HIGH-THROUGHPUT DIRECT SURFACE PATTERNING BY SHADOW DEPOSITION THROUGH DUV/MEMS NANOSTENCILS

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Continuous improvement in sub-micron and recently sub-100 nm scale lithography methods based on DUV, X-ray or electron beam exposure will allow further progress in integrated circuit hardware manufacturing for the coming years. The drawbacks of these advanced methods are the increased equipment costs as well as their limited process versatility. Increased flexibility however becomes important for the engineering of multi-material and multifunctional nano/micro-electro-mechanical systems (NEMS/MEMS), such as polymer-based electronic and sensor devices, 3D microfluidics, and bio-analytical systems. Often standard lithography methods can not be applied because the surfaces to be structured are either mechanically unstable, such as for cantilevers and membranes, and/or chemically functionalised for bio-sensor applications. Therefore, a series of alternative surface patterning methods are currently being developed that do not rely on photoresist exposure and thin-film etching steps. Well-known methods are e.g. scanning probe lithography, DipPen or NADIS lithography, soft-lithography, and nanoimprint lithography.

Another emerging complementary surface patterning method is based on the direct local deposition of thin film patterns through the apertures in miniature shadow-masks or nanostencils[1,2]. In the past, e-beam or focused ion beam prepared stencils where used to demonstrate sub-100 nm scale shadow nanofabrication on a small surface area, typically a few 10s of micrometers. Besides inherent mechanical stability limitations of large and thin membranes, the area limitation was mainly due to the lack of suitable techniques to fabricate nanoscale patterns in large thin membranes.

The presentation will provide details of a new DUV/MEMS process for the fabrication of silicon nitride (SiN) nanostencils on a 100-mm size full-wafer[3]. The smallest exposed apertures (200-nm) were transferred by an inductively coupled plasma (ICP) process into the 200-nm thick SiN layer with excellent pattern transfer quality. Wafer-through etching by a combination of wet and dry process releases the stencil membrane. Application as large-area nanostencil shadow-mask for the deposition of thin metal film nanopatterns (Au, Al, Bi, Pt, and Cr) shows promising results with high pattern accuracy.

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[2] G. M. Kim, M. A. F. van den Boogaart and J. Brugger, Microelectronic Engineering, Volumes 67-68, June 2003, Pages 609-614
[3] M.A.F. van den Boogaart et al. (Proceedings of EIPBN 2004, June 1-4, 2004, San Diego, USA, (publication in preparation)

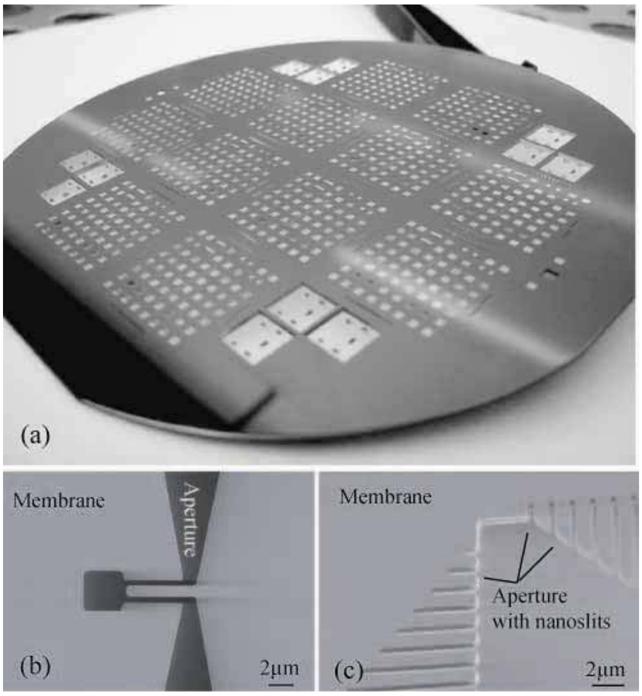

Figure 1: (a) Optical image of a 100-mm size full-wafer stencil containing various silicon nitride (SiN) membranes. The SiN layer is 200-nm thick. Each window contains numerous geometrical apertures as shown in the scanning electron micrograph (SEM) close-up of (b) and (c): Free-standing 200-nm thick SiN membrane containing micro and nano apertures ranging from 200 nm up to several 100 µm.

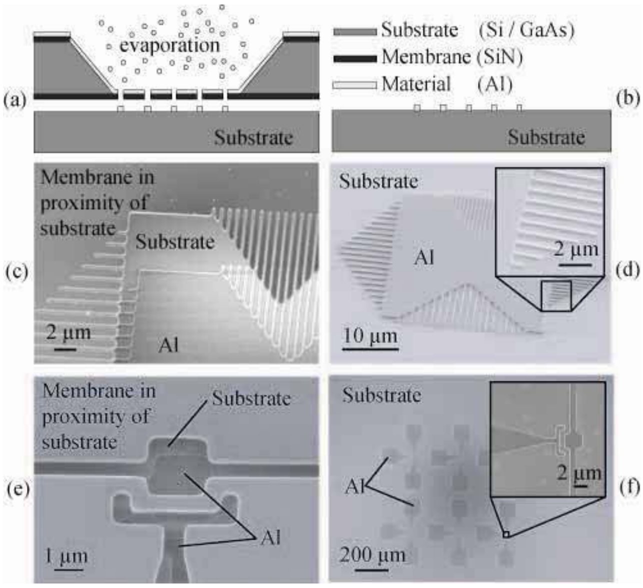

Figure 2: Illustration and SEM images showing the nanostencil deposition process. (a) 100-nm thick Al is evaporated from a distant source and deposited through the apertures in the membrane; (b) The stencil is removed from the substrate; (c) and (e) The SEM-images show the stencil mask and the underlying substrate; (d) and (f): The SEM-images show the resulting sub-micrometer Al structures.