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Self-Assembly of Thin Disk-Shaped GaAs Blocks on Si Substrates

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1. Introduction

Recently, a considerable amount of effort has been devoted to co-integrate III-V devices onto Si VLSIs. Various new applications including OEICs, intra and inter-chip optical wiring should be realized with this technology. One of the most interesting techniques for this is the fluidic self-assembly (FSA) proposed by Ashish and his coworkers [1]. They reported that the small semiconductor blocks, the size of which was ranged from a few tens of microns to a few hundreds of microns, could be assembled into the recesses made on the Si substrate when the blocks were scattered on the substrate placed in fluid. The details of this technique are not yet clear, though they reported some promising results. Here, we will report the results of our FSA experiments using thin disk-shaped GaAs blocks, and discuss the importance of the sonic vibration.

2. Fluidic Self-Assembly

Figure 1 schematically depicts the FSA method. The host (for example, Si) substrate is placed on the sample holder tilted in the fluid. The device blocks are made of the guest material (for example, GaAs) using epitaxial lift-off method. The blocks scattered onto the Si substrate slide over the substrate and fall into the recesses. Then the blocks adhere to the bottom of the recesses by the van der Waals force. This is a stochastic process, and the blocks not captured by the recesses are collected and scattered again until all of the recesses are filled with blocks.

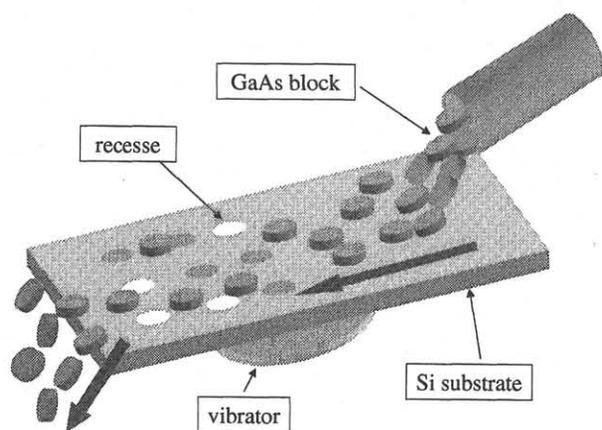


Fig. 1 Schematic of fluidic self-assembly (FSA) method.

The FSA method has various advantages compared to heterogenous epitaxial growth and wafer bonding. First, the lattice mismatch and difference in the thermal expansion coefficients have little effects on the FSA. Second, large host wafers, for example 10" Si, can be used for this method though we can obtain smaller guest (III-V) wafers. Third, the FSA process is very cost-effective due to the excellent efficiency of the material use. This is because the device blocks can be fabricated densely all over the wafer, and also, the substrate can be re-usable after the epitaxial lift-off process. These advantages make the FSA promising for various heterogenous integrations. Furthermore, this method is applicable to non-crystalline materials, such as glass and plastic films. So, it should be possible to fabricate integrated circuits using the best devices made of the best materials on the best substrates.

3. Effects of the sonic vibration

Simple disk-shaped GaAs blocks were used in our experiments to study basic processes in the FSA. The size of the disks was 50- μm -diameter and 4- μm -thick. This thin block is practically advantageous since the growth time is short and the material is not restricted, which is different from the trapezoidal blocks used in [1]. The blocks were fabricated using epitaxial lift-off technique with an AlAs as a sacrificial layer. We used methanol as the fluid. The host substrates were Si covered by SiO_2 . The recesses were fabricated by RIE, and the bottom of

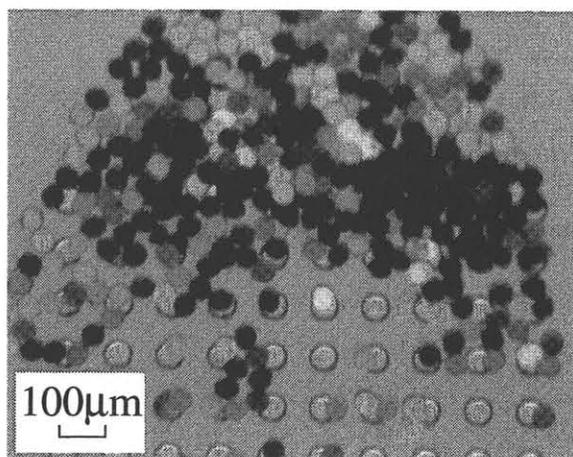


Fig. 2 Microphotograph of blocks that stuck outside the recesses.

the recesses was Si.

First, the experiments were carried out without a sonic vibrator. We observed many blocks stuck outside the recesses as shown in Fig. 2 and they obstructed the assembly. These stuck blocks could not be removed only by increasing the tilt angle of the substrate to 30 degrees, over which the blocks were scarcely captured in the recesses.

