

(c) Université Gustave Eiffel, Université Paris-Saclay, ENS Paris-Saclay, CNRS, SATIE, 78000, Versailles Satory

Context

Each year, approximately **62 million metric tons** of electronic waste are generated, much of which is not designed for easy recycling. Printed circuit boards (PCBs) alone contribute **3 to 6 million metric tons**, representing 5–10% of this e-waste.



Goal

- Evaluate the viability of PLA-IMS: Assess the functionality and performance of PLA-based insulated metal substrates (IMS) for power electronics applications.
- Demonstrate reliability: Test the durability and stability of PLA-IMS under electrothermal stress and cycling conditions

Advantages

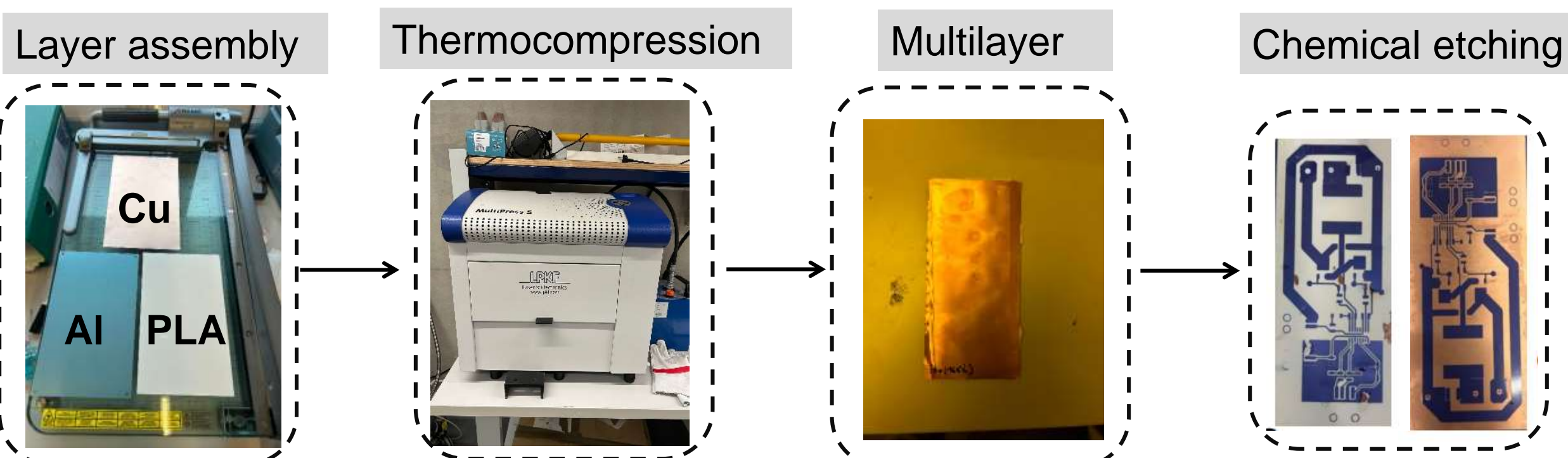
- Derived from fermented plant starches (e.g., sugarcane, cassava).
- Widely used in food packaging and additive manufacturing.
- Bio-based, biodegradable, and cost-effective (€2/kg).



