Nano Aperture Ion Source Fabricated Using 3D Focused Electron Beam Induced Deposition

Aya Mahgoub, W.D. Laur, C.W Hagen, P. Kruit
Delft Univ. of Technology, ImPhys Department, 2628CJ Delft, The Netherlands
M.I.M.A.Mahgoub-1@tudelft.nl

3D printing on the mm scale is now a mature technology that is widely used in many fields. However, the demand for '3D nanoprinting' is now rising in fields such as nanomagnetism[1], plasmonics[2], biomedical engineering, mask repair, fabrication of AFM tips and more. Structures include vertical nanowires, helices, membranes and others[1]. We present here the design and fabrication of a novel ion source, based on electron impact ionization of gases[3,4]. The design exploits the 3D fabrication capability of Focused Electron Beam Induced Deposition (FEBID). The deposited structure consists of two concentric hollow cones, as illustrated in figure 1, the inner one deposited on the upper membrane, the outer one on the bottom membrane. The gas (e.g. Ar, O_2, He, H_2, etc.) is inserted between the two membranes and ionized by a focused electron beam. To extract the ions, an extraction electrode below the source creates an electrostatic field, which is enhanced by the geometry of the cones.

FEBID is a flexible single-step technique for direct-write of 3D shapes that are almost impossible to fabricate with existing lithography techniques. Recently a number of reports appeared in literature on the fabrication of 3D shapes using FEBID [5, 6, 7], some even using simulation guided deposition. The approach used in this work is a rather experimental one, starting with an educated choice of the beam energy and probe current. The dwell time determines the volume of a deposited dot for each beam position. Then, for various dwell times, test deposits are made to determine the best pitch between deposited dots in two directions: i) along the circumference of the cone and ii) along the radial direction of the cone. Both pitches are chosen such that closed-wall cones are achieved at the fastest growth rate. The two cones are deposited simultaneously layer by layer as a set of dots on a circle. The layers consist of circles of decreasing radius going towards the cone apex. An example of a double cone deposited by FEBID from the $MeCpPtMe_3$ precursor is shown in figure 2. We will discuss the challenges involved in optimizing the deposition parameters and the writing strategy to achieve the most efficient growth.

---

[1] D. Sanz-Hernández, et al., Nanomaterials. 8(7): p. 483 (2018).
[2] R. Winkler, et al., ACS Applied Materials & Interfaces, 9(9): p. 8233-8240 (2017).
[3] L. V. Kouwen, P. Kruit, Journal of Vacuum Science & Technology B, 36(6): p. 06J901 (2018).
[4] P. Kruit, V.N. Tondare, United States Patent No. US 7772564 B2 (2010).
[5] L. Keller, M. Huth, Beilstein Journal of Nanotechnology, 9: p. 2581-2598 (2018).
[6] J. D. Fowlkes, et al., ACS Applied Nanomaterials (2018).
[7] L. Skoric et al., Nano Letters, 20(1): p. 184-191 (2020).

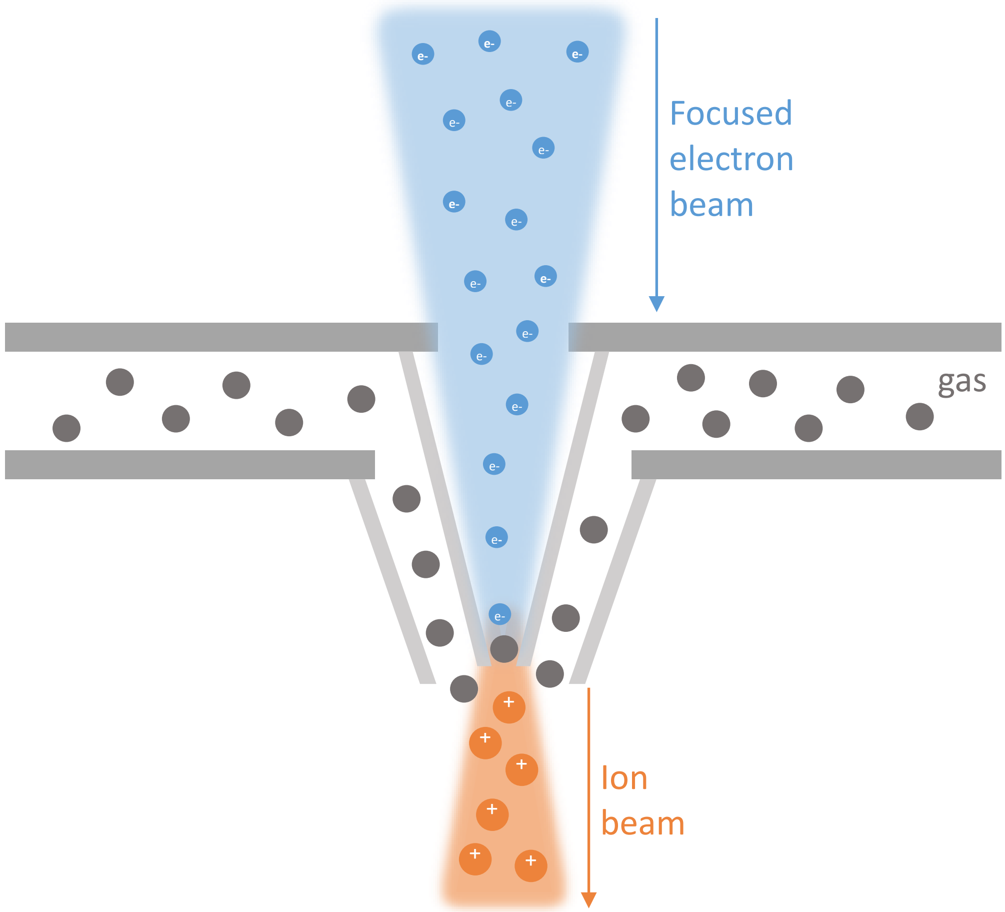

Figure 1: A cross section of the ion source chip is shown. There are two membranes in between which the gas is inserted. Electrons enter through the aperture in the upper membrane. An electrostatic field is applied to the cones using extraction electrodes. The gas (e.g. Argon) flows between the two cones. The shape of the double cone enhances the field and ensures that the ions are extracted in the correct direction. Please note that the cross section of the double cone in this cartoon is inverted compared to figure 2.

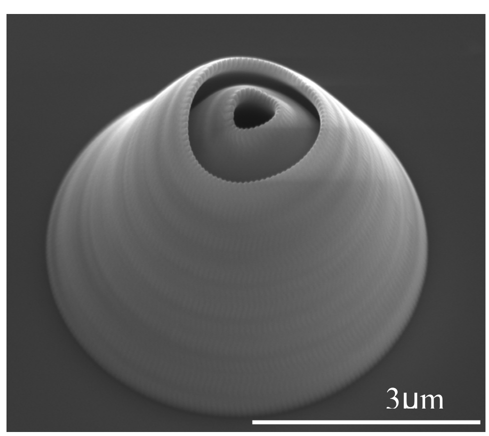

Figure 2: 3D double hollow cone deposited by FEBID from the $MeCpPtMe_3$ precursor.