DYNAMIC STENCIL LITHOGRAPHY ON FULL WAFER SCALE

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Stencil lithography is an emerging micro and nanopatterning technique based on the deposition of material through the apertures in a thin mechanical membrane. The technique is promising for several reasons: it requires only a single process step to define surface patterns, and thus avoids harsh steps such as resist spinning, high temperature baking, exposure to radiation and solvents. In the past, considerable advances have been made in terms of reliability, scaling (<50 nm structure width), alignment (< 1 um), reduction of pattern blurring (by corrective etch), as well as stencil stability (by mechanical rims) [1].

In this paper we present a breakthrough extension of the stencil lithography tool and method. In the so-called dynamic mode the stencil is repositioned with respect to the substrate inside the vacuum chamber and synchronized with the deposition. This can be done either in a step-and-repeat or in a continuous mode. It allows for truly flexible patterning of multiple material layers without exposing the micro/nanostructures to atmospheric pressure. This opens totally new paths for the fabrication of ultra-clean nanoelectronic devices such as nanowires, molecular electronics, and tunnel junctions. Dynamic mode nanostenciling has been shown in the past on mm-sized chips inside UHV tools [2]. Our results demonstrate scaling of the method to full wafer (100 mm) in view of a high-throughput, cost-effective manufacturing of nanodevices. The basic components are micro/nano-machined silicon-nitride stencils, high-precision x,y,z positioning tables inside a HV chamber, a material emission source, and a computer controlled feedback system (Figure 1). First we show three successive 30-nm-thick Ag depositions through a membrane containing four slits (2 x 100 μm^2, 800-µm spaced). Between each deposition, a precise lateral motion of the stencil was performed (100 µm and 800 µm respectively). Figure 2 shows a stitching accuracy of 2.5 µm over a translation of 900 µm, and an angular error between stencil and xy actuators of ~ 2.5 mrad. We also demonstrate the dynamic stencil tool in continuous mode. Here, a 19 x 19 array of 2 µm circular stencil apertures was moved with a lateral speed of 2 µm/s during the deposition of Au and Ag with a deposition rate of 2 Å/s to write a pattern in the shape of a silver house with a golden roof, or hundreds of them in parallel.

References:

[1] J. Brugger et al., E-nano newsletter, (8)2007, p. 22-28, www.phantomsnet.net
[2] Lüthi, R., et al., APL, 1999. 75(9): p. 1314-1316; Egger, S., et al., Nano Lett., 2005. 5(1): p. 15-20; H. Guo, et al. APL, 90 (2007) 093113 (3 pages)

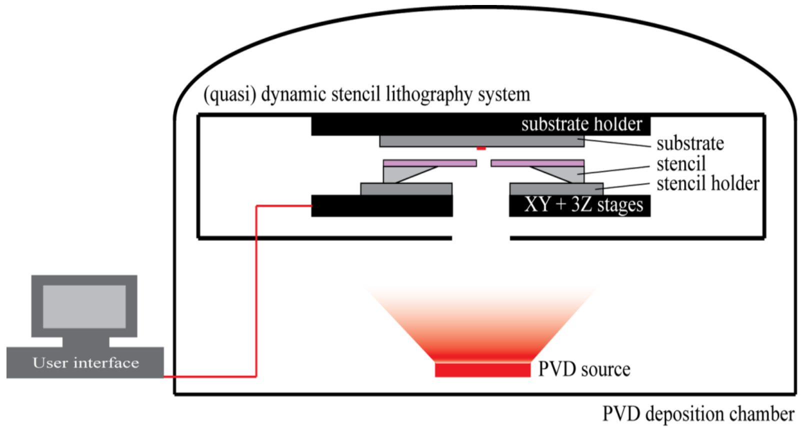

Figure 1: Schematic representation of a dynamic stencil lithographic set-up. A stencil and a stencil holder are mounted on a high precision xy-stage. A substrate holder with a substrate is maintained at a controlled gap by three z-actuators. A PC user interface controls the parameters.

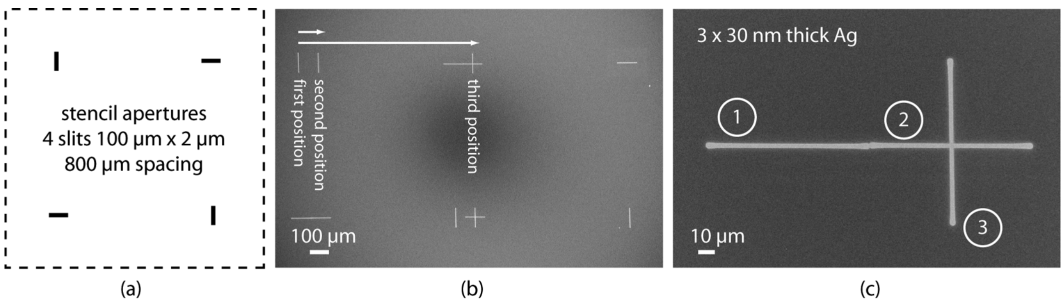

Figure 2: Images showing step-and-repeat stencil lithography. (a) Drawing of the membrane containing four apertures (2 x 100 μm^2) equally spaced by 800 µm, (b) SEM images showing three successive 30-nm-thick Ag depositions through the same stencil. Between each deposition the stencil was moved by 100µm and 800µm respectively, and (c) SEM image zooming into a stitched multi-deposition structure demonstrating a placement accuracy of < 2.5µm over a translation of 900 µm. Numbers in the circles corresponds to each successive deposition. The angular error between stencil and xy actuators is ~ 2.5 mrad.

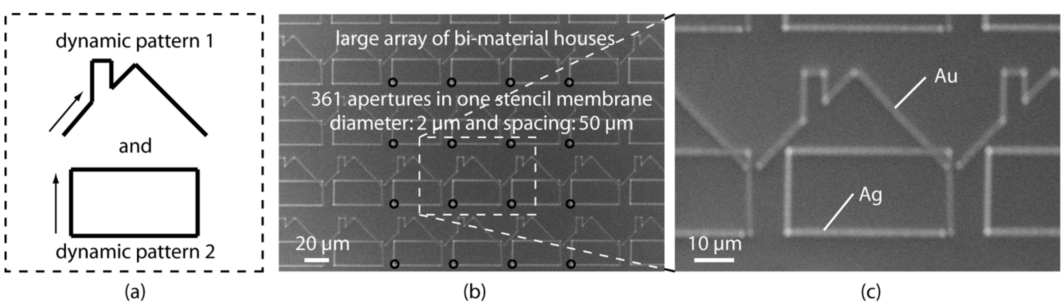

Figure 3: Parallel fabrication of multi-material surface structures (house) made by dynamic stencil lithography. (a) Drawing of the two sequential actuation patterns of the stencil with respect to the substrate with a speed of 2 µm/s; (b) SEM image showing a part of the parallel micropatterns realized using a stencil with an array of 2 µm circular apertures spaced by 50 µm, and (c): SEM image showing details of the Au/Ag house. The misalignment is caused by the distance between the Ag and Au source.