Formation and Characterization of GeSi Quantum Dots on Miscut Si(001) Substrates

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Ⅰ. Introduction

Self-assembled GeSi quantum dots (QDs) have attracted much attention due to their compatibility with the Si integration technology in the past several decades. To obtain desired QDs, enormous effort has been devoted to learn the inherent mechanism of self-assembly during heteroepitaxy. It is well established that growth conditions remarkably affect the self-assembled QDs. Recently, it was found that the miscut Si (001) substrates could provide an alternative routine to control over the shapes and the properties of self-assembled QDs. On miscut Si (001) substrates, elongated {105} faceted islands and ripple structures are obtained [1-4]. However, studies of the physical properties of the self-assembled GeSi QDs on miscut Si (001) substrates are still in the initial stage.

Ⅱ. Experiment

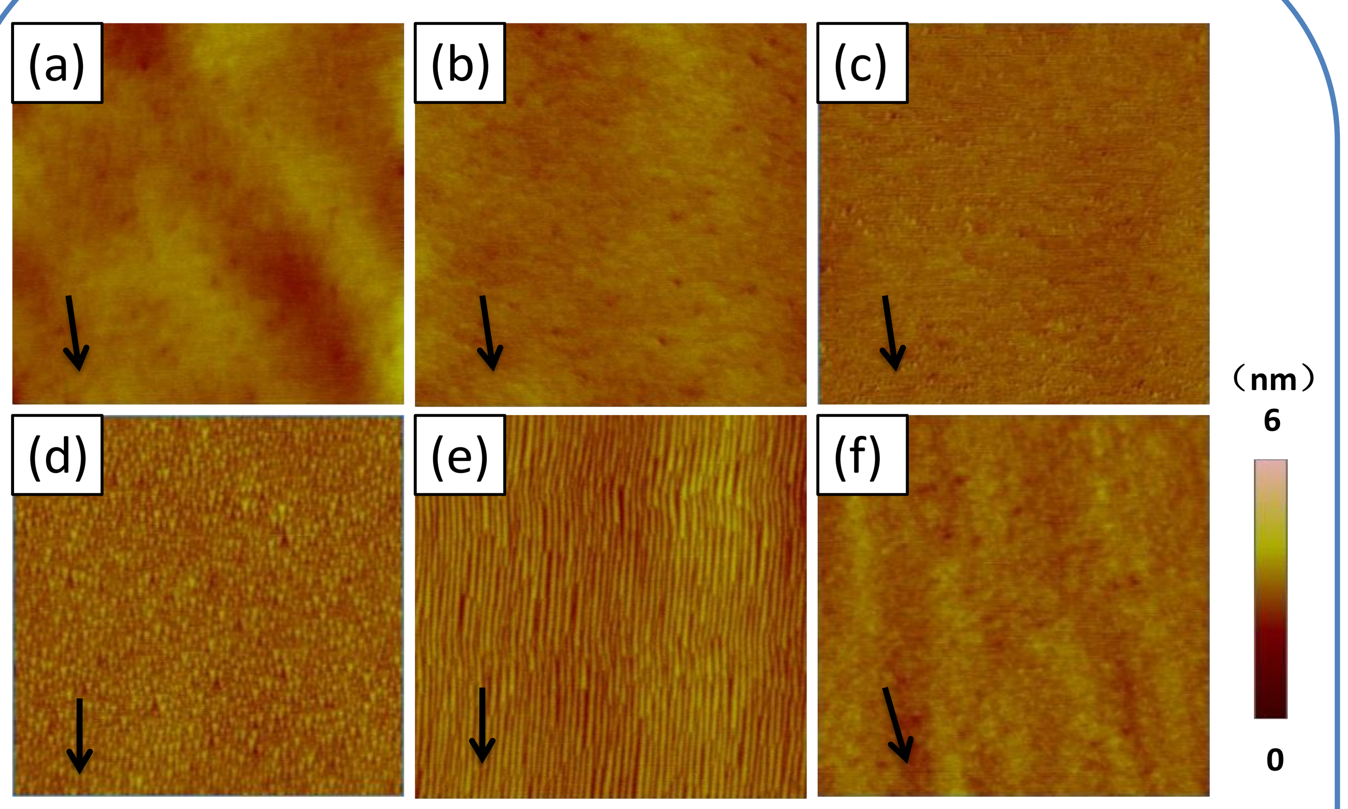

Fig 1. AFM image (1×1μm²) of 0.9-nm-thick $Si_{0.3}Ge_{0.7}$ layers on vicinal Si (001) substrates with (a) 0°, (b) 2°, (c) 4°, (d) 6°, (e) 8°, (f) 16° off toward <110>. The black arrows denote the miscut direction.

