Soft photocurable nanoimprint lithography for compound semiconductor nanostructures

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A persistent challenge in leading-edge compound semiconductor device processing is, as it is for silicon, the lithography step. However, the problems are different in compound semiconductors. In the quantum device field in particular, the application window is quite narrow. The feature sizes necessary to observe quantum effects are about 10-100 nm, and in many studies vast, dense arrays of these nanostructures are required in order for their collective effects to be observed by macro-scale instruments. At these feature sizes, the traditional approaches of electron beam lithography and optical lithography are both bad choices for reasons of throughput and cost, respectively. In this work, a nanoimprint lithography (NIL) approach to the problem is investigated and found to be very suitable.

A soft photocurable nano-imprint lithography (NIL) process for producing dense 100 nm features in compound semiconductors will be described. The imprinting process uses composite poly(dimethylsiloxane) (PDMS)[1] technology to replicate the pattern from a Si master template. The PDMS molds are then contacted to resist-coated samples and the resist exposed by ultraviolet light with no pressure applied between the mold and sample. Pattern transfer to the samples is by anisotropic reactive ion etching. The process is very minimalist because there is no pressure between mold and sample, avoiding the need for an imprinting machine and the risk of damage to delicate compound semiconductor substrates.

Patterns with 100 nm half-pitch were realized over an area of several square centimeters. Dense two-dimensional arrays of both holes (Figure 1) and pillars (Figure 2) were produced. The nanostructures have been produced in both GaAs and InP, and processing will be discussed for each material. Finally, preliminary results and considerations for producing optically active devices using this technique will be presented. Some possible applications in the optoelectronics field include etched quantum dots and photonic crystal devices. In summary, we have achieved an extremely low-cost and high-throughput lithography technique to create dense sub-100 nm nanostructures in III-V compound semiconductors.

[1] Hyewon Kang, Jiyeon Lee, Joonhyung Park and Hong H Lee, Nanotechnology **17**, pp. 197-200 (2006).

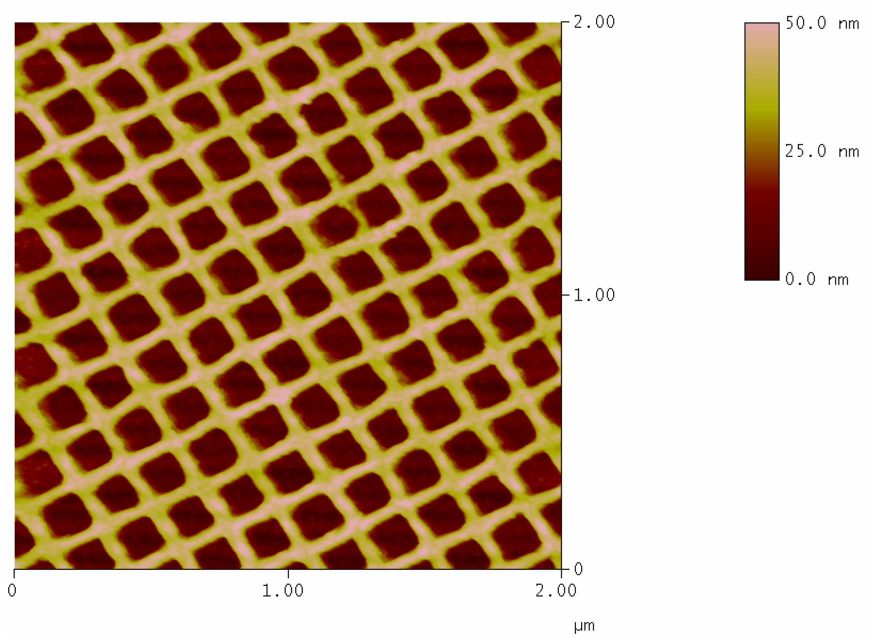

Figure 1. Atomic force micrograph showing a piece of GaAs which has been patterned with nominally 100 nm holes through NIL followed by wet etching. The sample was cleaned of all resists before the imaging.

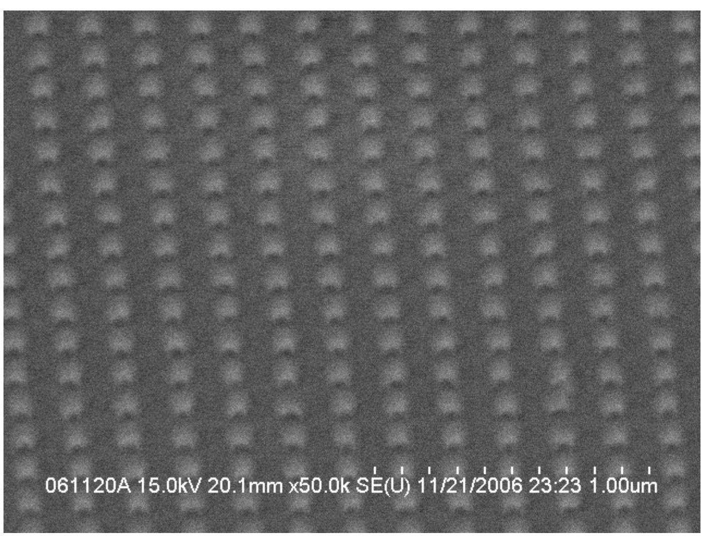

Figure 2. Scanning electron micrograph showing a piece of InP which has been patterned with nominally 100 nm pillars through NIL followed by reactive ion etching. The sample was cleaned of all resists and pattern transfer layers before the imaging.