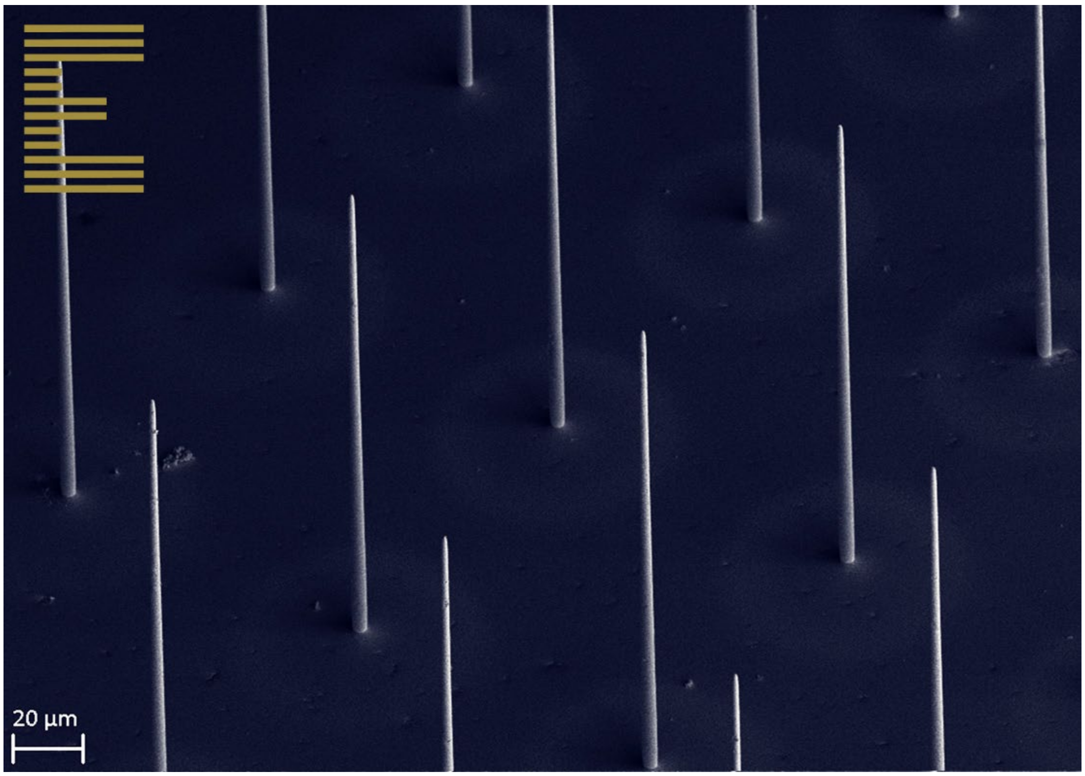
WHITE PAPER

EXADDON CERES – Gold Printing

The Exaddon CERES µAM system prints microscale metal structures with submicron resolution by additive manufacturing. Following the continual refinement of our copper printing capabilities, we have developed an analogous process with gold. This advance brings our unique additive micromanufacturing (µAM) technology to those industries which require minute gold structures in complex geometries.



GOLD µAM. An array of pure gold micropillars, produced by additive micromanufacturing.

INTRODUCTION

Through analyzing market feedback and recognizing the increasing role of gold within microelectronic applications, we took the exciting step of focusing R&D efforts on gold, with a view to delivering it to market as a mature product.

Winter 2020 sees the culmination of that process, and we are very proud to show off what we consider to be a great advance in the additive manufacturing (AM) of complex metal objects at the

MULTIPURPOSE. The CERES system allows different metals to be printed by changing only the consumable printing tip and associated chemicals.

Subject to change without notice.

microscale - this time in pure gold. While researching and refining electrodeposition of copper on both metal and polymer substrates, our engineers and electrochemists began developing and optimizing the same process with gold.

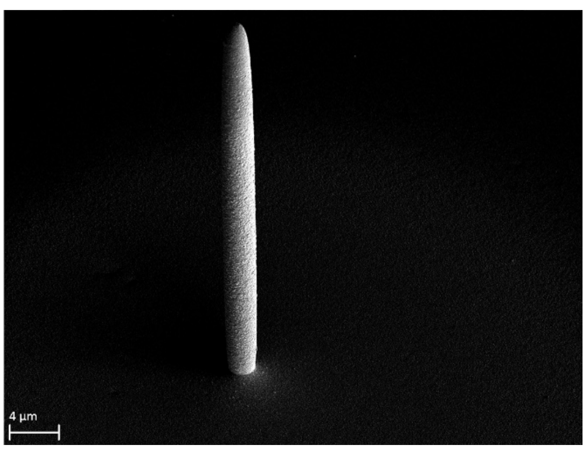
Printing complex microscale metal objects by electrodeposition means that a change in print material has profound implications for the entire electrochemical print process, and it is in this area that a great deal of time and effort has been invested.

WHY GOLD?

Through extensive collaboration and feedback from various partners in different industries, it is abundantly clear that gold has great importance in microscale applications.

Within the MEMS area, gold is frequently used for electrical connections and structural layers, due to its high conductivity and corrosion resistance. This paper will look at two use cases where µAM of gold has great potential.