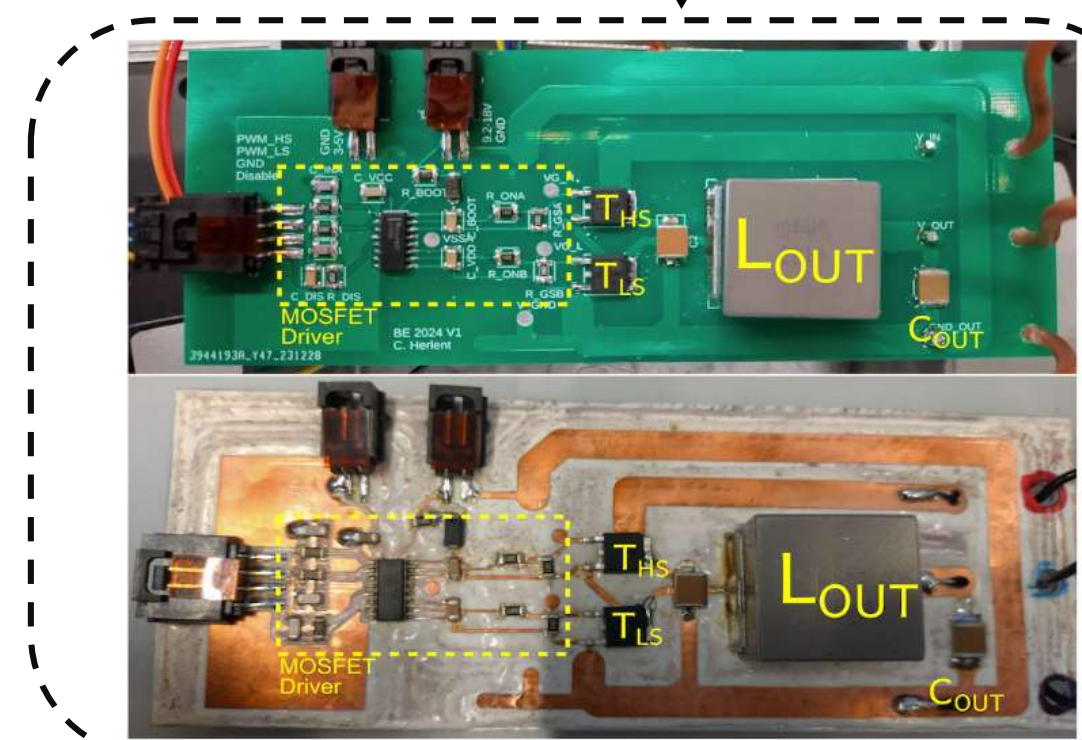
Fraunhofer Institute for Solar Energy Systems ISE

