Robust Mask-Layout Synthesis for MEMS[1]

Category: *Design, Modelling and Synthesis*

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This paper describes an automatic method for synthesizing MEMS mask-layouts that are robust to fabrication variations and modeling inaccuracy. For a given desired shape, one or more mask-layouts can be found which not only can result in fabricated shapes sufficiently close to the desired one, but also are robust to the expected variations. An approach for mask and process synthesis using genetic algorithms, assuming no variations and inaccuracy during the fabrication and modeling procedure, was reported at MSM'2000 [6]. Some target shapes and synthesized mask-layouts are shown in Figure 1. This paper reports a method to improve the robustness of the synthesized results by introducing fabrication variations and modeling inaccuracy into the synthesis iteration. By favoring the candidate solutions that are more robust to variations through fitness values during the synthesis iteration, mask-layouts that are both accurate and robust to the variations can be evolved as the final solution.

Our synthesis approach works as an iteration loop. For a given desired device shape, an initial random population of valid mask-layouts is produced. For each candidate, samples of Gaussian-distributed noise (*e.g.*, mask misalignment, and etch rate variations) are introduced, and the fabrications of the mask under the effect of the applied sampled noises are simulated using a 3-D etching simulation tool (SEGS) [4, 5]. A closeness value is obtained for each simulated shape by comparing it with the desired shape [1], and the closeness values for all the sampled noise cases for a candidate are combined to construct a shape mismatch metric which is used as the fitness value for this candidate. According to the fitness values of all candidates in the population, a genetic algorithm [2, 3] is then applied, and the selection, crossover and mutation operators in the genetic algorithm explore the solution space for better mask-layouts, and the next candidate generation obtained will normally have better performance. The procedure is then repeated, and the simulated shapes will gradually converge to the desired shape. The iteration is stopped when one or more simulated shape is sufficiently close to the desired shape.

An example is shown to demonstrate our approach. Considering mask misalignment as a Gaussian-distributed noise with $\mu = 0$ and $\sigma = 1^\circ$, and taking a mesa as the target shape, robust synthesis of mask-layouts is conducted and a mask (called a robust mask here) is synthesized which produces a simulated shape close to the mesa, and is robust to the mask misalignment variations. This robust mask is compared with the optimum mask-layout from synthesis assuming perfect mask alignment (called a non-robust mask). Figure 2 shows both mask-layouts and the fabricated shapes when the mask misalignments are 0°, 1.5°, and 3°. Both mask-layouts generate shapes close to the target shape (mesa) when perfectly aligned (0° misalignment), but when the misalignment increases, the superiority of the robust mask-layout can be easily observed.

To statistically demonstrate the higher robustness for the robust mask, both the robust mask and the non-robust mask are tested with 600 experiments of randomly generated misalignment values. Histograms of shape mismatch distribution for both masks under Gaussian distributed misalignment noise are shown in Figure 3 and Figure 4. The smaller mean and smaller deviation for the shape mismatch distribution for the robust mask can be observed from the histograms. Additional details about shape mismatch vs. mask misalignment for both masks can be observed from Figure 5.

Similar tests were conducted for etch rate variations. The etch rate is taken to be a Gaussian-distributed variable with standard deviation of 5% of the mean value, and mask-layout robust to the etch rate variations is obtained from the robust synthesis procedure.

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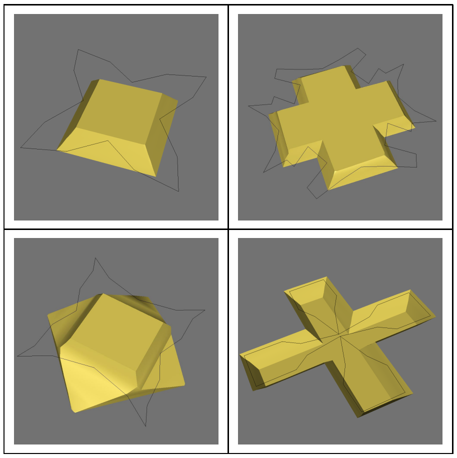

