CERES µ3Dprinter Exaddon, CISUP: 2021 and 2022 activity report

Giuseppe Barillaro, Alessandro Paghi, Martina Corsi, Alessandro Verde, Farbod Abazar

Location: Department of Information Engineering, Via Girolamo Caruso, 16, Pisa, Italy
Lab head: Prof. Giuseppe Barillaro
Contact: info@cisup.unipi.it

Laboratory web-page: https://cisup.unipi.it/labs/fluidfm-%ce%bc3dprinter-cytosurge/

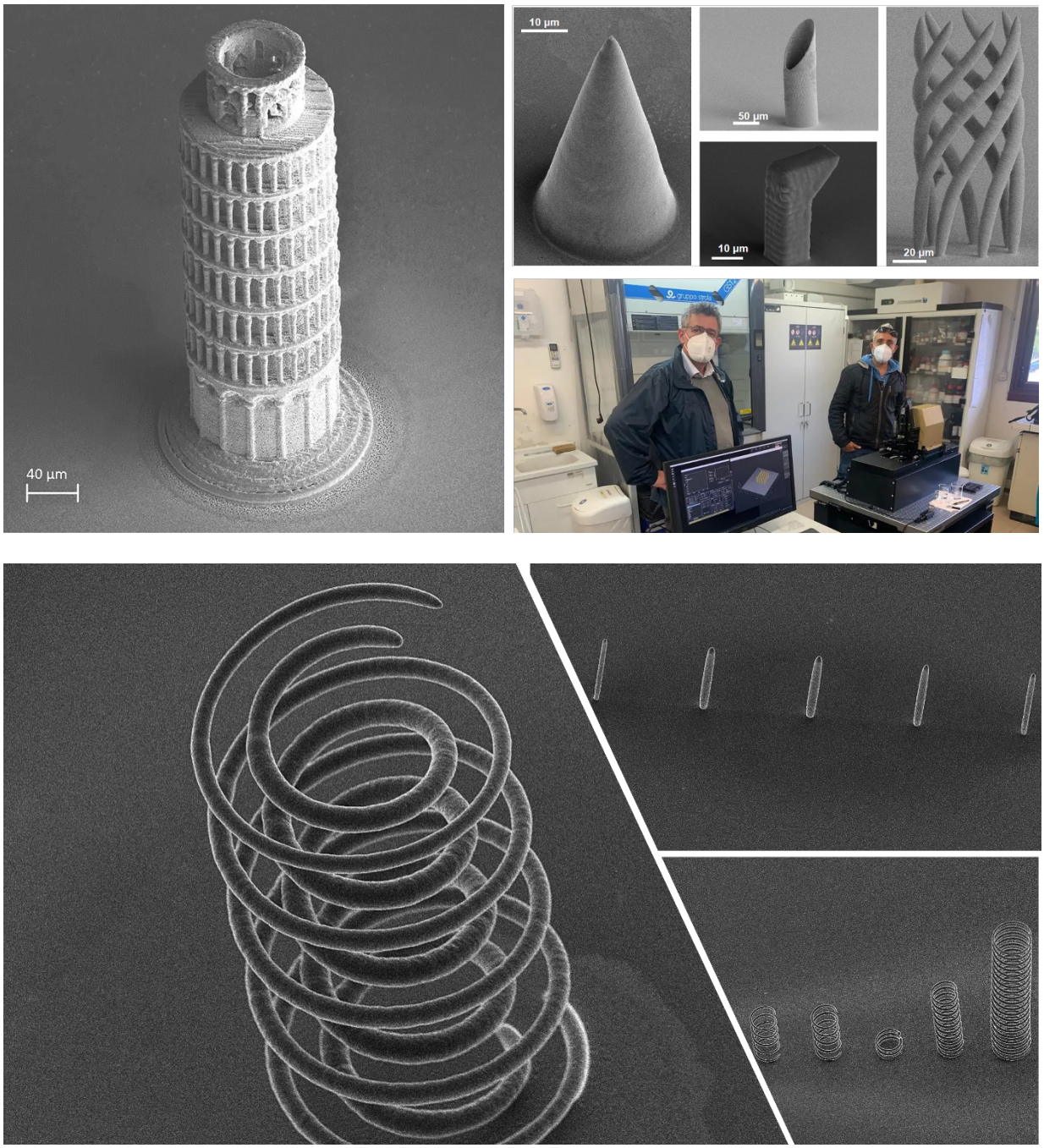

Figure.1: *SEM images of copper microstructure printed with CERES µ3Dprinter Exaddon during 2021 activity. Upper SEM images are presented as courtesy of Exaddon CERES. Lower SEM images were acquired with JEOL JSM-6390 located at DII, UniPi.*