Methodology

Manufacturing a printed circuit board

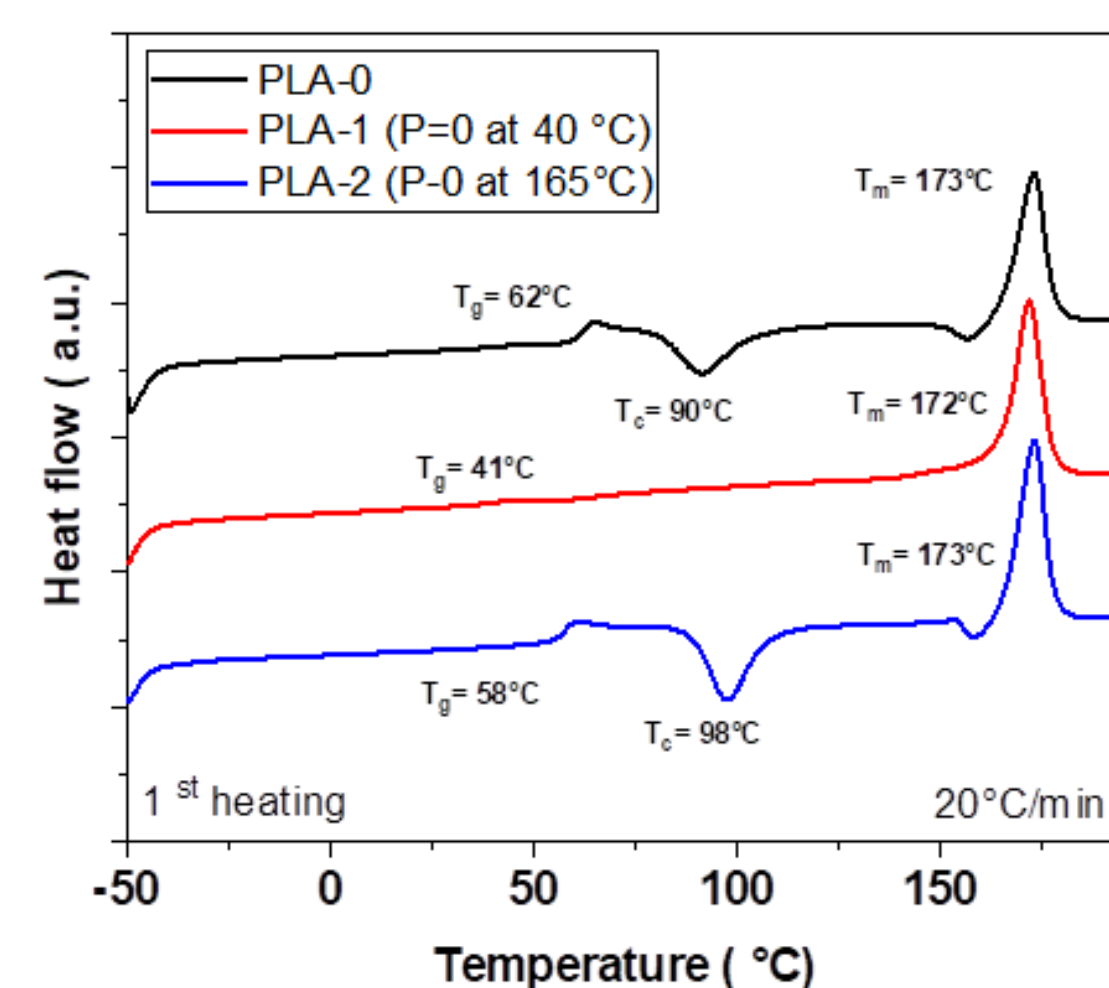
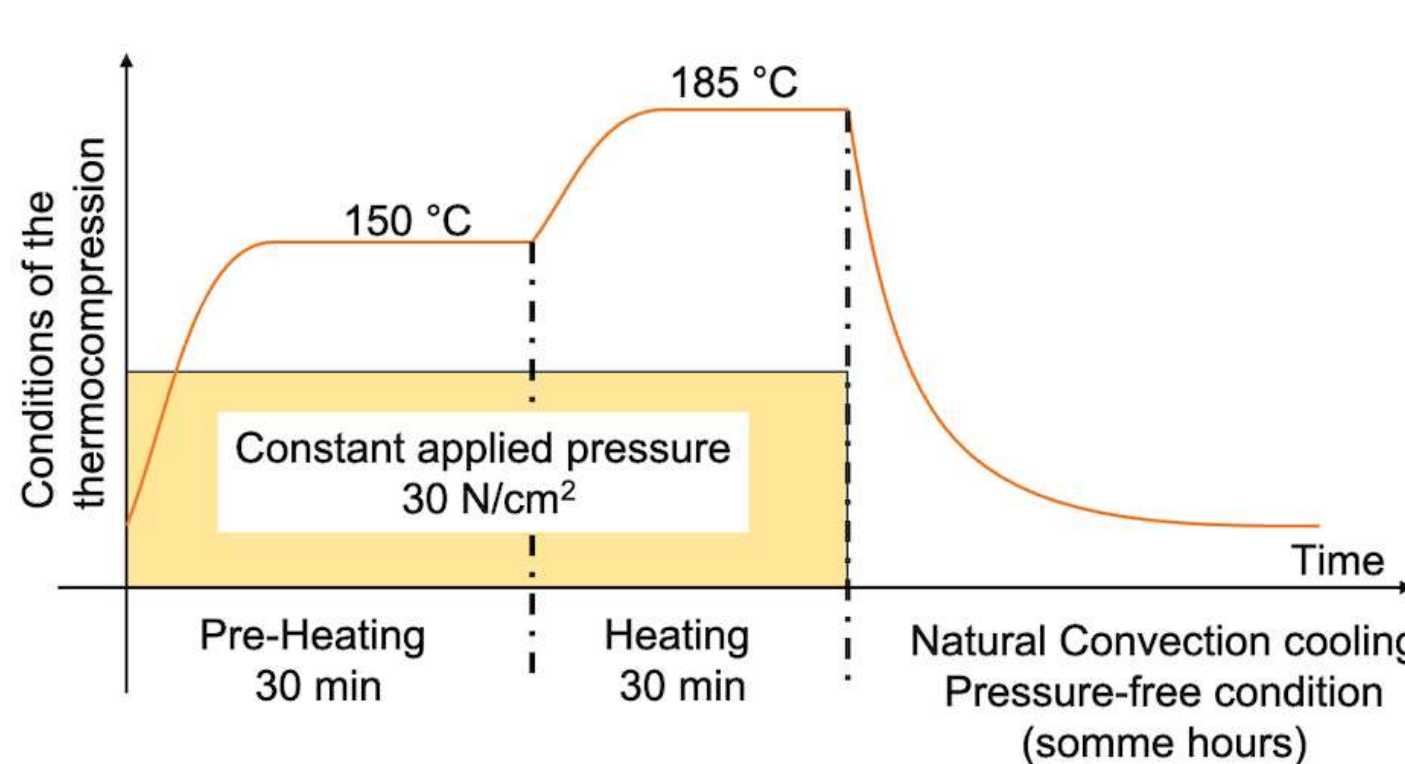


