Large-area ultraviolet nanoimprint lithography for the detailed understanding of silicon-germanium island nucleation on pit-patterned silicon substrates

J. Danzberger, L. Häusler, I. Bergmair, M. Mühlberger
Functional Surfaces and Nanostructures, Profactor GmbH, 4407 Steyr-Gleink, Austria
e-mail: lukas.haeusler@profactor.at

E. Lausecker, M. Glaser, F. Schäffler, T. Fromherz
Institute of Semiconductor and Solid State Physics, University of Linz, Austria

In the present work, we demonstrate large area ultraviolet nanoimprint lithography (UV-NIL) for the use in experiments to understand in detail the growth of silicon-germanium (SiGe) islands by molecular-beam epitaxy (MBE). Self-assembled SiGe islands, formed in a strain-driven Stranski-Krastanov growth mode on pit-patterned substrates, are compatible with the CMOS-based Si technology. For the application in integrated optoelectronic circuits both, a homogenous size and Ge content distribution of the single SiGe islands and their addressability are mandatory. For the later a cost-efficient and fast nano-patterning method is required. In a former study it was shown, that pit-patterned Si substrates fabricated with UV-NIL are an excellent basis to achieve extremely homogenous island arrays with uniform optical properties [1]. Deliberately introducing a non-homogeneous Ge distribution on the wafer allows the investigation and study of the influence of the amount of deposited Ge during the island nucleation with ultra-high resolution [2]. Due to the specific position of the Ge source within the MBE chamber a Ge gradient over the Si wafer with a Ge rich and Ge lean side can be established.

Si masters for NIL were purchased from Eulitha AG. The patterned area is 46 x 46 mm², containing hexagonally arranged holes with a nominal period of 600 nm and a diameter of 285 nm [Fig. 1 (a)]. Stamp replication was executed with Ormostamp® on 100mm glass wafers as backplanes [Fig. 1 (b)] [3]. UV-NIL on 100mm Si wafers was performed using the self-made imprint tooling from Profactor GmbH that enables uniform imprinting over the entire area of wafers up to 6 inch in diameter. In this tooling, the replicated stamp and the substrate are centered in a sealed environment, in which the imprint pressure can be adjusted up to 3 atmospheres. After a short O_2 etch step, the pattern was transferred into the Si substrate by CF_4 reactive-ion etching to a depth of 50 nm [Fig 2 (a)]. During MBE growth a Ge gradient, covering the deposition range from 3.14 to 3.76 ML, can be established. On the Ge lean side, only pit faceting occurs [Fig 2 (b)], whereas pyramidal-shaped SiGe islands are formed on the Ge rich side [Fig 2 (c)]. As a next step, the islands' volumina in dependence on the depositied Ge amount will be evaluated to obtain novel insight into the growth mechanism on pit-patterned substrates.

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[1] E. Lausecker, M. Brehm, M. Grydlik, F. Hackl, I. Bergmair, M. Mühlberger, T. Fromherz, F. Schäffler, G. Bauer, Appl. Phys. Lett. 98 (2011) 143101.
[2] M. Brehm, F. Montalenti, M. Grydlik, G. Vastola, H. Lichtenberger, N. Hrauda, M. J. Beck, T. Fromherz, F. Schäffler, L. Miglio, G. Bauer, Phys. Rev. B 80 (2009) 205321.
[3] A. Klukowska, A. Kolander, I. Bergmair, M. Mühlberger, H. Leichtfried, F. Reuther, G. Grützner, R. Schöftner, Microelectron. Eng. 86 (2009) 697.

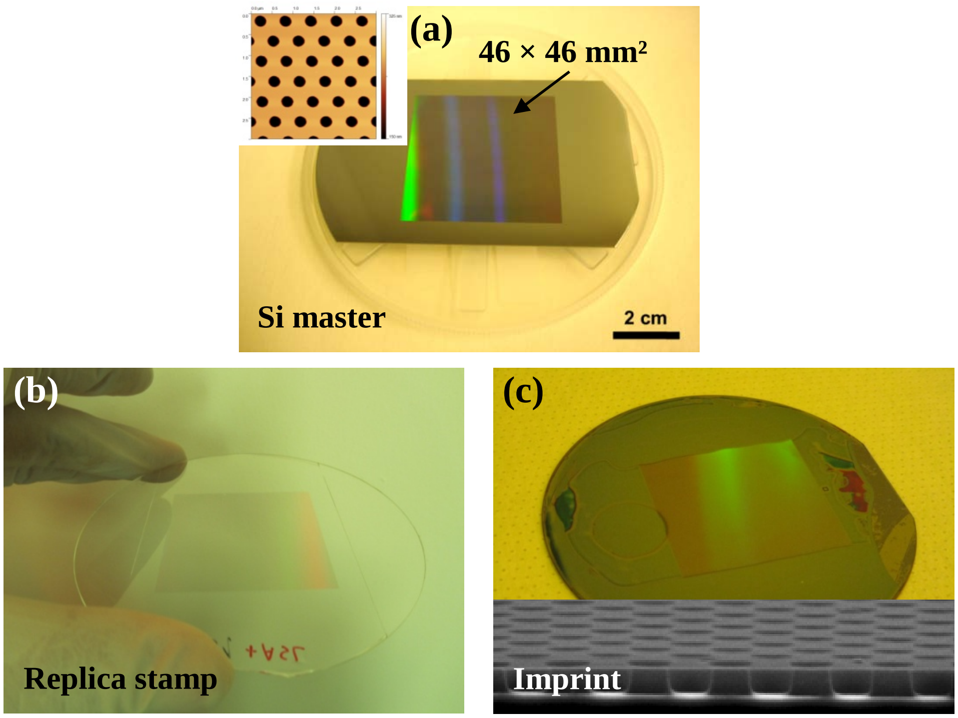

Figure 1. (a) Photograph of the Si PHABLE® master with a 46 x 46 mm² patterned area, consisting of hexagonally arranged holes with a period of 600 nm and a diameter of 285 nm (inset: AFM image of the hole pattern on the Si master). (b) Photograph of the replicated stamp on a transparent quartz wafer for large area UV-NIL. (c) Photograph of the final imprint on the Si substrate (inset shows a SEM image of the hole pattern, demonstrating a thin residual layer).

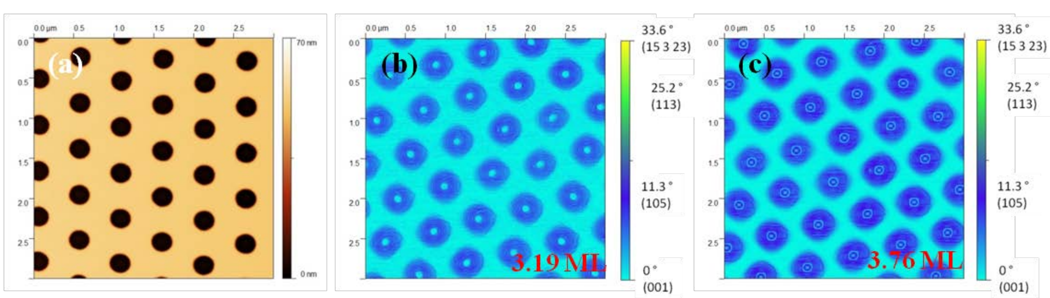

Figure 2. (a) AFM image of the resulting hole-pattern in Si reactive-ion etching. AFM images (surface-inclination presentation) recorded at the (b) Ge lean side and (c) Ge rich side of the patterned wafer, demonstrating two stages of island nucleation.