WHITE PAPER

EXADDON CERES – Mapping of Surface Topography Using µAM

The Exaddon CERES µAM (additive micromanufacturing) system prints complex metal structures with submicron resolution by additive manufacturing. Utilizing the unique technology of our iontip printing probes, we have developed a surface mapping functionality that scans and prints on existing structures in one seamless workflow, allowing microscale metal objects to be printed on contact lines and pads with submicrometer precision.

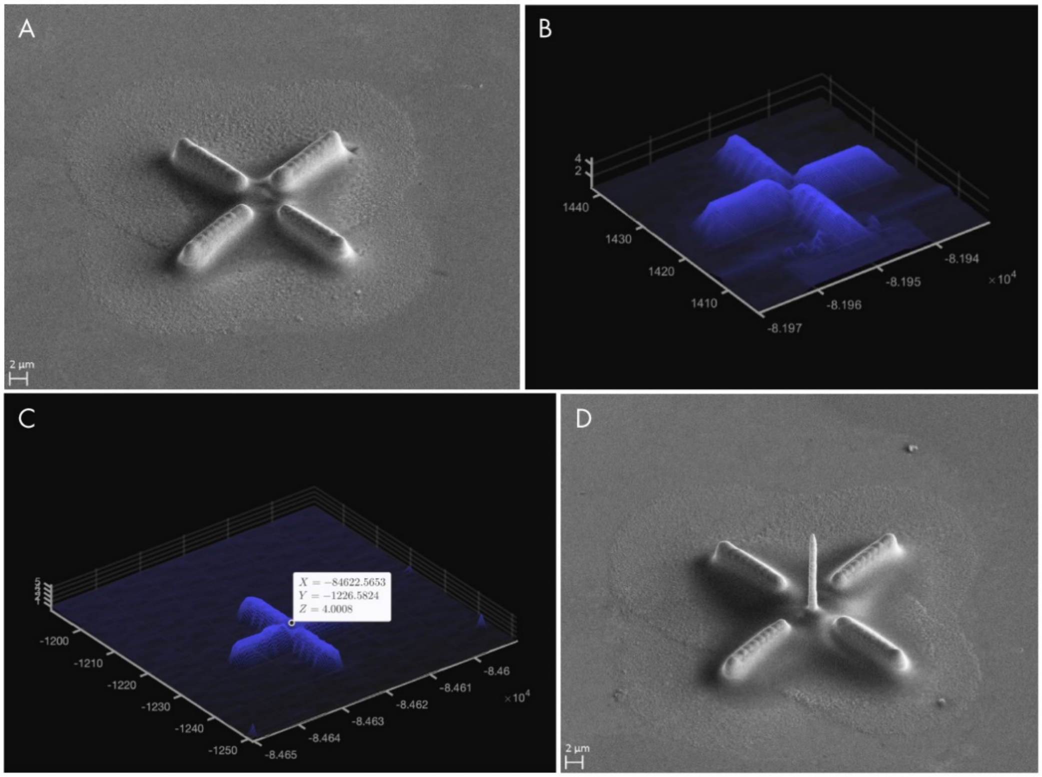

Fig. 1: UNIQUE TECHNOLOGY. The iontip of our CERES µAM print system enables a surface to be mapped prior to printing on it. A user wants to print on an existing structure (A) with submicrometer precision. The mapping operation produces a visual representation of the structure (B), and the user selects the desired print location (C). The new object (D) is printed, in this case a 500 nm ∅ pillar.

EXPLORING NEW POSSIBILITIES.

At the heart of Exaddon's CERES µAM print system is our unique iontip; a hollow atomic force microscope (AFM) cantilever from which an aqueous solution containing metal ions is dispensed. Through electrodeposition, these ions are then reduced into solid metal atoms, enabling the printing of individual voxels of pure metal. The use of a hollow AFM cantilever offers twofold benefits; the ability to additive manufacture complex metal structures in microscale dimensions with nanometer precision, and the ability to scan a surface as per a conventional AFM. This topographical analysis capability, or "mapping" as we term it, is a recent breakthrough which we achieved after extensive research and testing. The aim of this process was to print on contact lines and pads, thus enabling ultra-precise modification of semiconductors and other devices with the unique capabilities of metal µAM.

WHAT NEW FUNCTIONALITY DOES THIS BRING?

In conventional AFM, the cantilever is used to physically trace the surface of the material to create an 'image', of its surface features. This process can achieve a resolution many times higher than the optical refraction limit, and it is this functionality which we sought to exploit.