Then we set a sonic vibrator under the substrate holder to avoid such block sticking. With appropriate strength of the vibration, the blocks did not stick outside the recesses. We obtained 100 % yield after optimizing the substrate tilt and the vibration strength. Figure 3 shows the sequential microphotographs of the process when two blocks are being captured in the recesses. Figure 4 shows the microphotograph of the Si substrate after the FSA when 100 % yield was achieved. Here, some blocks are visible to different colors due to small difference in surface tilt.

Figure 5 shows the dependence of the fill ratio, which is defined as the number of blocks captured in recesses divided by the number of recesses, on the number of blocks scattered on the substrate. In the simple approximation the fill ratio, n , should satisfy the rate equation,

$$\frac{dn}{dt} = p\lambda(1 - n). \quad (1)$$

Here, λ and p are the number of the blocks supplied to the substrate per second, and the capture coefficient, respectively. Consequently the fill ratio is expressed as

$$n = 1 - \exp(-p\lambda t) = 1 - \exp(-pm), \quad (2)$$

where, $m = \lambda t$ is the number of blocks scattered on the substrate. This curve is also shown in the figure with the fitting parameter p of 0.006. It should be noted that only 900 blocks is sufficient to fill 100 recesses.

4. Summary

We studied the fluidic self-assembly method using thin disk-shaped GaAs blocks. Using sonic vibration we obtained 100 % yield of the block assembly.

Acknowledgments

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References

[1] Ashish K. Verma, Mark A. Hadley, and J. S. Smith, Proc. 45th Electronic Components Technology Conf., Las Vegas, Nevada, USA, 1995, p.1263

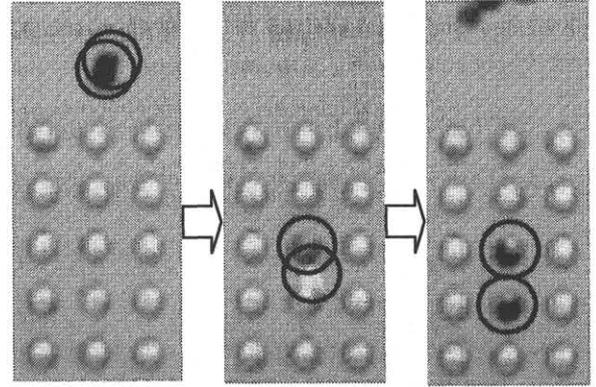


Fig.3 Process of FSA.

Two blocks are being captured in the recesses.

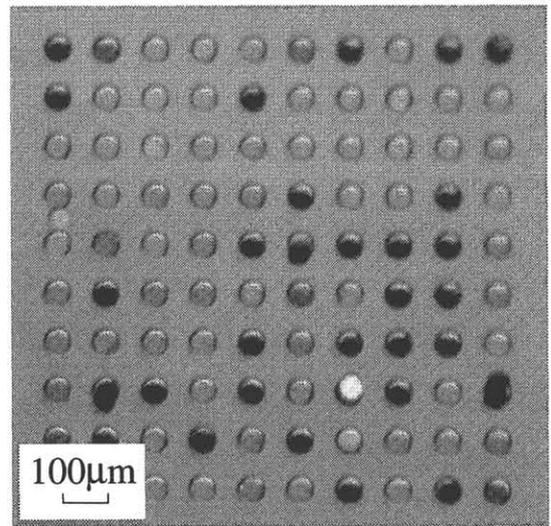


Fig. 4 Microphotograph of the substrate after FSA.

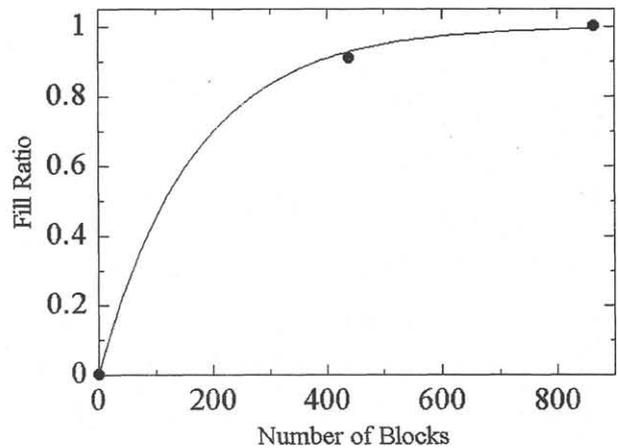


Fig. 5 Fill ratio as a function of the number of blocks scattered on the substrate.