Simulating the generation of 3D printed micro-objects

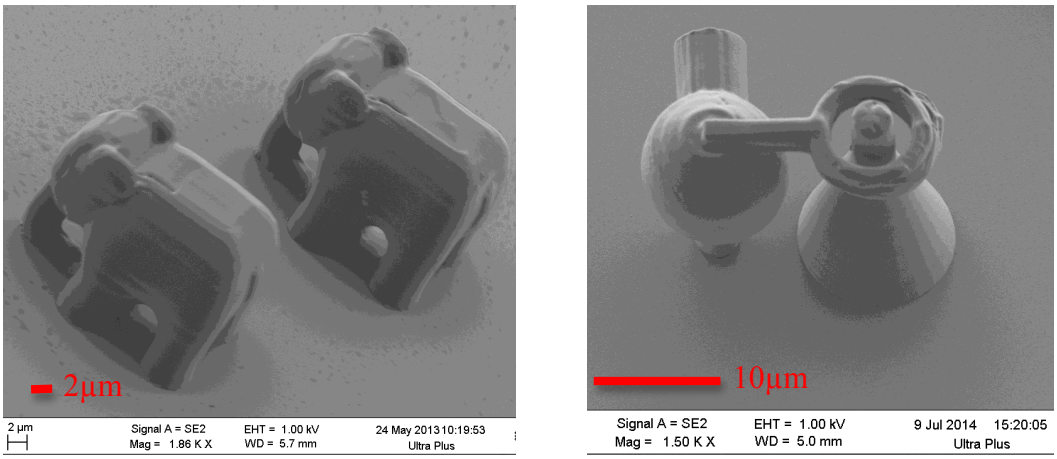

Figure 1: Examples of 3D micro-objects and associated dimensional scales.

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Context

3D printing is a rapidly evolving technology that generates 3D objects. The framework of the proposed project fits into the partnership between the IMAGINE team and the LIPHY laboratory that jointly work on the technology to print 3D micro-objects. One talk about micro-objects 3D because their dimensions reach the size of several tens of µm (see Figure 1). These micro-objects find applications in natural sciences, the development of micro-mechanisms, …

The currently developed manufacturing setup generates a polymerization reaction in an area inside a resin drop where the micro-object is actually manufactured. The elementary polymerized zone take the shape of an ellipsoid of revolution. Indeed, it is the elementary voxel of the micro-object that can be manufactured. Its size reaches a few hundreds of nm. The objects obtained are manufactured as a set of overlapping voxels. The trajectories of the laser beam are computed using an in-house software [1, 2]. After the polymerization with the laser beam, a solvent is used to remove the liquid resin and free the 3D micro-object thus manufactured.

Because of their size, the micro-objects obtained cannot be straightforwardly observed. Their morphology is visible only through an electron beam microscope under a chosen viewpoint, as in Figure 1. This is fairly constraining because it is mandatory to move the micro-object to an adequate microscope and the possible viewpoints do not allow the user to check the quality of the micro-object, its dimensions, its imperfections or its surface roughness.

Key-words: 3D printing, micro-fabrication, implicit surfaces, 3D simulation.

Objectives:

From the trajectories of the laser beam that generate a micro-object and the parameters of the laser (power, exposure time, displacement velocity of the laser beam, …), we have available, through our physico-chemists colleagues of the LIPHY laboratory, mathematical models that predict the shape and location of ellipsoids.

The objective of this project holds in the development of a simulator capable of describing with details, the shape of the 3D object that will be generated. To this end, it is necessary to describe the successive voxels forming the 3D micro-object to be able to precisely evaluate the dimensions of the manufactured object, its surface roughness, its shape imperfections deriving from the planned laser trajectories, the influence of laser parameters, …

Additionally, the 3D model of the micro-object derived from this simulator will enable a thourough and reliable analysis of the object whereas the effectively manufactured objects are generally observed from a single viewpoint using an electron beam microscope.

The 3D geometric model of the micro-objet will result from the union of its constitutive ellipsoids. Thus, the detailed geometric model of the object could be achieved using implicit surfaces [3, 4], or alpha-shapes [5, 6, 7] or other similar approaches that can efficiently represent the whole set of voxels describing the micro-object. The laser parameters could be taken into account to develop approaches based skeleton-based implicit surfaces in order to structure the geometric model obtained with the laser trajectories.

To take into account the monitoring parameters of the laser and of its movements, the previous objectives will be addressed in partnership with the physico-chemists colleagues of the LIPHY laboratory.

Profile: background in geometry, computer graphics, applied mathematics.

References

[1] CY, Liao, J.-C., Léon, P., Baldeck, C., Masclet, M., Bouriau, T.T. Chung, Using extended layered manufacturing method to improve fabricating efficiency of three-dimensional microfabrication base on two-photon polymerization, Applied Physics Letters, Vol. 91, 033108, Juillet, 2007

[2] C-Y Liao, J-C Léon, C Masclet, M Bouriau, P L. Baldeck, T-T Chung, Product Model Preparation and Processing for Micro-manufacturing, Int. J. ASME, JCISE, Vol. 8, n°2, June, 2008

[3] Macêdo, I., Gois, J. P. and Velho, L., Hermite Radial Basis Functions Implicits. Computer Graphics Forum, 30: 27–42. 2011, doi: 10.1111/j.1467-8659.2010.01785.x

[4] Zanni, C., Bernhardt, A., Quiblier, M. and Cani, M.-P., SCALe-invariant Integral Surfaces. Computer Graphics Forum, 32: 219–232. 2013, doi: 10.1111/cgf.12199

[5] Teichmann, M., & Capps, M.. Surface reconstruction with anisotropic density-scaled alpha shapes. In Visualization'98. Proceedings (pp. 67-72). IEEE, Octobre 1998

[6] F. Bernardini and C. Bajaj. Sampling and reconstructing manifolds using alpha-shapes. Tech. Report CSD-TR-97-013, Dept. Comput. Sci., Purdue Univ., West Lafayette, IN, 1997

[7] H. Edelsbrunner and E. P. Mücke. Three-dimensional alpha shapes. ACM Trans. Graph., 13(1):43–72, January 1994.