Abstract – This report includes: i) Upgrade and maintenance; ii) price list; iii) hours worked; iv) collaboration and project; v) funded project; vi) objectives and future prospective. We note our laboratory's growing impact on research and educational activities within UniPi, with the involvement of an increasing number of different projects.

1. Laboratory implementation

In November 2021 we executed the lubrification of x-y-z mechanism, the axis calibration, and the maintenance of the head of the printer to ensure good printing with the Exaddon expert. We installed a new software CAPA 2.0 with updates that improve the user interface. The system is now configured to improve the printing and design more complex structures. CAPA 2.0 enables the mapping of a substrate onto which the print will be performed. The resulting map is a grid of points defined by the user at which the height of the substrate is measured by the ion tip. This height map offers a higher spatial resolution than the old feature, whose resolution is limited by the optical resolution of the top view system. The Exaddon expert carried out a technical hands-on training on the µ3Dprinter for two PhD students at the Department of Information Engineering.

In June 2022, CISUP assigned one grant for a postdoc position on the direct 3D printing of micro and nano metal structures and components for gas sensing applications (*NExT3D* project). The *NExT3D* project has been prepared by Prof. G. Barillaro and funded to CISUP with 60 kEur (50% Tuscany Region, 20% Colorobbia, 30% Prof. Barillaro).

In July 2022 we executed the maintenance step of µ3Dprinter to ensure optimal printing with the Exaddon expert. We installed a new firmware for the software CAPA 3.0 with updates that improve the user interface. We also installed the new Voxel Cloud Generator tool with a new interface "Voxelizer" (Beta version). The system is now configured to design new structure and convert CAD 3D projects in files that can be printed with µ3Dprinter. The Exaddon expert carried out a technical hands-on training on the µ3Dprinter to the new postdoc enrolled at CISUP.

In September 2022 we executed the lubrification of x-y-z mechanism, the clean maintenance of the cell used for electrodeposition of metals and, the total calibration of the instrument to ensure good printing.

In October 2022, we start to prepare in our laboratory the printing chamber solution, as suggested the Exaddon expert, to personalize the print in-home.

In December 2022 we upgrade the head of the µ3Dprinter to gold printing. Prof. Barillaro provided six prototypes of ion tips with 540 nm of aperture to improve the printing of structure simultaneously from few microns up to tens of microns.

2. Price List

Price list to be published on the CISUP website with the instructions for quote requests (table 1).

Type of experiment	UNIPI	Research institutes	Privates
Printing of default/standard microstructures	190 €/printing head + 10€/h operator	190 €/printing head + 15€/h operator	190 €/printing head + 20€/h operator
Printing of nonstandard microstructures	190 €/printing head + to be defined with operator	190 €/printing head + to be defined with operator	190 €/printing head + to be defined with operator

Table. 1 Price list 2022, VAT excluded.

All fares referring to standard/routine microprinting are fixed and include the presence and support of authorized experts. The pricing for nonstandard applications (e.g., development of novel microstructures to be printed) will be discussed for each individual case, including research projects, collaborations, agreements with research institutes.
Interested users are invited to contact the Scientific Committee to discuss the specific case study and to request a quote. Interested users can also register on CISUP website and book a printing section in the book calendar available here: https://cisup.unipi.it/booking/booking-ceres-fluidfm-%ce%bc3d-printer/.

3. Hours worked

Table 2 shows the worked hours of the µ3Dprinter in 2021. During year 2021, the printer worked for 744 hours in total for print, maintenance, upgrades, and work-training.