- Layer Assembly:** Assemble the copper (Cu) and PLA layers, carefully aligning them to form the multilayer structure.
- Thermocompression:** Apply heat and pressure to bond the layers together.
- Etching:** Remove unwanted copper to form the electrical circuit.
- Soldering:** Solder the components onto the PCB through a brazing process.

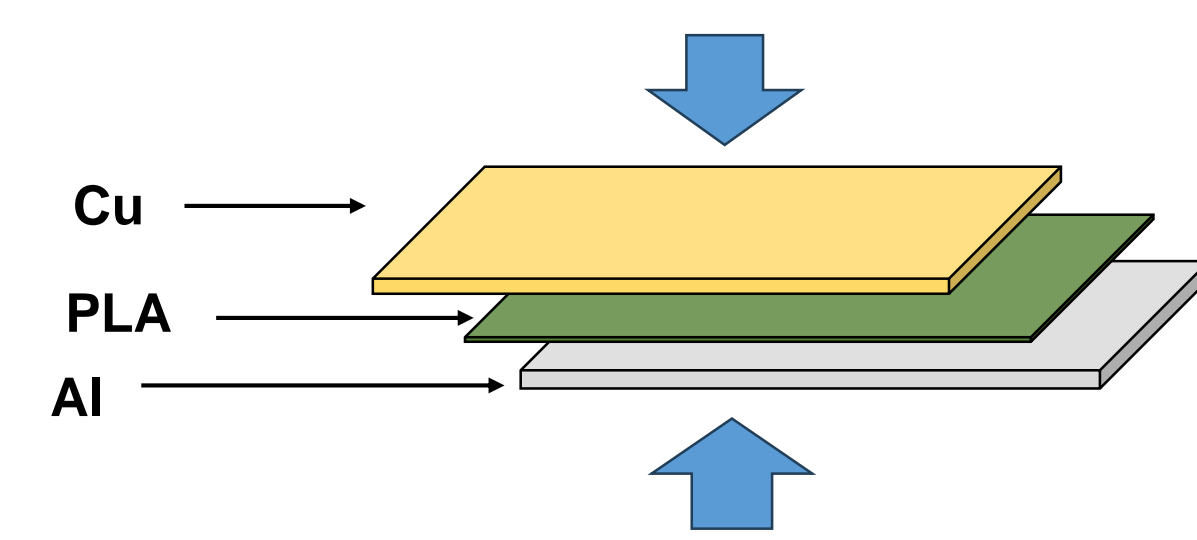


Soldering of components

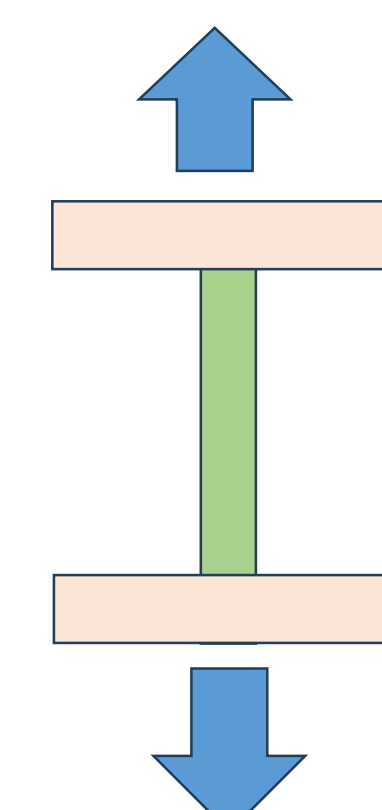
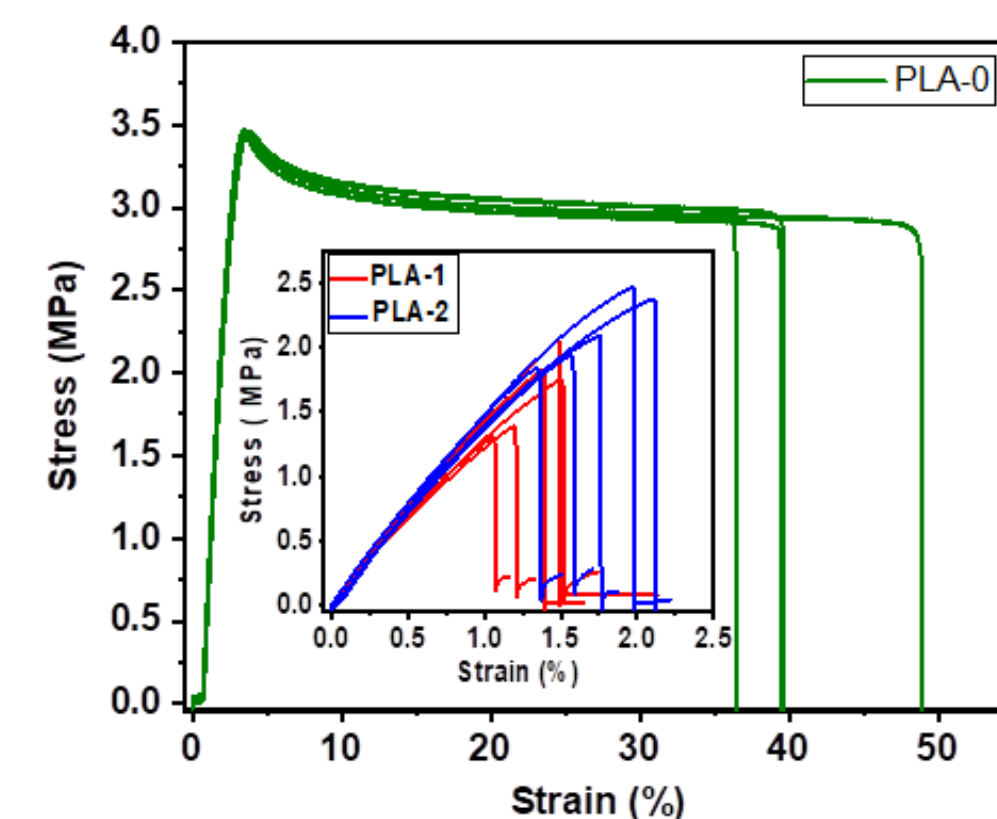
Thermocompression conditions



DSC analysis was performed to assess the PLA's glass transition (T_g), melting temperature (T_m), and crystallization. These properties guide the optimal temperature range for thermocompression, ensuring effective processing and preserving material integrity.

