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POLYHYDROXYALKANOATES FOR BIODEGRADABLE PRINTED CIRCUIT BOARDS FOR BIO-MICROELECTRONICS

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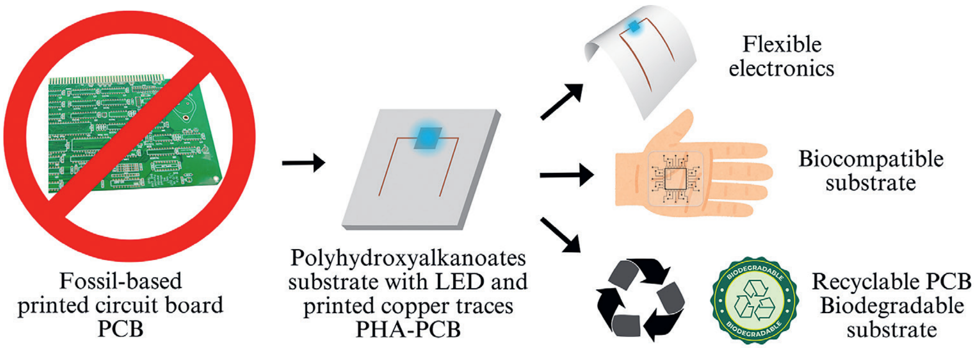
Abstract – Printed circuit boards (PCBs) are essential components of nearly all electronic products and consist of laminated structures combining conductive and insulating layers. Conventional PCB manufacturing relies on fossil-based and poorly degradable materials, with FR-4 – composed of woven fiberglass reinforced epoxy resin – being the most widely used substrate. When improperly managed at the end-of-life stage, PCBs pose significant environmental and health risks. Current disposal practices, including incineration and e-waste storage, contribute to the release of carcinogenic and persistent pollutants such as dioxins and polycyclic aromatic hydrocarbons, with severe impacts on ecosystems and human health. Consequently, there is an urgent need to develop simplified recycling strategies and to adopt environmentally friendly materials for both substrates and processing reagents. Polyhydroxyalkanoates (PHAs) represent a promising class of biopolymers synthesized by microorganisms. PHAs combine functional performance with intrinsic biodegradability and enable controlled degradations of electronic substrates after disposal. In this work, PHAs are investigated as sustainable PCB substrate materials, processed through additive manufacturing techniques such as drop casting, spray coating, inkjet printing, and laser activation to support material-efficient and low-impact fabrication routes. The research is presented in the scheme. The surface morphology and topography of the surface of the new substrates are characterized using optical profilometry. while cross-section analyses and scanning electron microscopy (SEM) are employed to evaluate layer integrity, microstructure, and interfacial quality. Thermal properties are evaluated by thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), while physiochemical behaviour is assessed through viscosity measurements to determine processability for printing-based techniques. Mechanical performances are investigated via strength tests. In addition, eco-friendly solvent-based approaches are explored for the recovery and recycling of materials, aiming to close the material loop and enhance circularity. Overall, the integration of biodegradable polymers, advanced manufacturing techniques, comprehensive material characterization, and green recycling strategies suggest viable pathways toward environmentally responsible microelectronics and support the transition to a more sustainable future for electronic materials.

Keywords – Additive manufacturing; alternative biomaterials; biodegradable polymers; bioplastics; bioresources; bio-substrates; e-waste management; microelectronics; sustainable electronics



Scheme of the current research to replace fossil-based PCBs with biodegradable substrates