Time period	***Jan-Mar 2021***		***Apr-Jun 2021***		***Jul-Sep 2021***		***Oct-Dec 2021***		***Tot***	
Unit	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*
Maintenance	4	0.5	4	0.5	4	0.5	4	0.5	16	2
Training	-	-	-	-	-	-	8	1	8	1
Print	216	29.5	144	19.0	96	13	264	35.5	720	97
Tot	**220**	**30**	**148**	**19.5**	**100**	**13.5**	**276**	**36**	**744**	**100**

Table. 2 µ3Dprinter usage in terms of hours during 2021.

In mid-May 2021 we had problem with the tips of the printer. The O-ring of the head nose, where the print-tip is secured, had become slack. Moreover, the ink had deposited on the printing nose and sealing screw. Keeping the head clean helps to prevent leaks and ensures the performance and reliability of the system. In May 2021 we executed the deep head nose cleaning through the online support of Exaddon.

Table 3 shows the worked hours of the µ3Dprinter until September 2022. During year 2022, the printer worked for 537 hours in total for print, maintenance, upgrades, and work-training.

Time period	***Jan-Mar 2022***		***Apr-Jun 2022***		***Jul-Sep 2022***		***Oct-Dec 2022***		***Tot***	
Unit	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*	*Hours*	*%*
Maintenance	4	0.6	4	0.6	4	0.6	20	3	32	4.8
Training	-	-	-	-	8	1.2	-	-	8	1.2
Print	133	20.4	114	17.5	270	41.3	96	14.8	613	94
Tot	**137**	**21**	**118**	**18.1**	**282**	**43.1**	**116**	**17.8**	**653**	**100**

Table. 3 µ3Dprinter usage in terms of hours during 2022.

Note that, in the period October-December 2022 the printed was down, which explain the reduced number of worked hours in Oct-Dec 2022.
We experienced a technical problem with the head of the printer and the time dedicated to the print is decreased. The grippers that locked the ion tip on the head did not work. The head was sent to Exaddon in Switzerland for fixing the problem and perform the update of the head to also enable gold deposition. The repair and the gold update were paid with institutional funds of Prof. Barillaro, transferred to CISUP. Exaddon service had problems with the shipment and the printer was stuck at the custom until end of December 2022.

4. Collaborations and projects

The users of the µ3Dprinter over the year 2021-2022 include PhD students and postdocs from Department of Information Engineering of the University of Pisa (DII) and one postdoc from CISUP, who have been trained for copper printing.

The activities have been mainly focused on the field of microfabrication of electronic components for high frequency technologies, biomedical applications, and environmental sensors, as reported in Fig.2.

The main projects that have been carried out in 2021 and 2022 are:

- 3D-printed micro-inductors for high frequency applications (2021-current): copper micro-coil printed directly on a patterned substrate with an operation range from DC to 10 GHz. This project is supported with internal funds of Prof. G. Barillaro and aimed at intercepting funding from industrial partners and provided preliminary data supporting the *NExT3D* proposal (see below)

- 3D-printed metallic microneedles for physiological signal acquisition (2021-current): development of conductive array of minimally invasive needles for monitoring bioelectrical signals from the skin to analyze the activity of the motor neuron in humans. The project is in collaboration with the Imperial College of London and aimed at getting preliminary results to leverage in EU project applications.

- 3D-printed metallic metal oxide micro gas sensors and metal electronics components at the microscale within the *NExT3D* project (2022-current): The research activity focuses on the direct 3D printing of an array of micrometric chemitransistor sensors and electronic components for environmental monitoring applications, in collaboration with an industrial partner, namely, Colorobbia. The project was funded to CISUP with 60 kEur (50% Tuscany Region, 20% Colorobbia, 30% Prof. Barillaro).

- 3D-printed metallic microneedles for sensing applications (2022-current): development of microneedles for multianalyte sensing. This project is in collaboration with the company ab medica, leader in the production and distribution of medical technologies, and it is aimed at getting preliminary results to leverage in industrial contracts.

Collaboration with UNIPI research groups, though not limited to, are welcome.

