Pre-Defined SiGe Island Growth on Large-Area, High-Density Pit-Patterned Si Substrates Fabricated by UV Nanoimprint Lithography

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We present the fabrication of pit-patterned substrates using ultra-violet nanoimprint lithography (UV-NIL) [1] for the ordered growth of silicon-germanium (SiGe) islands. For the realization of optoelectronic devices and circuits, it is mandatory to precisely address the position and control the size and chemical composition homogeneity of the islands by pits etched into the substrate [2].

We fabricate replica molds for imprinting by a replication process of a Si master. The molds (17.5 x 17.5 mm^2 in size) contain a pillar pattern (Fig. 1 (a)) which is transferred to a hole pattern in the resist during the imprint process. Four fields, each extending over a continuous area of 3 x 3 mm^2 are defined in one imprint step. The hole pattern is transferred to the Si substrate by reactive-ion etching to a depth of 35 nm. We increase the pattern density by reducing the pit period of each field from 260 nm down to 170 nm in steps of 30 nm. The diameter of the pits is reduced as well, down to 120 nm for the smallest period of 170 nm.

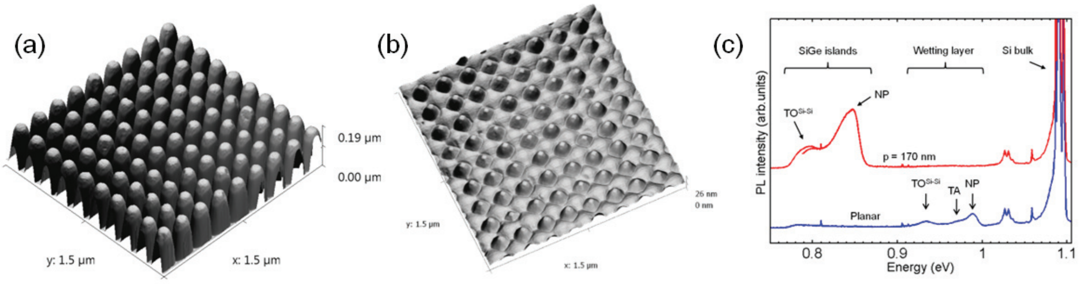

Fig. 1: AFM image of (a) the pillar pattern on a replicated nanoimprint mold and (b) ordered SiGe islands with a period of 170 nm grown at 625 °C with 8.3 ML of Ge. (c) Low temperature (5.5 K) PL spectrum recorded from ordered SiGe islands with a period of 170 nm. The bottom PL spectrum was measured on the planar substrate area.

After the molecular-beam epitaxy growth of a Si buffer layer, 8.3 monolayers of Ge are deposited at 625 °C. Then, the island surface is capped with a 10-nm-thick Si layer.

Atomic force microscopy (AFM) images reveal the nucleation of one SiGe island per pit [Figure 1 (b)]. Photoluminescence (PL) measurements show two narrow peaks for the signal of the ordered islands at 0.79 and 0.85 eV [Figure 1 (c)]. Under these growth conditions, the island-signal shifts to lower energies compared to previous work [3] in which islands were grown at 690 °C with a Ge coverage of 6 ML. Furthermore, dislocations are already introduced in the islands on the planar substrate area, and therefore the PL signal is vanishing.

Our results suggest that UV-NIL opens a route to define high-density SiGe islands with sub-100 nm period over large areas and excellent optoelectronic properties.

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References

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