MIAM-3D—Metallic Inks Applied to Additively Manufactured 3D parts

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MIAM-3D aims at developing a process to apply printed and plated metallic inks on 3D surfaces and inside thin channels, both built from structural polymer substrates processed by additive manufacturing (AM). The association of AM to manufacture complex shapes, ink printing and plating shows an interesting potential to bring electronics functionalities to a wide range of products. In particular, the metallization of inner channels is a pre-requisite to route electric power or signals inside the structure of a part and therefore to enable the supply of integrated components such as sensors or active elements for heating, cooling, magnetic fields generation, etc. To define target specifications, the project considered an industrial use case from RUAG Slip Rings SA (RSSR), namely the re-design of a Slip Ring Assembly (SRA). To date, MIAM-3D showed the feasibility of the base bricks, namely the deposition and plating of inks on tilted and curved surfaces, as well as inside channels.

The Additive Manufacturing of polymer materials enables a wide range of applications in the field of functionalized parts. During the last twenty years, huge development efforts were dedicated to those technologies, leading to multiple proof of concepts. Fused Deposition Modeling (FDM) techniques allow producing multi-material parts, thanks to the extrusion of melted thermoplastic filaments through multiple nozzles. By using filaments charged with conductive material, mechanical parts including basic electrical functions can be produced. The main drawbacks of FDM are that the parts show anisotropic mechanical properties and poor surface resolution. Furthermore, the thermosetting polymers charged with conductive particles show limited electrical conductivity. An alternative to FDM is Material Jetting 3D Printing which uses printheads to dispense droplets of photosensitive materials that solidify under ultraviolet. Thanks to multiple printheads, multi-material parts including conductive materials can be produced but their electric conductivity and overall durability are poor. Finally, the use of raw metallic inks processed with inkjet or Aerosol jet printing shows moderate conductivity and is limited to 2D or 2.5D surface applications.

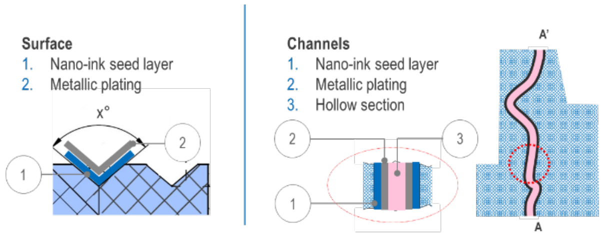

Figure 1: Cross sections of the geometries to be functionalized and illustration of the plated seed-layer. The outer surface has the shape of a V-groove roaming the perimeter of a cylinder. The channel is inside the structure.

To overcome those drawbacks, MIAM-3D proposes to use standard AM processes to manufacture complex shapes and to print metallic inks which will be used as a seed layer for a subsequent metallic plating process. The plated inks will therefore offer the conductivity of the bulk material, a strategic asset when electrical power is to be transmitted. Moreover, the durability of metallic plating layers is well proven. Provided an upgrade of the inkjet setup, inks can be printed on surfaces including 3D topologies. The inks can also be injected to coat hollow channels running inside the structure of the part (see Figure 1). Subsequent plating of the channels will allow achieving high electrical conductivity. As shown on Figure 1 and Figure 2, the Slip Ring Assembly (SRA) use-case of RSSR gathers both requirements: conductive layers on curved and tilted surface, as well as inside channels in order to route the signals from one location to another.

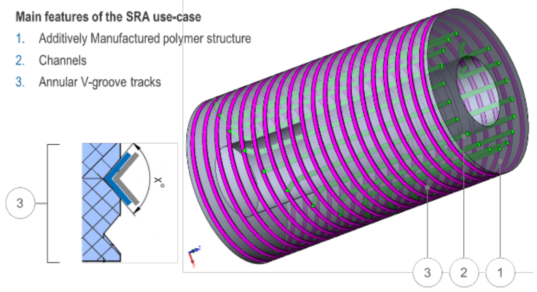

Figure 2: Pre-design of the SRA use-case with its main features.

Current status

The critical geometries shown in Figure 2 were successfully achieved thanks to DLP 3D printing of a ceramic-polymer composite (see Figure 3). Some fine tuning of the geometries is ongoing to improve the shape of the V-grooves. Silver nano-particles ink was successfully printed to representative V-groove samples and finally plated with copper. The electrical resistance of the plating is in the range of 1Ω and the adhesion was validated by means of tape lift testing. The conductive channels were successfully achieved on representative samples by means of an electro-less plating of nickel. The current line resistance is in the range of 1Ω. For both tracks and channels, the electrical properties will be further improved since the plating parameters are not yet optimized. The project is currently continuing with the plating and testing of the prototypes illustrated by Figure 3.

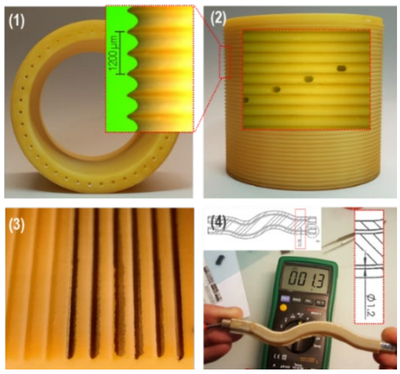

Figure 3: (1) & (2) 3D printed SRA prototype, (3) V-grooves plated ink layers, (4) channel test sample electrical resistance measurement.

• RUAG Slip Rings SA (RSSR)