5. Funded Projects

- Acronym: "*NExT3D*"

Project Title: "Direct 3D printing of metal structures at the micrometer scale for the development of a new generation of electronic and photonic sensors and components", Cofunded by the Tuscany Region.

Amount: 60 kEur
Year: June 2022- May 2024

The project has been funded to CISUP with 60 kEur (50% Tuscany Region, 20% Colorobbia, 30% Prof. Barillaro).

- Microneedle project:

For the projects focused on microneedles, Prof. G. Barillaro transferred in 2022 an amount of 6 kEur to CISUP to support these research activities with the microprinter.

Amount: 6 kEur
Year: 2022

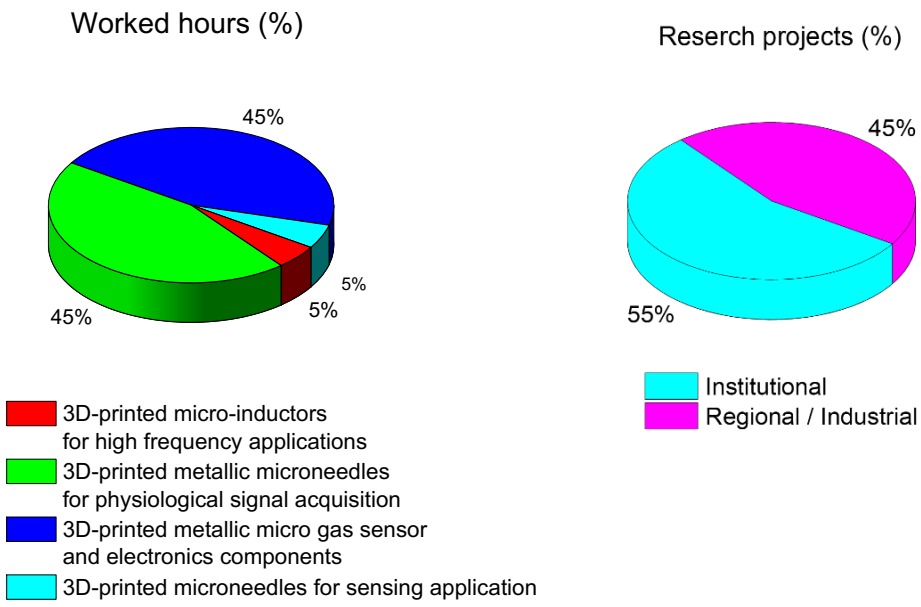

Figure 2. *Percentage of worked hours on projects and funds.*

6. Objectives and future prospective

Achievements. Most of the work carried out so far has been focused on the use of the µ3Dprinter and the optimization of printing process of copper microstructures, given the printer is mainly a research tool. We can now print copper microstructures with different geometrical characteristics on different conductive substrates (e.g., silicon, metallized boards and flexible fols), also patterned with complex geometries. We can now prepare the printing solution and the ink solution with the aim of improving the performance of the µ3Dprinter.

Future prospective. In April 2022 University of Pisa announced the public selection, for the assignment of one grant for research activities that will focus on the direct 3D printing of micro and nano metal structures and components for gas sensing applications, cofounded by the Tuscany Region and the industrial partner Colorobbia. The project will leverage the unique features of the Exaddon CERES 3D printing available at the Center for Instrumentation Sharing University of Pisa – CISUP to enable the fabrication of groundbreaking structures and components not achievable with other state-of-the-art technologies. The project has allowed to enroll at CISUP a postdoc for 24 months that will be working full-time with the µ3Dprinter.
Besides, three other projects supported with institutional funds of Prof. Barillaro are going on, one on biomedical applications in collaboration with the Imperial College of London, one on high frequency applications of interest of an industrial partner leader in the field of telecommunication, one (starting in Dec 2022) on the printing of microneedles for biosensing applications of interest of ab medica. Preliminary demonstration of the functionality of these devices will be leveraged for the preparation of research proposal at EU level and/or for signing industrial contracts with companies.
As an outcome of the research activity that has been carried out with µ3Dprinter, we foresee collaboration with other research group at UNIPI and abroad, publication of scientific papers on high impact journals, applications to EU projects, research contract from industrial partners.