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Printed Electronics on Flexible Substrates and In-Mold Electronics Process for Production Optimization

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Summary:
The InteliPart project, integrated within the Illiance High Performing Energy consortium, is oriented towards the creation of pioneering solutions involving the functionalization of plastic components. These solutions will focus on the reduction of process steps, addressing sustainability and improving cost-effectiveness. This work outlines the development of sensing and actuation technologies, namely capacitive sensors and light-emitting solutions, through printed electronics and their incorporation in plastic parts by injection molding processes, achieving In-Mold Electronics.

Keywords: printed electronics, screen printing, sensors, IME, production optimization.

IME Towards Production Optimization

Due to the current highly competitive manufacturing landscape, the reduction of production steps has emerged as a critical motivating factor for companies pursuing an efficiency enhancement and decrease of operational costs, while maintaining a competitive level. This production optimization provides an improvement of cost-effectiveness by eliminating unnecessary or redundant processes, which not only improves profitability, but also enables businesses to offer more competitive pricing in high-end components. Besides, process steps reduction is important to address sustainability and environmental concerns. In this scope, the InteliPart project – part of the Illiance High Performing Energy consortium – aims to create innovative solutions and advanced technologies through the functionalization of plastic parts. Combining the technologies of printed electronics and injection molding – In-Mold Electronics (IME), the main objective is to successfully integrate electronics in plastic parts for the development of functional components that could easily be incorporated in many interface applications towards new advanced electronic devices and appliances.

Printed Electronics and IME

Printed electronics is one of the highest growing markets in most recent years for its possibility to combine printing technologies and functional inks while assuring economical and functional advantages, as it can offer design flexibility and use of a large range of lightweight, thin and flexible materials, enabling the integration of electronics into unconventional shapes and surfaces, aligned with contemporary demands. This versatility opens new possibilities for product innovation and differentiation, further enhancing a company's competitive advantage.
The work herein presented aims at developing printed electronics sensing and actuation systems resorting to screen printing. Screen printing stands as a pivotal technology which offers an efficient deposition of functional materials onto flexible and rigid substrates, is cost-effective and allows for an easy scale up to roll-to-roll configuration, for large scale pre-production continuous printing. After printing, an additional step can be introduced to enhance the films' intelligence which consists of the assembly of surface mount devices (SMD) such as resistors, capacitors, and light-emitting diodes (LEDs) [1]. Moreover, IME offers a unique approach to the reduction of production steps. In the injection molding process, a polymer is injected against the surface of a film of printed electronics, promoting the adhesion of the layers. Hence, electronic functionalities are directly integrated during the injection molding process, resulting in a seamless product and efficient manufacturing workflow. Therefore, a significant simplification and streamlining of manufacturing processes can be achieved [2].
In these processes, materials are carefully selected to fulfil the end application requirements

and the different components designed for a customized solution.

Results

Preliminary tests regarding the integration of printed electronics through injection processes were performed, specifically of hybrid electronics films, *i.e.* containing a printed component with SMD. Firstly, conductive silver tracks for LEDs powering were screen printed onto a flexible substrate, followed by the assembly of LEDs on its surface. The printed films were then successfully integrated into plastic components through injection molding without degradation of the printed tracks nor any of the materials and devices involved in each production step. Besides, LEDs' displacement was not verified, maintaining their functionality once integrated on the plastic part. Therefore, a functional light-emitting part was achieved, as represented in Figure 1.

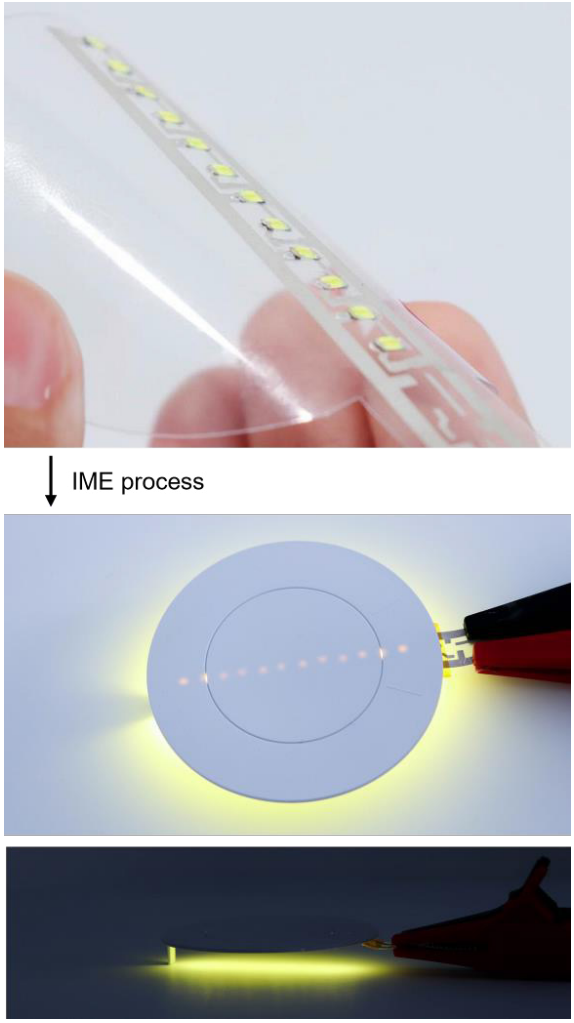

Fig. 1. Demonstration of preliminary test results on the integration of a screen printed film with assembled LEDs (top) on a plastic material through injection molding, achieving a light-emitting IME part (bottom).

Based on the favourable outcome attained in the preliminary tests, which proved the concept of eficiently incorporating a functional electronic film in a plastic component without affecting its initial properties, further electronics will be developed through screen printing and IME in order to achieve more advanced technologies. Under development and future work include a capacitive circuit, the pathways for LEDs powering and the respective control electronics. IME containing printed capacitive sensors will result on a part with touch response capabilities and the incorporation of LEDs will allow for a more appealing light solution. Additionally, through the course of the project, the functionalities inherent to the system will be specified, alongside the configuration of the plastic component's design. Moreover, in addition to injection tests, functional characterization tests and an evaluation of their properties will be conducted.

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