FIB based Sketch & Peel with various Ion Species for Fast and Precise Patterning of Large Structures

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FIB nanofabrication has proven unique strengths by numerous applications in R&D prototyping [1]. It helps to achieve scientific results faster by *in-situ* optimization of patterning parameters and reducing the number of steps for the overall process. Moreover the slow patterning speed of direct FIB milling itself (as compared to resist-accelerated lithography) can be overcome by the method of sketch & peel. This approach has been proposed for direct patterning of thin gold films before [2] and is able to create isolated metallic structures by milling only the outline of the design elements plus "peel off" with a scotch-tape method instead of completely removing the unwanted gold areas.

Here we further investigate sketch & peel as well as its applications. First, we have employed continuous writing strategies based on a laser interferometer controlled stage movement for creating a seamless groove across extended distances. This enables mm sized patterns within minutes and at the same time nm features, still showing clean removal (figure 1). Second, the combination of sketch & peel with high resolution milling has been shown for examples of plasmonic patterns (figure 2). Large arrays of circles, which are otherwise by conventional milling time consuming to fabricate, are defined by sketch & peel and in the same step the additional finest features like various cuts into the gold circles are made by direct milling. Third, we have compared the sketch & peel process for different ion species provided by a liquid metal alloy ion source and selected through a mass separation filter (figure 3). This gives patterning capabilities on the 10 nm scale for various ions besides Ga including Si, Ge and Au [3], however some processes here give significantly different results.

We present application examples as well as a study of patterning strategies, doses, substrate material, ion species and other aspects. The limits of these approaches and further thoughts on the mechanism of sketch & peel will be discussed.

[1] L. Bruchhaus et al., Appl. Phys. Rev. 4, 011302 (2017); doi: 10.1063/1.4972262
[2] Y. Chen et al., ACS Nano 2016, 10, 11228-11236.
[3] S. Bauerdick et al., JVST B 2013, 31, 06F404.

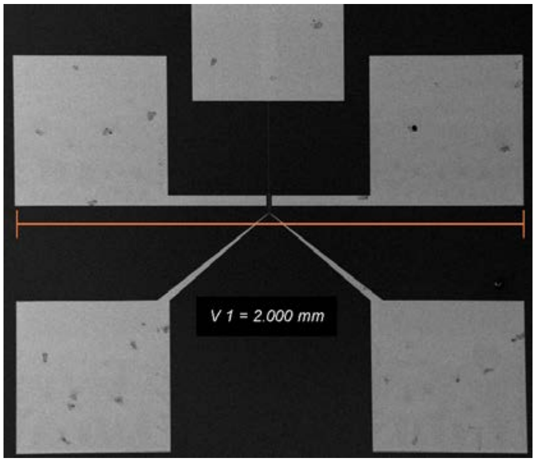

Figure 1a: SEM image of a gold contact pad structure created in less than 10 min.

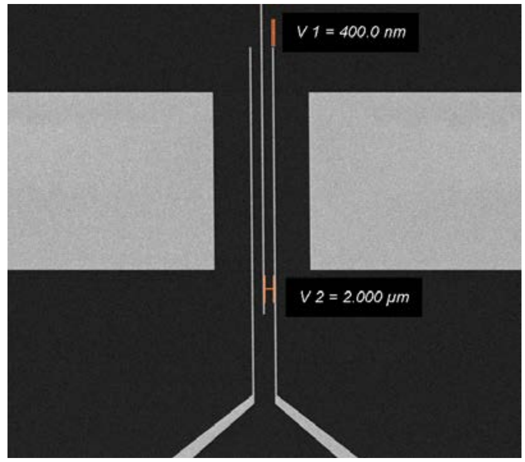

Figure 1b: Inner part of the contact pad structure.

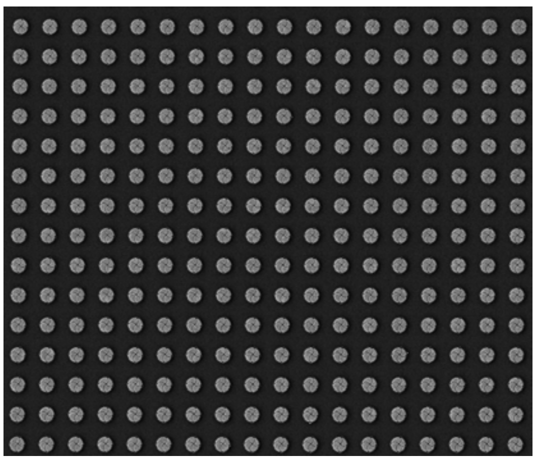

Figure 2a: SEM image of plasmonic nano-particle array created by sketch & peel.

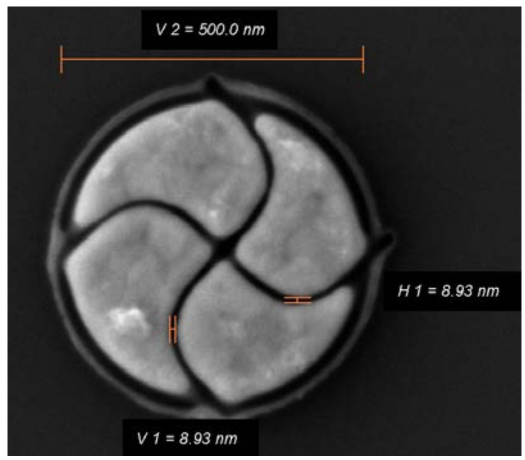

Figure 2b: The additional sinusoidal cuts are made by conventional milling directly.

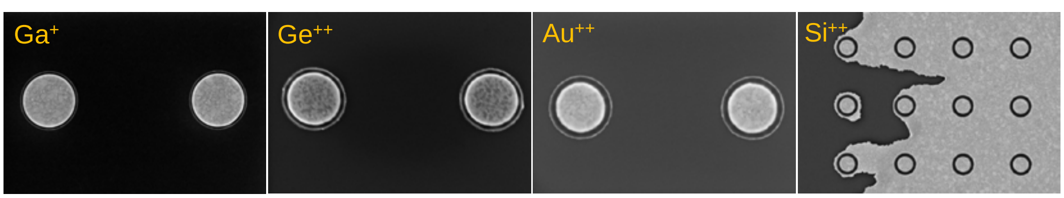

Figure 3: Test arrays with 800 nm circles created with 4 different ion species.