Figure 1: Synthesis examples: etched shapes with mask-layouts shown with black lines

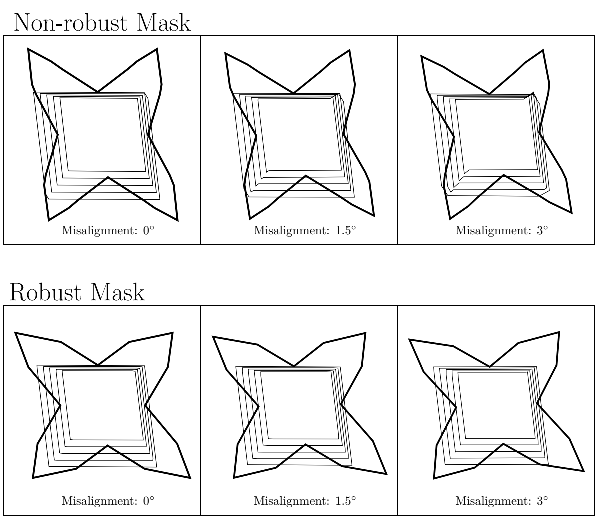

Figure 2: Masks and simulated shapes: first row is for non-robust mask, second row for robust mask

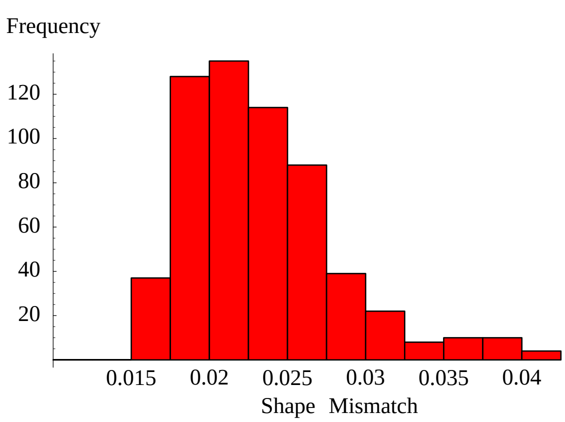

Figure 3: Histogram for non-robust mask

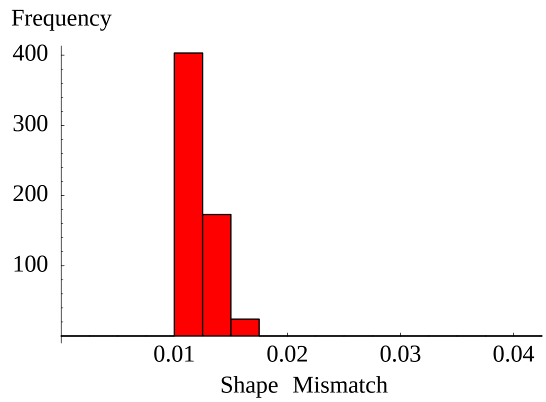

Figure 4: Histogram for robust mask

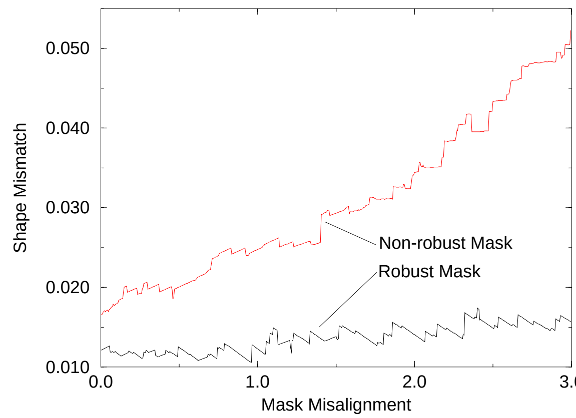

Figure 5: Shape mismatch vs. mask misalignment for both masks

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