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Perspectives of controlled GeSi dots on prepatterned Si (001) substrates

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Self-assembled GeSi dots on Si (001) substrates have attracted broad attentions not only because of their potential applications in novel devices compatible with the sophisticated Si-integration technology [1], but also to understand the fundamental physics during heteroepitaxial growth as a prototype model. The GeSi dots via Stranski-Krastanov (SK) growth mode during heteroepitaxy result from the balance between the relaxation of misfit strain and the cost of the surface energy [2]. They are dislocation free and small. On the other hand, these self-assembled dots are always spatially random, and their size uniformity is rather poor. Such disadvantages degrade the properties of these dots, which hamper their applications in devices. Enormous effort has been devoted to improve the size homogeneity and to control the site of self-assembled GeSi dots. Remarkable progresses have been made particularly on prepatterned Si (001) substrates [3].

The patterned Si (001) substrates are always composed of periodic nanostructures, e.g. trenches and pits, on the surface, as shown in Figure 1a. They can be fabricated by conventional photolithography [4], holographic lithography [3], electron beam lithography [5], EUV-IL [6], and nanosphere lithography [7]. Those nanostructures considerably affect both the surface energy and the misfit strain energy. As a result, the nucleation and the evolution of dots on patterned Si (001) substrates are much different from those on flat Si (001) substrates.

It is well documented that GeSi dots preferentially grow within trenches or pits [3-9]. Such preferentially growth is energetically favorable [8,9]. As a result, ordered or site-controlled dots can be realized on patterned substrates, as shown in Figure 1b. Such ordered dots always exhibit remarkably improved size uniformity in comparison with that on flat substrates [3]. In addition, the nucleation and the evolution of dots on patterned substrates are intimately related to the geometrical morphology of the nanostructures [8-14], as well as the growth conditions [15,16]. Enhanced strain relaxation and intermixing in GeSi dots on pre patterned Si (001) substrates were also found [17].

The preliminary results about the physical properties of GeSi dots on pre patterned Si (001) substrates demonstrate that these controlled dots exhibit some unique features. It is feasible to explore the properties of single nano island [18] and the transportation properties of holes between dots [19]. The controlled dots of a large period on patterned substrates may have a distributed feedback effect, which improve the optical properties of dots [20]. The strong coupling of ordered GeSi dots with a small period on patterned substrates can make them act as a quantum dot crystal [21]. Given the precise control ability of GeSi dots on prepatterned Si (001) substrates, they can act as excellent candidates to thoroughly explore the unique properties of single dot and coupled dot molecule, as well as the collective properties of ordered dots.

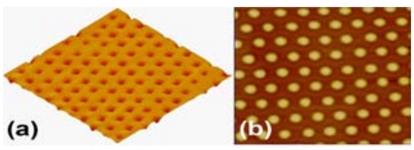

Figure 1: AFM image of (a) a prepatterned Si (001) substrate, (b) controlled GeSi dots after Ge growth. The periods are all 220 nm.

References

1. Pillarisetty R (2011) Academic and industry research progress in germanium nanodevices. Nature 479: 324-328.
2. Mo YW, Savage DE, Swartzentruber BS, Lagally MG (1990) Kinetic pathway in Stranski-Krastanov growth of Ge on Si(001). Phys Rev Lett 65: 1020-1023.
3. Zhong Z, Bauer G (2004) Site-controlled and size-homogeneous Ge islands on prepatterned Si (001) substrates. Appl Phys Lett 84: 1922.
4. Jin G, Liu JL, Wang KL (2000) Regimented placement of self-assembled Ge dots on selectively grown Si mesas. Appl Phys Lett 76: 3591.
5. Zhong Z, Halilovic A, Lichtenberger H, Schaffler F, Bauer G (2004) Growth of Ge islands on prepatterned Si (0 0 1) substrates. Physica E Low Dimens Syst Nanostruct 23: 243-247.
6. Grutzmacher D, Fromherz T, Dais C, Stangl J, Muller E et al. (2007) Three-Dimensional Si/Ge Quantum Dot Crystals. Nano Lett 7: 3150-3156.
7. Chen P, Fan Y, Zhong Z (2009) The fabrication and application of patterned Si(001) substrates with ordered pits via nanosphere lithography. Nanotechnology 20: 095303.
8. Zhong Z, Schwinger W, Schaffler F, Bauer G, Vastola G, et al. (2007) Delayed Plastic Relaxation on Patterned Si Substrates: Coherent SiGe Pyramids with Dominant {111} Facets. Phys Rev Lett 98: 176102.
9. Hu H, Gao HJ, Liu F (2008) Theory of Directed Nucleation of Strained Islands on Patterned Substrates. Phys Rev Lett 101: 216102.
10. Zhong Z, Schmidt OG, Bauer G (2005) Increase of island density via formation of secondary ordered islands on pit-patterned Si (001) substrates. Appl Phys Lett 87: 133111.
11. Zhang JJ, Stoffel M, Rastelli A, Schmidt OG, Jovanovi V, et al. (2007) SiGe growth on patterned Si(001) substrates: Surface evolution and evidence of modified island coarsening. App Phys Lett 91: 173115.
12. Chen G, Vastola1 G, Lichtenberger H, Pachinger D, Bauer G, et al. (2008) Ordering of Ge islands on hill-patterned Si (001) templates. Appl Phys Lett 92: 113106.
13. Vastola G, Grydlik M, Brehm M, Fromherz T, Bauer G, et al. (2011) How pit facet inclination drives heteroepitaxial island positioning on patterned substrates. Phys Rev B 84: 155415.
14. Chen HM, Kuan CH, Suen YW, Luo GL, Lai YP, et al (2012) Thermally induced morphology evolution of pit-patterned Si substrate and its effect on nucleation properties of Ge dots. Nanotechnology 23: 015303.
15. Zhong Z, Chen P, Jiang Z, Bauer G (2008) Temperature dependence of ordered GeSi island growth on patterned Si (001) substrates. Appl Phys Lett 93: 043106.
16. Zhang JJ, Rastelli A, Groiss H, Tersoff J, Schaffler F, et al. (2009) Shaping site-controlled uniform arrays of SiGe/Si(001) islands by in situ annealing. Appl Phys Lett 95: 183102
17. Schulli1 TU, Vastola G, Richard MI, Malachias A, Renaud G, et al. Enhanced

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Relaxation and Intermixing in Ge Islands Grown on Pit-Patterned Si(001) Substrates. Phys Rev Lett 102: 025502.

18. Katsaros G, Spathis P, Stoffel M, Fournel F, Mongillo M, et al. (2010) Hybrid superconductor–semiconductor devices made from self-assembled SiGe nanocrystals on silicon. Nature Nanotechnology 5: 458-464.

19. Zhang HY, Yuan H, Zhang B, Zhong ZY, Fan YL, et al. (2009) Hole transport in one-dimensional aligned GeSi quantum dots at low temperatures. J Phys D Appl Phys 42: 205302.

20. Chen Y, Pan B, Nie T, Chen P, Lu F, et al. Enhanced photoluminescence due to lateral ordering of GeSi quantum dots on patterned Si(001) substrates. Nanotechnology 21: 175701.

21. Ma YJ, Zhong Z, Lv Q, Zhou T, Yang XJ, et al. (2012) Formation of coupled three-dimensional GeSi quantum dot crystals. Appl Phys Lett 100: 153113.