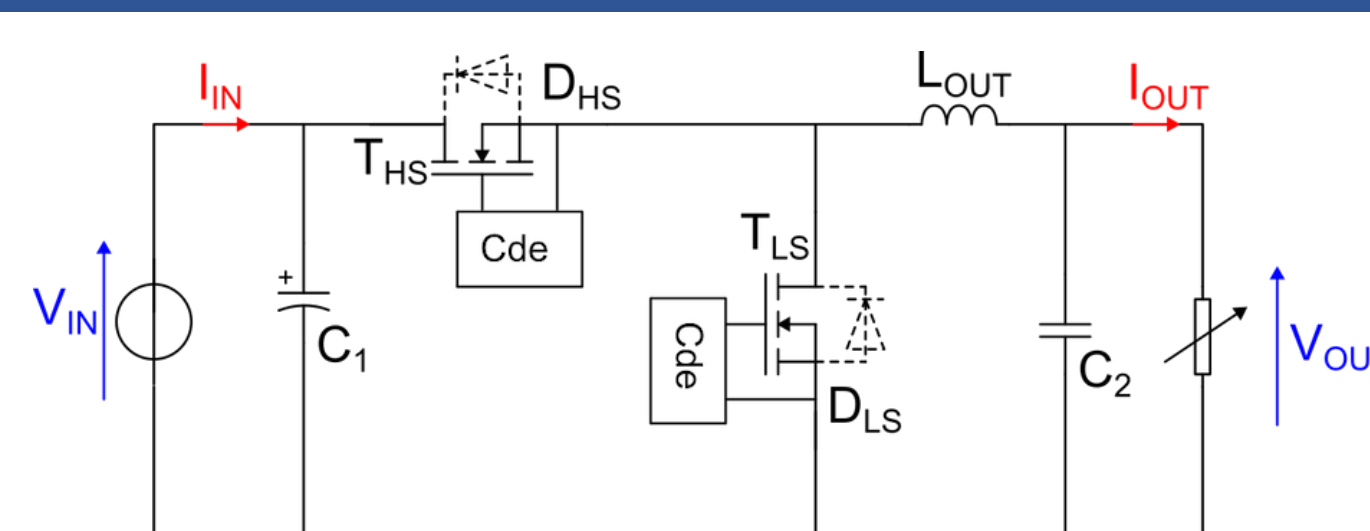


Mechanical analysis of PLA

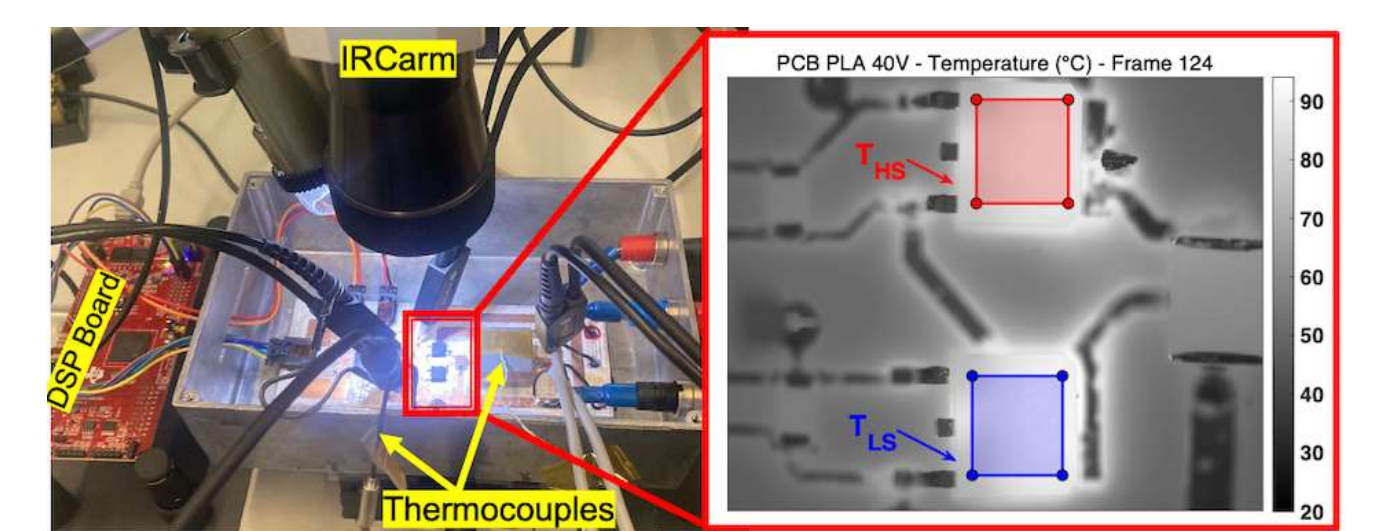


The PLA tested as-supplied (PLA-0) is highly elastic, with a break point around 40%. However, when thermocompressed, the break point drops significantly to 2-4%, depending on when the pressure is released during the process