As well as printing objects directly onto blank substrates, we wanted to enable our CERES system to print microscale objects upon existing structures, such as connectors between contact pads on a wafer. This is an extremely demanding operation which requires incredible precision to locate and print on structures with submicrometer accuracy.

Whilst identification of the exact print location is typically achieved using the in-system cameras (sufficient for the majority of microscale uses), this presented a potential limitation when such extreme precision was required. Even though our CERES system incorporates high-resolution optics, they do not provide sufficient accuracy to precisely locate pre-existing flat or patterned structures <5 µm in diameter, and <1 µm in height (our cameras allow XY accuracy to less than 4 µm).

Accordingly, we conducted extensive research and testing to develop a surface mapping functionality that allows the system to map the anticipated print area before then printing on it. All of this is carried out in one seamless workflow, which is essential for print accuracy. This is best explained through an example use case, as per below.

EXAMPLE USE CASE: LOCATING AND PRINTING ON CONTACT PADS.

A user has an integrated circuit (IC) with pre-existing conductive traces and contact pads, which they want to print on (e.g., microscale connectors). In our printer software, the user creates a square grid over the area within which the contact pads are located, and defines the size of the grid required. Each intersection of this grid denotes a point where the iontip actually moves down and touches the surface; the tighter the grid, the higher the mapping resolution.

Once this grid has been defined, the user initiates the mapping workflow, and the system proceeds to map the area as defined, thus locating the contact pads exactly within that area. The software outputs a plot representing the mapped area, essentially a height map of Z coordinates from within this grid (as per Fig. 2 below).

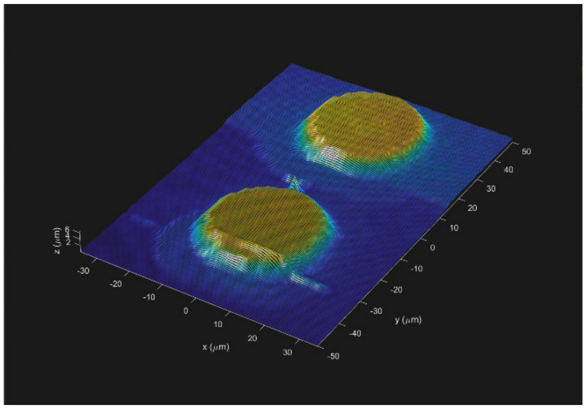

Fig. 2: NANOSCALE APPLICATION Our mapping workflow outputs a visual representation of the detected surface topography, such as the two contact pads displayed here.

FULL USER CUSTOMIZATION.

A key feature of the mapping functionality is that the user can define the resolution and speed of mapping which they require; it is fully customizable.

Example: a 40 x 40 µm grid with 1 µm increments would be ideal for an extremely accurate scan of a small area, i.e. a high resolution map. Alternatively, the user could set the grid to be hundreds of micrometers long in both X and Y stages, with larger increments, for example every 1 µm, 5 µm, or 20 µm.

It is important to remember that this functionality is for mapping what can be considered 2D or "2.5D" structures, such as pads or conductive traces, not full 3D objects.

In terms of duration, the more increments, the slower the mapping process: the time taken increases linearly with the number of grid points. For reference, a 40 x 40 µm grid with 1681 points takes approximately 6 minutes to be mapped, with a set iontip retract height of 5 µm in between each point.

ACCURACY AND DURABILITY.

As our iontip was originally based on an AFM cantilever, this functionality does not affect print accuracy. Repeated map – print – map – print operations are possible without affecting the alignment or precision of the system, thus allowing multiple print operations to be carried out on a single wafer.

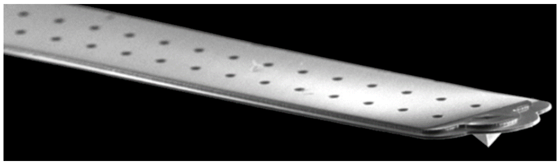

Fig. 3: EXADDON IONTIP The printing tip of our CERES machine utilizes a hollow AFM cantilever, called an iontip

In terms of detection capabilities, we designed this to address the need to locate pre-existing structures on wafer surfaces. Accordingly, the mapping function can detect structures with heights as low as 200 nm. In test scenarios, we located and printed upon conductive lines 500 nm in height. A real-world application of this is printing at a very specific location on a silicon chip patterned with a copper or gold layer; our mapping function can detect and locate tracks in the pattern to ensure exact placement of printed structures with a resolution of less than 1 µm.

LOOKING FORWARD.

This mapping functionality will be integrated with the latest release of our print system operator software, with full notes within the user manual for ease of use.

This mapping functionality forms the basis of a series of new developments which will extend the already unique capabilities of our CERES system yet further.