USE CASE 1 – NEURONAL INTERFACES



MICROSCALE AM. A micropillar printed in pure gold.

Neuronal interfaces such as implantable electrodes or multiple-electrode arrays have recently received much media coverage, and for good reason. They have great value as transformative tools for monitoring and modifying neural electrophysiology, both for fundamental studies of the nervous system, and for the diagnosis and treatment of neurological disorders. These neuronal interfaces require high electrical conductivity to minimize background noise and enhance recording fidelity [1].

Within this field, gold has seen extensive use as a material of choice for implantable electrodes due to both its conductivity and durability paired with the material's inherent cell compatibility. We see additive micromanufacturing in medical applications as the next step.

USE CASE 2 – BIOSENSORS & BIORECEPTORS

Similarly, biocompatible biosensors using a gold contact layer have proven efficacy in the detection of tumor biomarkers and carcinogenic cells. Additive manufacturing's ability to produce intricate geometries has led to its identification as the ideal technology for pharmaceutical applications requiring a high degree of accuracy and personalization.

In recent years, wearable electrochemical biosensors have proven their worth for real-time reporting and continuous management of diseases, such as glucose monitoring or detection of biotoxins [2]. The durability and conductivity of gold as an electrode has been demonstrated in this arena in numerous studies [3].

As an indication of the importance of these devices, the market value and forecast for biosensors shows great growth. As of Sept 2020, the global biosensors market is expected to grow from USD 21.5 bn in 2019 to USD 41.29 bn by 2027 - a CAGR of 8.5% [4].

BENEFITS OF ELECTROPLATING VS OTHER METHODS OF FABRICATION

Electrodeposition of gold is a crucial process in modern day microelectronics and has been for some years.

Notably, gold can be electroplated with relative ease, enabling higher film thickness than can be achieved with physical vapor deposition (PVD) methods such as sputtering, whilst also enabling higher rates of deposition.

A crucial point here is that both sputtering and thermal expansion require a high vacuum chamber to be carried out. Furthermore, these methods cannot be used to build 3D objects, but only to coat entire areas of an object (if partially coating an object, masks are needed). In the case of Exaddon's unique electrodeposition process, our CERES print system operates at room temperature in normal atmospheric conditions, and enables almost free form 3D design possibilities. This opens up a huge range of possibilities in terms of printing options, and indeed the types of pre-existing structures which can be modified and printed upon.

Microelectronic components can be extremely sensitive to conventional manufacturing environments such as heat or adverse pH. And Exaddon's μAM technology utilizes a very benign room temperature process, thus minimizing the chance of potential damage to delicate components.

COMPLEXITY OF GOLD PRINTING R&D

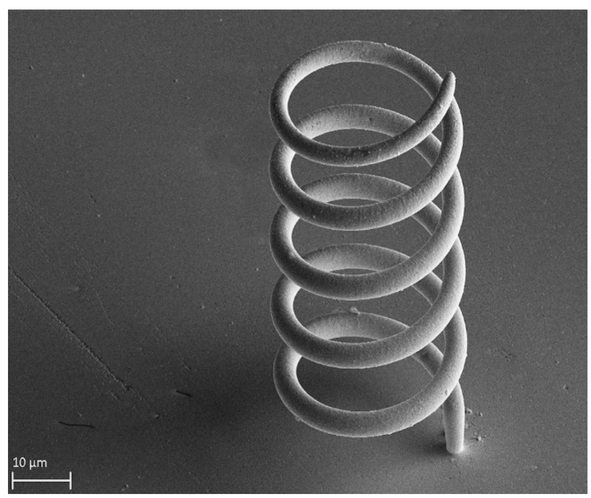
The technical challenges of developing a microscale gold AM are manifold; it is not simply a case of changing the printing ink from copper to gold and commencing printing. The electrochemistry is highly complex and requires extensive R&D and technical knowledge to configure successfully. Accuracy and replicability are essential in μAM, and these attributes only result from robust electrochemical R&D.

The first challenge is that unlike ionic copper, gold ions are not stable in solution, and thus require the addition of certain chemical agents to prevent the ionic gold precipitating out of solution, which could otherwise clog the printing tip and exhaust the supply of gold available for printing.

Additionally, due to interaction with the chemicals, we needed to develop modified iontips with a protective coating to achieve successful gold deposition.

EXADDON GOLD μAM CAPABILITIES

Using our standard 300 nm aperture iontips, we can print voxels of 800 nm to 4.5 μm in diameter, allowing for an extremely small minimum feature size. The surface quality of objects printed with our gold ink is extremely good. This is very important for end use applications such as bioreceptors or neuronal interfaces, where precision and durability are critical.



SURFACE QUALITY. Through extensive electrochemistry R&D, we have achieved exceptional surface quality with our gold print process.

In terms of print substrates, the substrate surface must be conductive and compatible with electroplating. Accordingly, our standard metal substrates such as copper and gold are of course viable, as are flexible polymers such as PEDOT.

Our development of an industry-ready gold µAM solution is a genuine breakthrough in the application of Industry 4.0 technologies to real-world use cases, and one which has the potential to change the game.

REFERENCES

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