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Abstract

Digital printing of high-performance microstructures for miniaturized active medical implants

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The miniaturization of active medical implants provides numerous advantages, including improvement in compliance with ERAS (Enhanced Recovery After Surgery) protocols and MIS (Minimally Invasive Surgery) techniques, enhanced device performance, reduced hospitalization time and a decreased immunological response due to the compliance with ISO 10933-series for medical devices' biocompatibility. There is a clear need for the miniaturization of devices like cardiovascular implants, implantable drug delivery systems, neurostimulators, insulin pumps and continuous glucose monitors (CGMs), cochlear implants, pacemakers and implantable cardioverter defibrillators (ICDs). In these devices, the size and electrical conductivity of a biocompatible electrode are critically important. Miniaturized markers and tooling subsystems for robotic surgery serve as another example, enabling automation of the surgical workflow. In this paper, we present Ultra-Precise Dispensing (UPD) technology [1], [2], a digital microprinting technique for creating high-performance structures on intricate surfaces. We will illustrate how the versality and precision of this technology make it particularly suitable for producing miniaturized active implants. UPD is an additive manufacturing method that enables the precise deposition of a broad range of materials, including high-viscosity gold inks and materials with functional properties. The dimensions of the printed structures vary from 0.5 μm to 10 μm and more, depending on specific requirements. The material can be dispensed on topographies with structures such as steps and trenches, as well as on edges and as a filler for microvias. The dispensing of high-viscosity materials is also independent of the surface type, allowing printing on amorphous materials and Personalized Medical Device (PMD) surfaces. These characteristics of the UPD technology offer unparalleled flexibility in the design of next-generation active implants.

We will focus on concrete examples relevant to the fabrication of novel miniaturized implants, providing a toolbox for creating such devices. The use cases will include printing gold electrodes at the micrometer scale with electrical conductivity reaching 45% of the bulk value. Both the high conductivity of the printed electrodes and the ability to create arbitrary geometries are essential for device functionality. Moreover, we will discuss strategies for advanced packaging and printed circuit board (PCB) stacking and biocompatible encapsulation to achieve further miniaturization of devices. We will also present printing on flexible substrates, such as biosensors and disposable substrates, enhancing the product's utility and application range. Finally, we will demonstrate the unique capabilities of UPD to print on steps and edges, enabling the creation of entirely novel device architectures.

Author's statement

The authors are employees of XTPL S.A., Stabłowicka 147, 54-066 Wrocław, Poland. Informed consent has been obtained from all individuals included in this study. Ethical approval: n(a

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