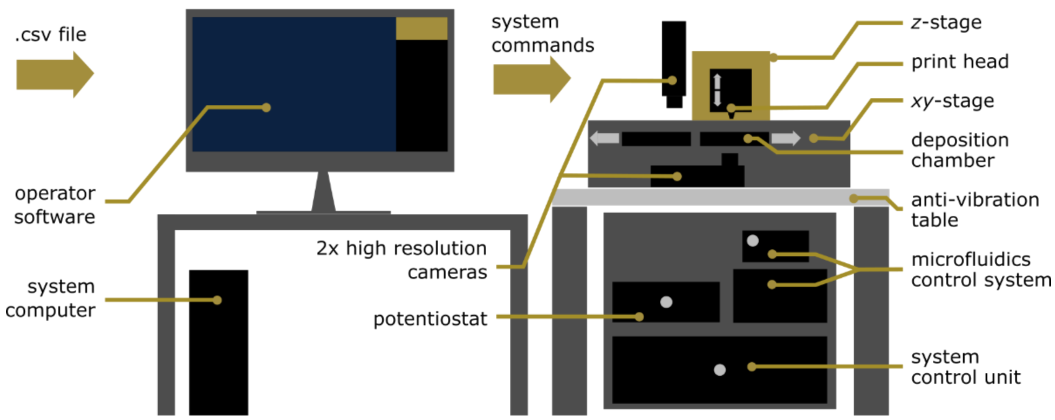
EXADDON

CERES

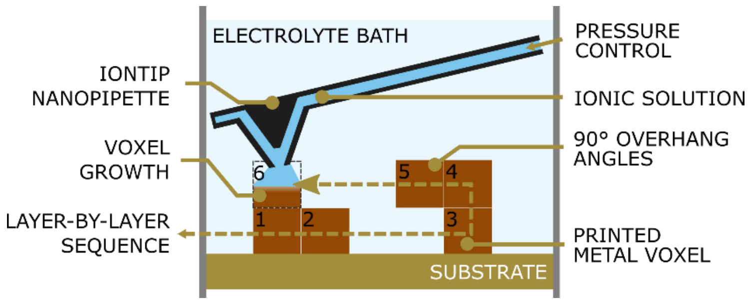
METAL 3D PRINTING WITH SUBMICRON RESOLUTION

The CERES system, developed by Exaddon AG, directly 3D prints metal under ambient conditions. The system builds complex structures with submicron resolution by additive manufacturing, opening new horizons in domains such as microelectronics, MEMS and surface functionalization.



USER FRIENDLY. Schematics of the CERES system. The system is controlled by an intuitive operator software and sits on an anti-vibration table. The controller hardware is located underneath the table.

up to 6'000'000 µm³ PRINTING VOLUME (metal)	**100 x 70 x 60** CHAMBER VOLUME (in mm)	**up to 200 µm/s** PROCESS SPEED	**XY ±10 nm & Z ±3 nm** POSITIONING JITTER

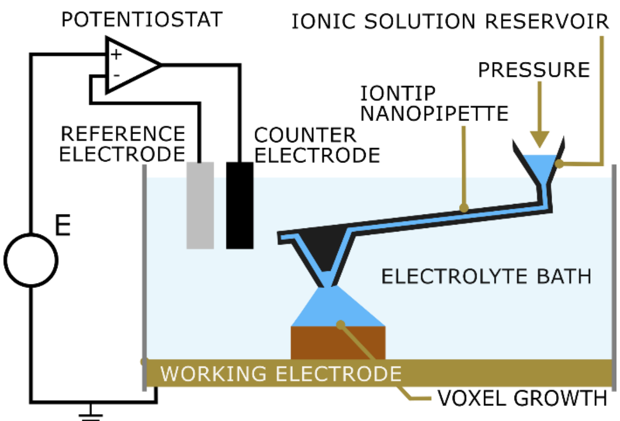


DESIGN. The printing process is executed voxel-by-voxel and layer-by-layer. The process allows 90° overhanging structures and free-standing structures.

The metal printing process is voxel based. Voxels are defined as elementary 3D blocks. Stacked in a layer-by-layer sequence at defined coordinates, the voxels form the desired 2D or 3D geometry. Free-standing structures and 90° overhanging angles are feasible without support structures, bringing true design freedom.

The printing process is automated by real-time feedback of the deflection of the iontip. As a voxel reaches completion, the top side of the voxel interacts with the tip, deflecting the cantilever by a minute amount. The process is much like an AFM cantilever operating in contact-mode. If a user-defined deflection threshold is reached, the voxel is considered as printed. The tip is then quickly retracted to a safe traveling height and is moved to the next voxel.

The voxel coordinates, the printing pressure and the deflection threshold of the cantilever are specified in a csv file. The file is loaded into the printer's operator software. The csv files are generated by a design assistant, the so-called Voxel Cloud Generator, provided by Exaddon. Alternatively, the files can be generated by any third-party software capable of exporting plain text files.



BUILD. The electrochemical setup used to printing a structure. The potentiostat applies a voltage to control the reduction reaction.

The voxels are built from an ionic solution, which is pushed out of the ion tip by a microfluidic pressure controller that regulates the pressure applied at < 1 mbar precision. Such a pressure resolution allows a local flow of the ion containing liquid of less than a picoliter per second. Under an appropriate voltage, applied by a potentiostat, a reduction reaction transforms the metallic ions into solid metal. Customer-defined ionic solutions, as well as Exaddon supplied ioninks, can be used to guarantee the printing quality.

An example of an ionic solution is a copper sulfate solution ($CuSO_4$) in sulfuric acid (H_2SO_4). The following reaction takes place at the working electrode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu\ (s)$.

Like for most electroplating techniques, a conductive liquid bath is needed for the electrolytic cell to work. In this case, the printing chamber is filled with sulfuric acid in water at pH = 3, to allow a current to flow.

A conductive surface is required for the working electrode on which the deposition occurs. A potentiostat controls the user-defined potential and supplies current in the electrochemical cell through a graphite counter electrode. An Ag/AgCl reference electrode is used to measure the working electrode potential. All electrodes are immersed in a supporting electrolyte.

Two high-resolution cameras (top and bottom view) enable iontip loading, printer setup and visualization of the printed structures. Computer-assisted alignment is built-in for printing on already existing structures. To print on, e.g., electrodes that are pre-defined on a chip surface.

The software gives feedback to the user, both during and after printing, of success, failure or difficulties encountered for each voxel.

The CERES system executes also other processes like 2D Nanolithography and nanoparticle deposition. The system is open and flexible so that the user can also design custom deposition processes.

The CERES system is a promising tool for academic and industrial research. It offers an unprecedented maturity and control in additive manufacturing of metal structures on the microscale.

REFERENCES

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2. Grüter *et al.* FluidFM as a lithography tool in liquid: Spatially controlled deposition of fluorescent nanoparticles. (2012) Nanoscale **5**, pp. 1097-1104, doi: 10.1039/c2nr33214k

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