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Focused ion beam processing of low melting polymers: new perspectives due to optimized patterning strategies

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During the last decade focused ion beam (FIB) processing became of increased importance due to its unique possibilities of site specific specimen manipulation. So far, FIB processing has been well established for transmission electron microscopy related ultrathin lamella preparation, but also gained importance as a method for 3D metrology and 3D surface structuring from the micro- to the nanoscale [1]. Due to its flexibility and straightforward implementation character, it represents a rapid prototyping tool for science and technology. Aside from these undoubted advantages, FIB processing entails unwanted side effects, such a spatially confined ion implantation, surface or bulk amorphization [1] and partial high thermal stress [2,3]. While the former two are intrinsic properties and therefore invariable, local heating effects have been shown to depend strongly on the patterning strategy. The reduction of this technically induced heating is of particular relevance for low melting materials such as polymers and biological material [4,5] but requires an improved understanding of the thermal effects during scanning.

As a starting point we discuss briefly a recently introduced alternative patterning strategy, which strongly reduced local temperatures by a decoupling from technically induced effects [6]. As a second point different polymers are subjected to this alternative process and compared to classical strategies. Characterization includes morphology via scanning electron microscopy (SEM), atomic force microscopy (AFM) and Kelvin force microscopy (KFM) as well as chemistry via Raman spectroscopy (RS). It will be shown that for FIB processing the materials can be roughly divided into two classes: 1) polymers that would mainly undergo cross-linking (CL) when exposed to thermal stress; and 2) others that would rather react by scissioning (SC) under the same conditions. This kind of reaction to thermal stress has a great influence on the morphology received when patterning.

Based on these results, spatially resolved simulations of the temperature evolution have been performed ranging from single ion events towards full patterning processes (Figure 1). The comparison with the experimental data suggest that CL materials increase their rigidity due to thermally induced cross linking while SC polymers reveal an increasing mobility on the micro-and nanoscale, which finally leads to extremely rugged surface structures. The careful adaption of the alternative patterning strategy to material related peculiarities, observed during FIB single pulse events, allows finally for strongly improved morphological stability (Figure 2). Finally, it is shown that the new patterning strategies decrease chemical degradation as well, which is of high interest for the final application or subsequent processes.

The study demonstrates the capabilities of FIB processing for low melting materials by using adapted scan strategies which can be easily implemented in most FIB systems. By that, new possibility for FIB based rapid prototyping on low melting materials might open up which have been considered as very complicated or even impossible before.

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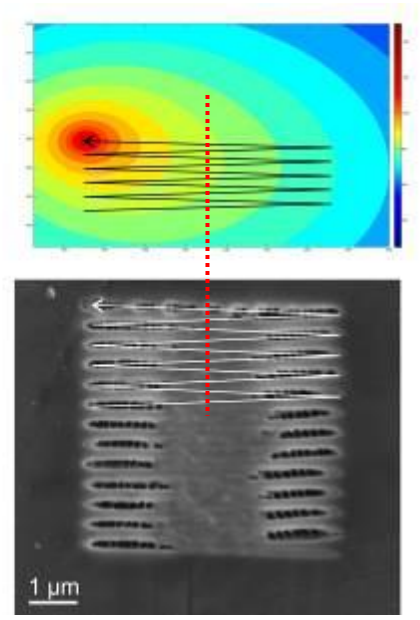

Figure 1. Simulated temperature evolution (top) during zig-zag scanning which reveals asymmetric temperature distributions and residual towards the center of the scanning lines (dotted red line). The correlated experiments (bottom) show a blurry area at the center which stems from temperature assisted material creeping. For higher temperatures closer to the end of the line, the material is immediately evaporated leading to deep trenches.

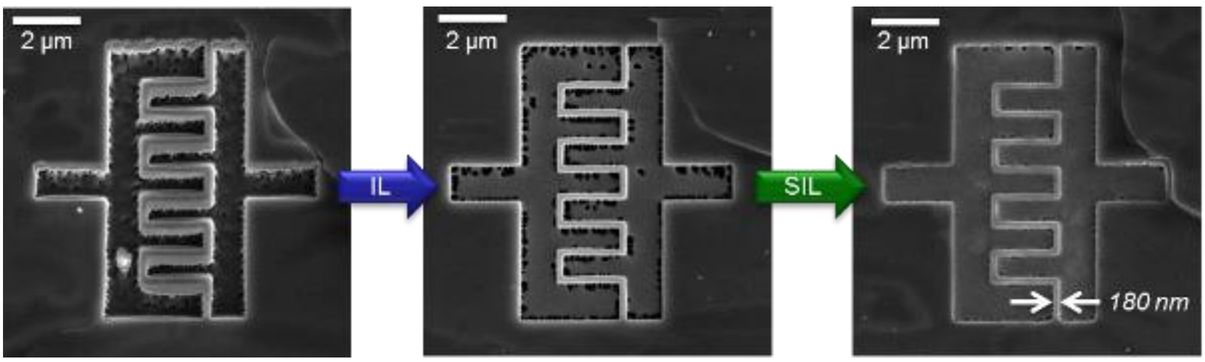

Figure 2. FIB processed polymer sample structured via classical approaches (left). While the introduction of an alternative interlacing (IL) strategy improves the morphological stability, the full potential is only exploit after parameter adaption to material dependent properties via smart interlacing (SIL) processing.