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D6.1 – Report on testing in industrially relevant environments

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1. Introduction

The main objective of the FemtoSurf project is to develop, test, and demonstrate industrial-grade solid-state 2-3 kW-level fs laser with parameters suitable for metal surface patterning applicable in industrial settings. FemtoSurf industrial-grade 2-3kW-level fs laser will be integrated into a propose-built optical chain enabling multi-beam processing (100+ simultaneous beams) with individually tailored spatial distributions in each laser spot, integrated into a fully automated processing setup for efficient patterning arbitrary shaped metal components with sizes exceeding several meters while retaining micrometer level precision and on-the-fly quality assessment (zero faulty parts delivered).

The present document is deliverable 6.1 of the FemtoSurf project (Grant Agreement No.: 825512), funded by the European Union's Horizon 2020 Research and Innovation programme (H2020).

The purpose of the deliverable is to provide a document that describes two laser based techniques for manufacturing of 3D printed electronics. The first technique focus on the creation of conductive patterns through the synthesis of a material that could be spay coated on any 3D printed part and upon laser treatment, selective copper tracks formed on the laser treated areas. The second technique focus on the creation of conductive patterns through laser surface modification of the 3D printing polymer followed by silver (I) activation and subsequent autocatalytic electroless copper plating on the laser surface treated areas. Both of the laser-based techniques, the synthesis of the material as well as their characterization are detailed in this report.

The following document made use of the HORIZON 2020 FAIR DATA MANAGEMENT PLAN TEMPLATE and was written with reference to the Guidelines to FAIR (Findable, Accessible, Interoperable and Reusable) data management in Horizon 2020.

Printed electronics can be an enabling technology for lightweight, functional components in many applications including automotive, aerospace and consumer electronics. Current technologies for depositing conductive traces in 3D can be split into two basic methods; 1. Direct deposition of conductive inks/pastes via air pressure, auger or piezoelectric actuation 2. Laser activation of a thermoplastic polymer impregnated with a special additive to form a seed layer for subsequent electroless plating, this is known as Laser Direct Structuring (LDS) process. The direct deposition methods are sensitive to ink formulation, have a short standoff distance and are limited to low layer thicknesses limiting their application in power electronics or high frequency antenna. The use of specialist injection mould polymers makes LDS cost prohibitive for some applications and unsuitable for rapid prototyping. In addition, despite being on the market for a long time, the processes for forming 3D printed circuitry have limitations on usable substrate materials. Alternative, material agnostic, processes are possible but require development for commercialisation. The Femtosurf deliverable 6.1 will develop the processes required to build 3D printed components with integrated electronics using a combination of a spray-coated precursor and a surface chemical treatment approach which is subsequently, selectively, activated by laser into a seed layer for electroless plating. The thick conductors formed by plating are suitable for high frequency antenna required in the latest generation mobile phones, demonstrator phone antenna will be manufactured as part of the project Figure 1.

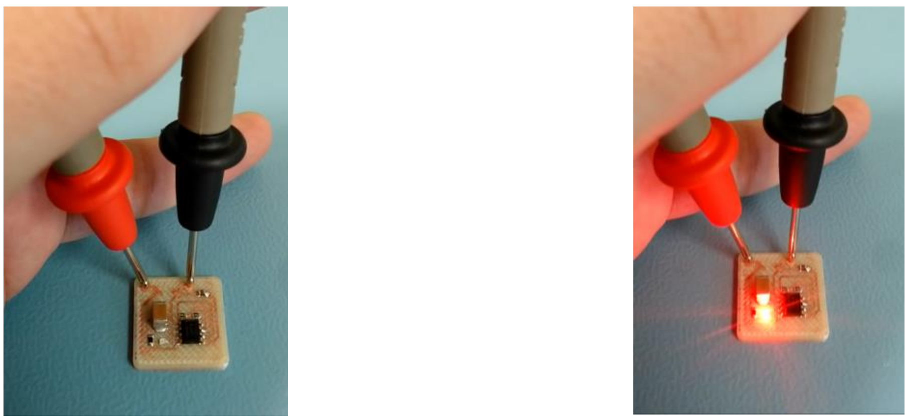
The technique developed in this case study is an alternative to LDS for depositing conductive tracks onto 3D parts. The benefits of this technique over direct deposition and LDS are 1–44,5

- The process has a high stand-off allowing access to tight corners.
- Laser defined tracking is high resolution, enabling tracking with <<100µm line/space.
- The pattern is digitally defined, no tooling changes are required between products.
- The track produced has similar conductivity to traditional PCB.
- The process is agnostic to the substrate material with no high temperature steps
- The metal precursors are localised to the surface, reducing costs and aiding with signal transmission through the substrate.
- The entire process can be digitalised and automated.

Figure 1. Application examples of the technology in industry[44]

2. Demonstrators

In order to demonstrate the capability of the developed process for real-time applications, a 555-timer circuitry is manufactured on the surface of the laser textured ULTEM and CE221 with the integration of a commercial IC chip, which has a broad application prospect. Figure2 shows a 555 timer circuitry with flashing LED powered made from 3D printed ULTEM 9085 (a) LED off, and (b) LED on. Figure3 shows the same circuitry on the CE221 material which has much higher ultimate tensile strength and glass transition temperature in comparison to the ULTEM 9085 and is capable of being 3D printed with much higher resolution opening new application areas for automotive, aerospace, and consumer electronics.



(a) (b)

Figure 2. 555 timer with flashing LED powered made from 3D printed ULTEM 9085 (a) LED off, and (b) LED on

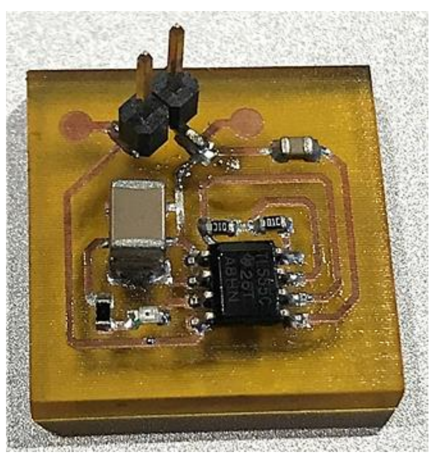


Figure 3. 555 timer with LED powered made from 3D printed CE221

4.10 Confidentiality

FemtoSurf partners must retain any data, documents, or other material as confidential during the implementation of the project. Further details on confidentiality can be found in Article 36 of the Grant Agreement along with the obligation to protect results in Article 27.

4.11 Conclusions

The work presented can lead to the realization of the fabrication of any shape conductive 3D printed electronic parts. This can enable the technology for lightweight, and highly customized functional components in many applications including automotive, aerospace and consumer electronics.