Electrothermal Evaluation of PLA Converter

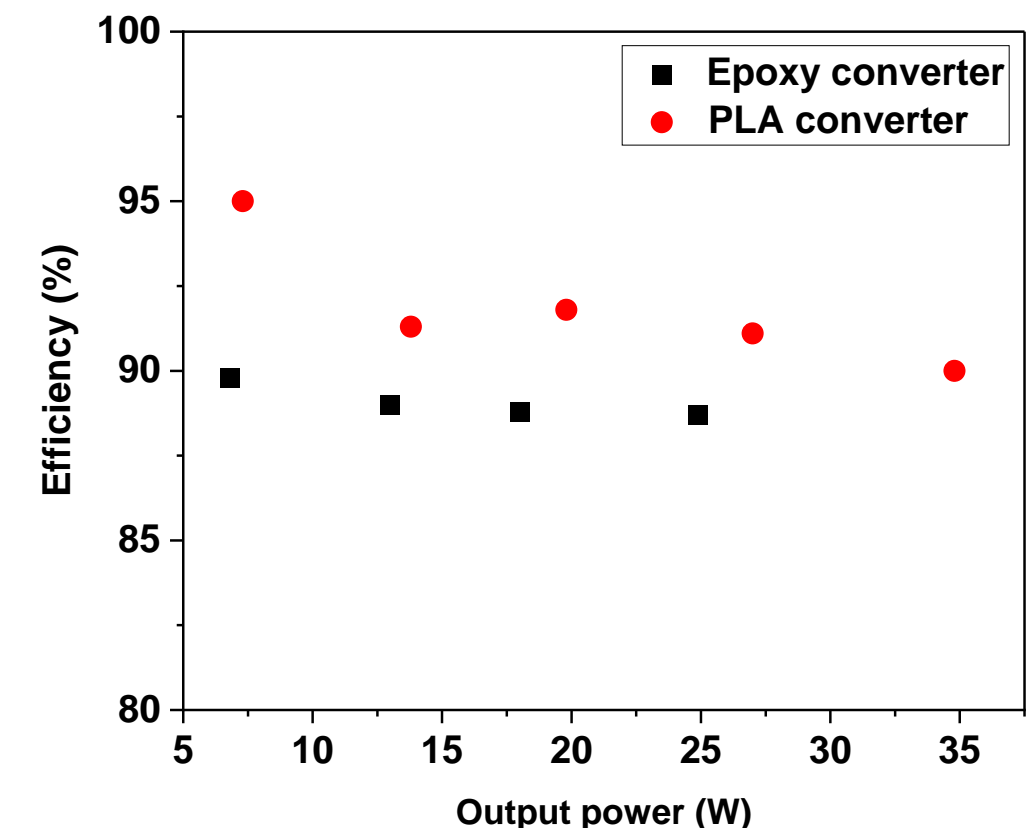


We use a buck converter, a common configuration for converting DC voltage



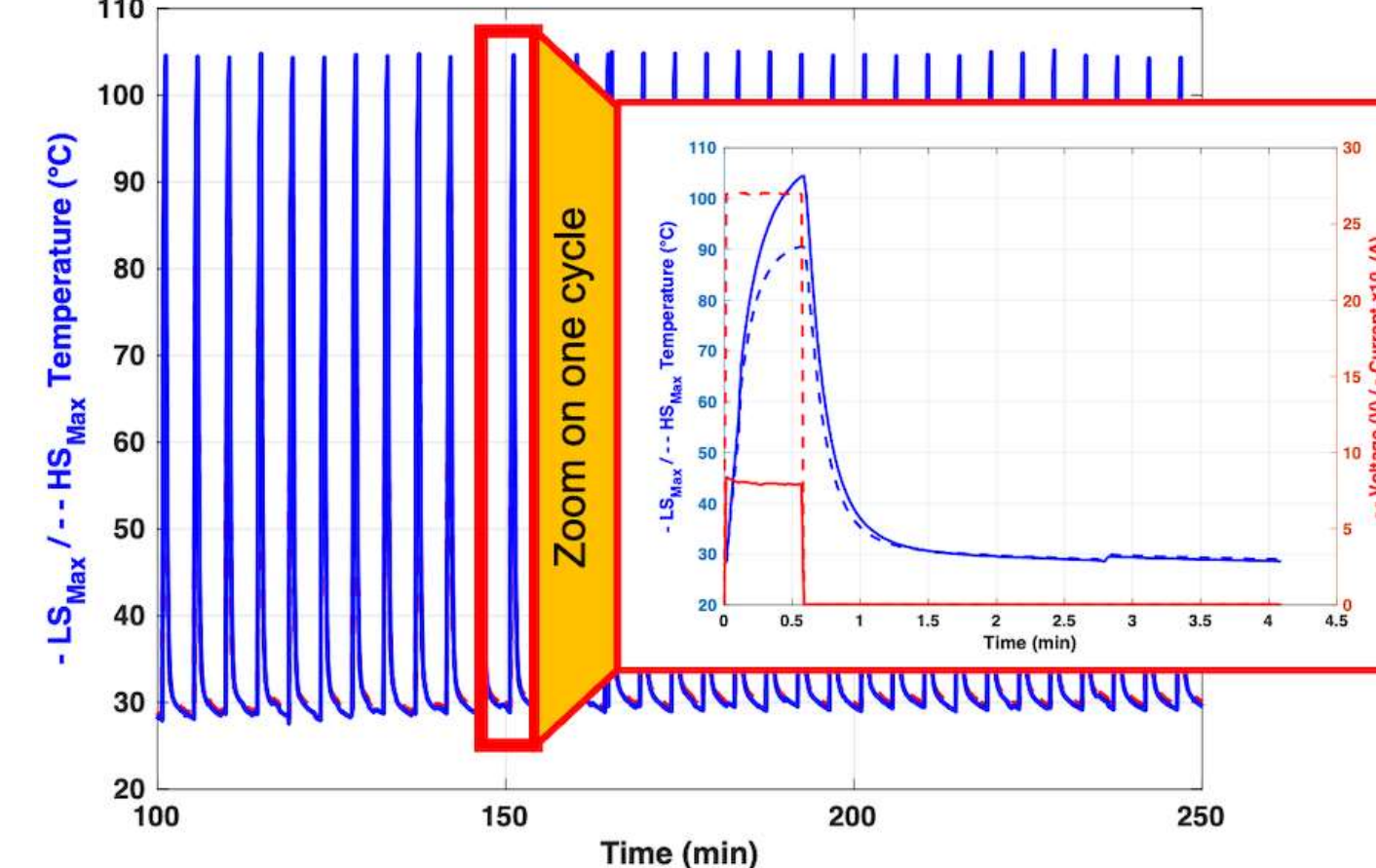
Test bench for an evaluation of the electrothermal performances DC converter

Energy performance



- The aluminum plate enhances thermal dissipation effectively.
- PLA efficiency slightly surpasses FR4, highlighting its suitability for power electronics.

Accelerated Power Cycling Test (APCT)



- Cycling tests were conducted over 100 cycles up to 110 °C.
- After 100 cycles, no noticeable change in component temperature was observed, indicating stability

Conclusion

- Validation of PLA-IMS:** The study demonstrated that PLA-based insulated metal substrates (IMS) can achieve performance levels comparable to traditional Epoxy PCBs for power electronics.
- Thermal stability:** After 100 cycles of accelerated power cycling tests, no significant changes in component temperatures were observed, highlighting the stability and reliability of the PLA-IMS assembly.
- Efficiency improvement:** The integration of an aluminum dissipation system contributed to slightly better efficiency compared to standard designs, confirming the potential of PLA-IMS for efficient thermal management in power converters

Perspectives

- Multilayer substrate:** Explore the design and fabrication of a stacked layers using PLA-based IMS to further demonstrate its scalability and functional versatility.
- Extended cycling tests:** Conduct long-term accelerated cycling tests to validate the durability of PLA-IMS over extended operational lifetimes

Acknowledgements

- SISEP Project:** This work has been partially funded by the CNRS Energy unit (Cellule Energie) through the project SISEP-2023.
- ModuFEET Project :** This work has received support under the PRCE program launched by the French Government and implemented by ANR-21-CE05-0040.