MINIMIZED BLURRING IN STENCIL LITHOGRAPHY USING A COMPLIANT MEMBRANE

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Stencil lithography (SL) is based on the principle of shadow mask technique, in which a solid mask is used to locally pattern the surface. This method can, for example, be applied to thin-film deposition, plasma etching or ion implantation through the apertures in the mask. The use of SL avoids resist coating, baking of the wafers and exposure to chemicals. SL has demonstrated to be a valid technique for the patterning of nanometric structures [1-3].

Improvements have been made making SL a reliable method and useful for various applications [4, 5]. A remaining challenge in SL is the so-called blurring, i.e. the enlargement of the transferred structures on the substrate compared to the aperture in the stencil (Figure 1). It is documented that the blurring depends on the gap between the stencil and the substrate [6]. Due to the non-planarity of stencil and substrate, the gap is unavoidable with a standard configuration. We propose a solution to this issue based on a novel geometry consisting in a stencil with protruding parts which are mechanically uncoupled from the silicon frame of the stencil wafer (Figure 1b).

In order to accomplish the targeted goal, we studied by means of FEM simulations the behavior of different geometries. The preferred geometry due to its linear behavior and the simplicity of the fabrication process consisted in a square membrane connected to the silicon body by 4 non-planar beams. The FEM simulations show that a membrane supported by four 250µm long cantilevers under a load of 25µN deflects 40µm. 200µm long and 150µm long beams require a load of 45µN and 72µN respectively.

The fabrication of these stencils starts with a 100mm Si wafer coated with 200nm SiN. Squares of SiN were left on the wafer after photolithography and subsequent dry etching. The wafer was exposed to KOH for 2h to define 40µm high mesa structures (Figure 3a). The SiN mask was removed by HF etching and a 500nm thick low stress SiN film was deposited by LPCVD (Figure 3b). Backside openings for the final etching in KOH were then defined (Figure 3c). The front-side was patterned using a 14µm thick resist layer followed by dry etching. The membrane supporting cantilevers on the KOH slope and the membrane apertures on top of the mesa structures were defined (Figure 3d). Finally, a backside etching in KOH released the membranes from the bulk silicon (Figure 3e, Figure 4). After releasing, nanoapertures were defined on some membranes by focused ion beam milling (Figure 3f).

A 100nm thick aluminum film was deposited by e-beam evaporation through the stencil on a flat silicon wafer. SEM inspection revealed that the performance of the membranes in contact with the substrate is comparable to the FEM simulations (Figure 5). Subsequently, the stencil was removed leaving the pattern on the Si wafer.

The aluminum structures on the substrate present a central thick part corresponding to the membrane aperture plus a geometric factor (geometric blurring contribution) and also an additional thin halo around (surface diffusion blurring contribution). Careful inspection showed that both blurring contributions were minimized by the use of compliant membranes, as it can be seen in Figure 6.

We have demonstrated that the use of a compliant stencil reduces the blurring as it adapts the stencil membrane to the surface and minimizes the gap between stencil and substrate. Ongoing work includes the definition of nanoapertures by means of e-beam lithography, for which blurring effects on wafer scale is the predominant reason for resolution loss. We anticipate that with a compliant stencil, sub-micrometer SL becomes reliable on full-wafer scale.

Word Count: 594

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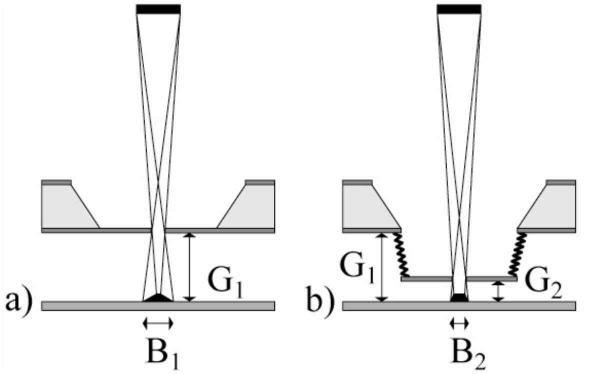

Figure 1. a) The Blurring B_1 is determined by the stencil and substrate curvature which results in a gap G_1. b) G_2 and B_2 are minimized due to a compliant stencil configuration.

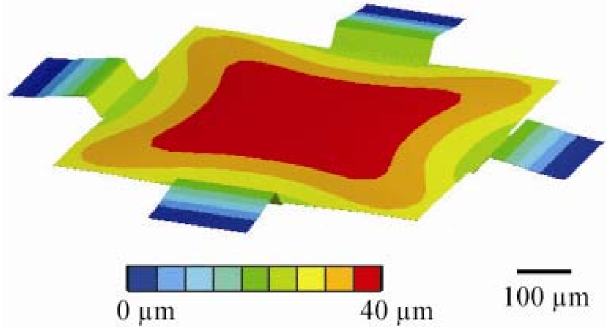

Figure 2. Result from a FEM simulation showing that a membrane supported by four 200µm long cantilevers deflects 40µm under a load of 45µN. Note that 40µm deflection was chosen because experimental evidences have shown this to be a typical maximum value for the gap.

