Field-Emission Scanning Probe Lithography with Diamond tips

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The nano-electronics manufacturing is based on the ongoing development of the lithography and encompasses also some ‘‘unconventional’’ methods. In this context, we use field emission scanning probe lithography (FE-SPL) to generate nano-scaled features in 10 nm calixaren-resist layers. This lithographic method has been explained in a previous publication [1]. Therefor we built a FE-SPL-and-AFM platform combine FE-SPL and AFM using the same (active) cantilever. The utilization of self-sensing and self-actuated scanning probes enables us to use two independent feedback loops in our setup: a feedback loop for the AFM and a second as a current-control feedback for FE-SPL [2,3].
Since both, FE-SPL and AFM results are dependent on the tip radius, for large area patterning tip wear plays an important role regarding resolution and image quality. To address this issue, we prepare probes made of diamond, since it is a very hard material, thus they guarantee a high stability during AFM measurements. Furthermore, diamond is a good electron emitter and can provide negative electron emission, resulting in metal like surface conductivity [4].
For this purpose, a small piece of CVD-diamond is integrated onto the active cantilever and afterwards it is micro-machined with a focused Ga^+ ion beam. Due to fine micro-machining with the Gallium beam, the previously non-conducting diamond becomes conductive. By EDX and Auger measurements of the tip Ga were found at the tip. Hence, the change of the conductivity of the diamond crystal could be explained due to Ga-implantation and amorphisation caused by the high-energetic Ga^+ ions during the FIB micro-machining process. The processed diamond tip can be seen in Fig. 1.
In this talk we will present the utilization of diamond tips for FE-SPL purposes. As can be seen in Fig. 2, it is possible to generate negative and positive tone features. Here, the applied voltage in each column was raised from 60 V to 100 V, whereas the line dose within each line was increased from 50 nC/cm to 250 nC/cm. Tip wear and stability regarding long-term SPL patterning or AFM measurements will be discussed.

[1] Rangelow, I.W. et. al., Proc. SPIE, 7637 (2010).
[2] Kaestner, M. et. al., Proc. SPIE, 8323 (2012)
[3] Vorbringer-Doroshovets, N. et. al., Proc. SPIE, 8680 (2013)
[4] Maier, F. et. al., Physical Review Letters, Vol. 85, Nr. 16, 3472 (2000)

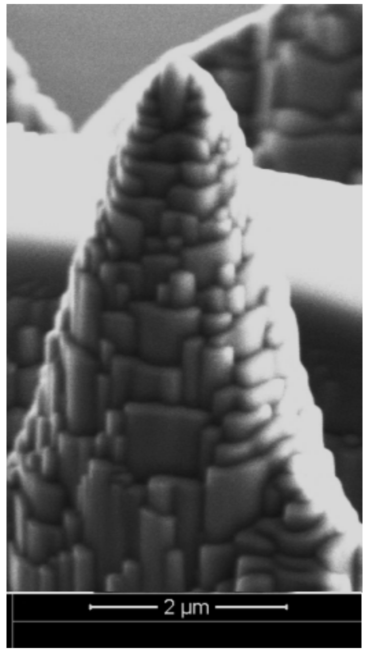

Figure 1: Processed diamond tip after micro-machining with a focused Ga+ ion beam

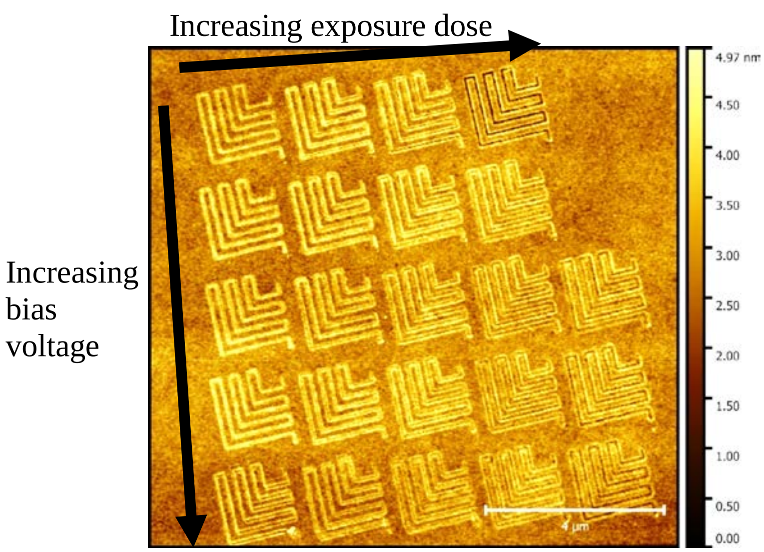

Figure 2: Exposure test by the utilization of a Diamond tip. Bias voltage was varied from 60 V to 100 V with steps of 10 V within a column, whilst the exposure dose for this process was in the range of 50 nC/cm – 250 nC/cm with steps of 50 nC/cm within a line of features. Patterns in positive and negative tone can be generated.