MAMOS–Metal-based Additive Manufacturing on Silicon

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We have developed an additive manufacturing method to write metal structures directly onto silicon. The method will enable us to extend our traditional MEMS offering with new and innovative devices manufactured with a combined technology.

Additive manufacturing (AM) has recently become a very popular method to fabricate a wide variety of devices. Its popularity stems from its quick turnaround time, which is especially attractive for rapid prototyping. But it has also become more and more interesting for small volume production, for its freedom to create intricate 3D structures and for its potential of material saving.

CSEM recognized the potential of AM and pursues developments in particular for microsystems applications. Hence our main focuses are:

- Optimize processes for micro-size dimensions
- Add functionalities such as flexible mechanical structure and electrically active components
- Combine additive manufacturing with other micro and nano technologies (i.e. MEMS, 3D micro-moulded parts, …)

In this work we have explored the AM-based fabrication on top of silicon substrates, as a starting point for integration with MEMS technology.

The combination of additive manufacturing with silicon MEMS requires a good adhesion of the parts additively manufactured to the silicon base material. We therefore executed an exploratory project with EPFL aiming to analyze how the adhesion could be controlled. As a test vehicle, we took the manufacturing of metal pickup rings on a silicon platform. The rings are intended as pickup rings for a Time-Of-Flight Mass Spectrometer. For this application, we need multiple rings that are relatively closely spaced and that will operate under vacuum. They, therefore, present a nice test case for the technology.

The process that was used to define the metal rings is Selective Laser Melting (SLM) [1]. This method, depicted in Figure 1, deposits a thin layer of a metal pre-cursor powder on a workpiece. The powder is then heated locally with a laser, melting the metal locally. A next metal powder layer is deposited and again locally heated. After the entire piece has been defined layer-by-layer, the un-sintered metal powder is removed, leaving behind the piece defined.

The SLM process has been executed with aluminum and silver particles of different sizes. It was found that the SLM locally heats the metal to very high temperatures, causing a metal line written directly on silicon to tear off a part of the silicon. The fracture stress of untreated silicon is more than 1 GPa, attesting to the stress induced by the process. This difficulty could be overcome by reducing the sintering energy and optimizing the writing strategy. With these optimized parameters, the structures shown in Figures 2 and 3 could be fabricated. The electrode wall thickness is about 100 µm and the electrode hole is 800 µm.

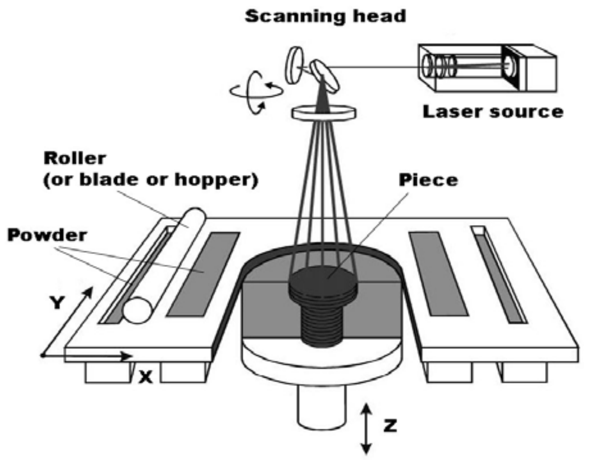

Figure 1: The selective laser melting additive manufacturing principle [1].

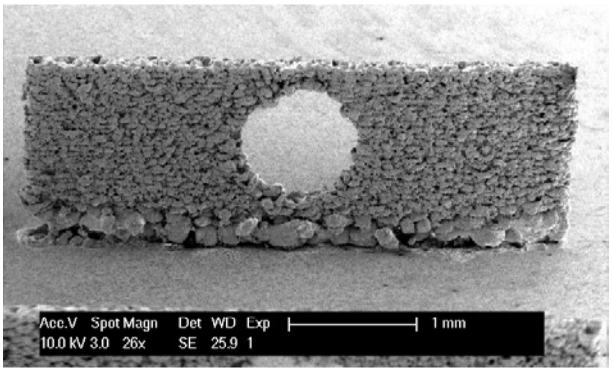

Figure 2: Side view of the Ag-electrode structures written on patterned silicon.

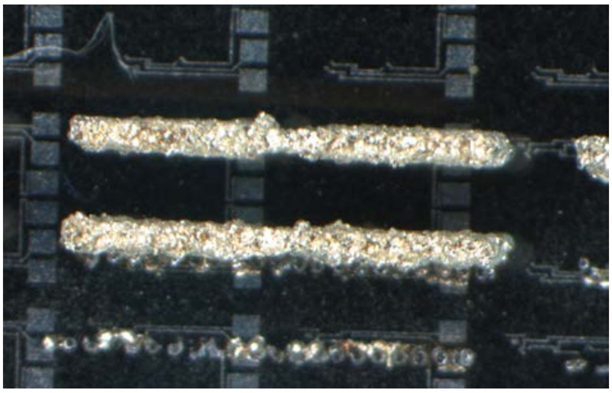

Figure 3: Top view of the structure of Figure 2 on aluminum patterned oxidized silicon (mockup of an interconnect base).

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[1] J. Jhabvala, "Study of the consolidation process under macro- and microscopic thermal effects in Selective Laser Sintering and Selective Laser Melting", PhD. thesis, EPFL. 4609, 2010.