CHAMELEON—Compliant Mechanism with Embedded Sensing

S. Lani, N. Hendricks, O. Chandran, H. Saudan, L. Kiener, F. Cosandier, N. Marjanovic, J. Schleuniger, J. Kaufman, R. Jose James

Structural health monitoring for preventive maintenance, control feed-back of moveable mechanisms, integrated actuation and adaptive objects necessitate a heterogeneous integration of numerous technologies. In order to bring Additive Manufacturing (AM) beyond state-of-the-art technologies of topology optimization, it is important to develop concepts and technologies allowing such functionalities while keeping the versatility and flexibility advantages of AM. Hence, CHAMELEON aims at developing technologies to manufacture metal-based 3D parts with embedded functionalities such as compliant mechanisms, electrical/pneumatic feedthroughs, sensors and actuators by combining advanced design, ink-jet printing (IJP), aerosol jet printing (AJP), polymer casting, laser powder bed fusion (LPBF) and surface post treatment. The main applications will focus on markets already using AM in production (space, aeronautic, and medical) that are requesting additional functionalities.

AM is taking more and more importance for the production of high-end components in application like space, aeronautics and medical fields. Such industries have critical needs for which AM has appealing features. Among them, they benefit very much from a manufacturing technology able to produce components with complex geometries that is suitable for moderate production volume as well as weight reduction thanks to topology optimization. However most of today's applications, for which AM is used, is for manufacturing "passive" elements with no functionality except providing a mechanical structure. To grow the market attractiveness of AM, it is important to develop technologies to bring new functionalities while keeping the advantages of flexibility and versatility of AM. Hence, CSEM is investigate the opportunity to combine 3D with 2D printing to obtain 3D compliant mechanisms with embedded sensors in order to elaborate complex AM-based Mechatronics devices.

Within the past years, CSEM has achieved the following milestones using LPBF AM technology:

- Minimum feature size reduced by a factor of more than two with stainless steel, aluminium and titanium alloys (reaching 100 µm features size with stainless steel).
- Compliant mechanism made by AM opening new design, mass reduction and reduced assembly steps.
- Embedded electrical wiring by combination of LPBF, polymer casting, and machining with the demonstration of a new slip ring rotor with RUAG Slip Rings SA©.
- Demonstration of various 2D printed sensors by IJP and AJP

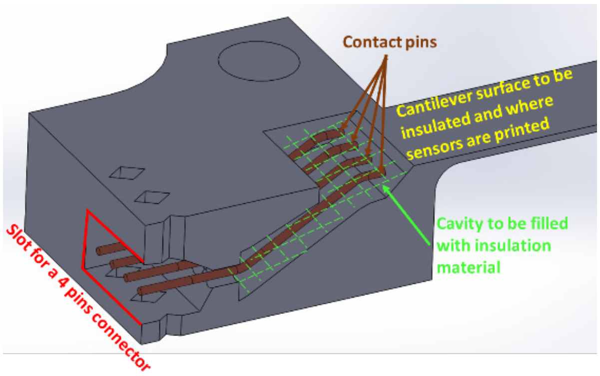

Figure 1: Cross section of the testing cantilever structure CAD design.

In this project we have used and optimized the above building blocks. Moreover, to demonstrate a complex mechatronics device, we have additionally successful demonstrated:

- The integration of built-in electrical wires and connecting interfaces to avoid wires soldering steps. The dielectric insulator has been made by polymer casting technique (see Figure 1).
- Laser smoothing of the metal surface to achieve <700 nm Ra surface roughness in order to provide a good quality surface for sensors printing.
- Ink jet printing (IJP) and aerosol jet printing development (AJP) to deposit electrical insulator layer and strain gauges on AM-flexure elements (see Figure 2). The measured gauge factor (GF) is 2 with silver based AJP gauge wires which is in-line with expected value with such technology.

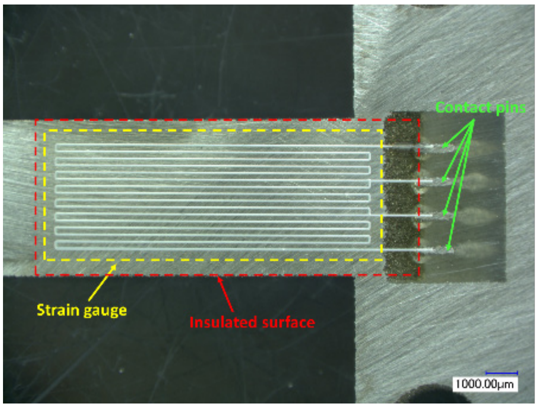

Figure 2: Printed strain gauge and insulation by Aerosol jet printing on a 300 µm-thick flexure element.

The demonstrator is currently under fabrication and consist of a ±5 mm-stroke XY stage with a laser mounted on its output platform. The high precision linear motion will be achieved by integrated 300 µm-thick flexure elements including built-in electrical wires to supply the laser source and to provide an interface for the printed strain sensors. The total structure will represent a volume of about 80x50x80 mm^3. The actuation of the demonstrator will be external.

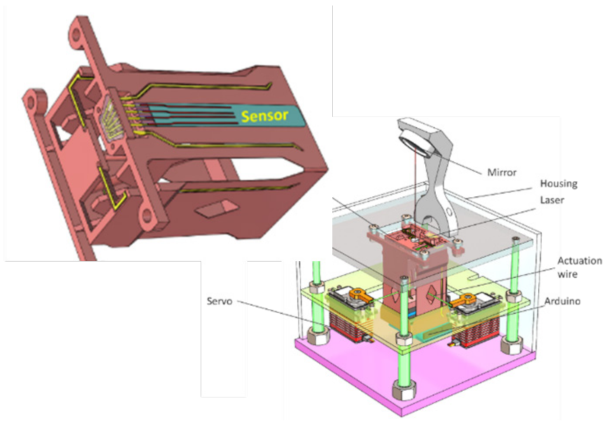

Figure 3: Final demonstrator consisting of the 3D printed XY-stage with embedded sensor and external actuator. A laser pointer is integrated to the moving platform to illustrate the capacity of the demonstrator.

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