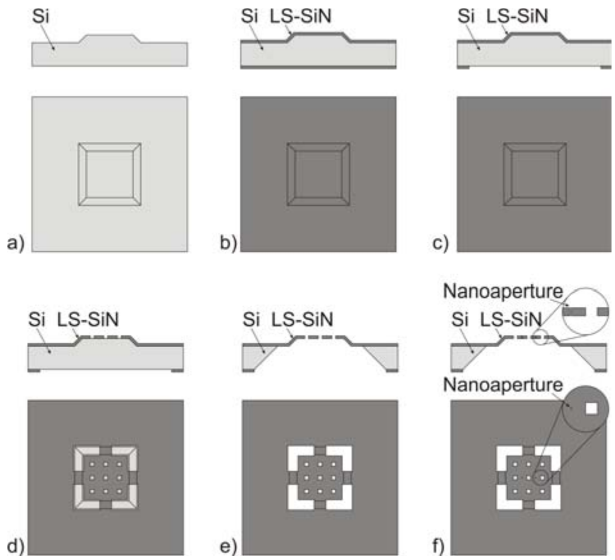

Figure 3. Side and top view of the process flow for a compliant stencil including nanoapertures.

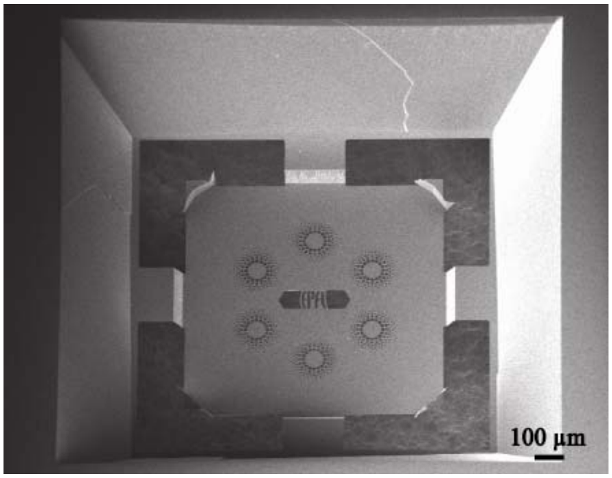

Figure 4. SEM micrograph of a free standing compliant stencil membrane supported by four cantilevers.

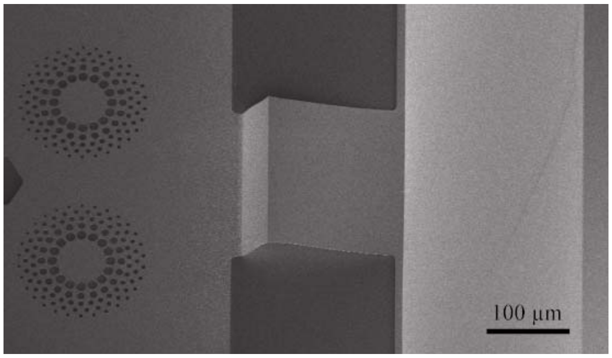

Figure 5. Deflected beam of a compliant stencil membrane in contact with a Si wafer. The beam bending is comparable to that predicted by FEM simulations in Figure 2.

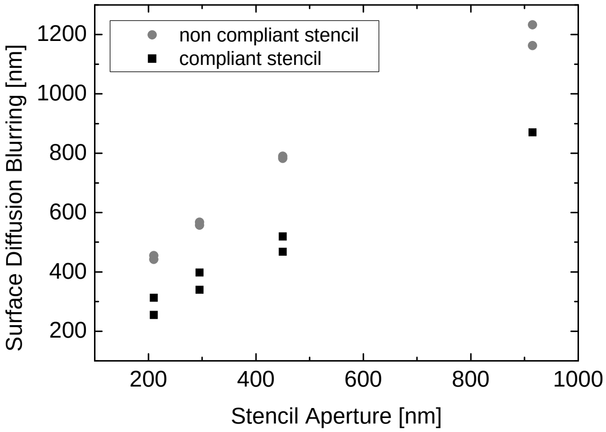

Figure 6. Graph comparing the blurring due to surface diffusion obtained from flat membranes and from compliant membranes. A reduction in size of approximately 40% can be observed in all the cases.