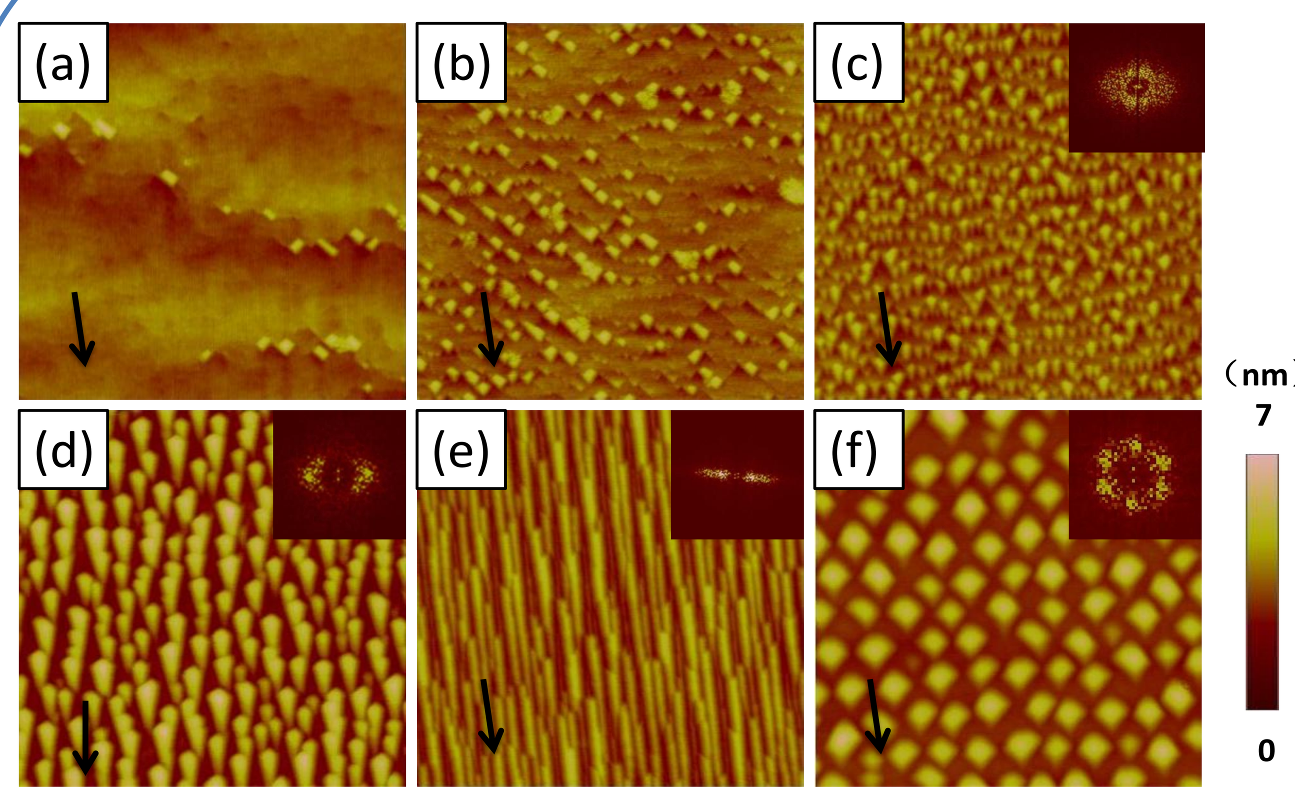

Fig 2. AFM image (1×1μm²) of 1.8-nm-thick $Si_{0.3}Ge_{0.7}$ layers on vicinal Si (001) substrates with (a) 0°, (b) 2°, (c) 4°, (d) 6°, (e) 8°, (f) 16° off toward <110>. The black arrows denote the miscut direction. The inset shows the 2D FFT of the AFM image.

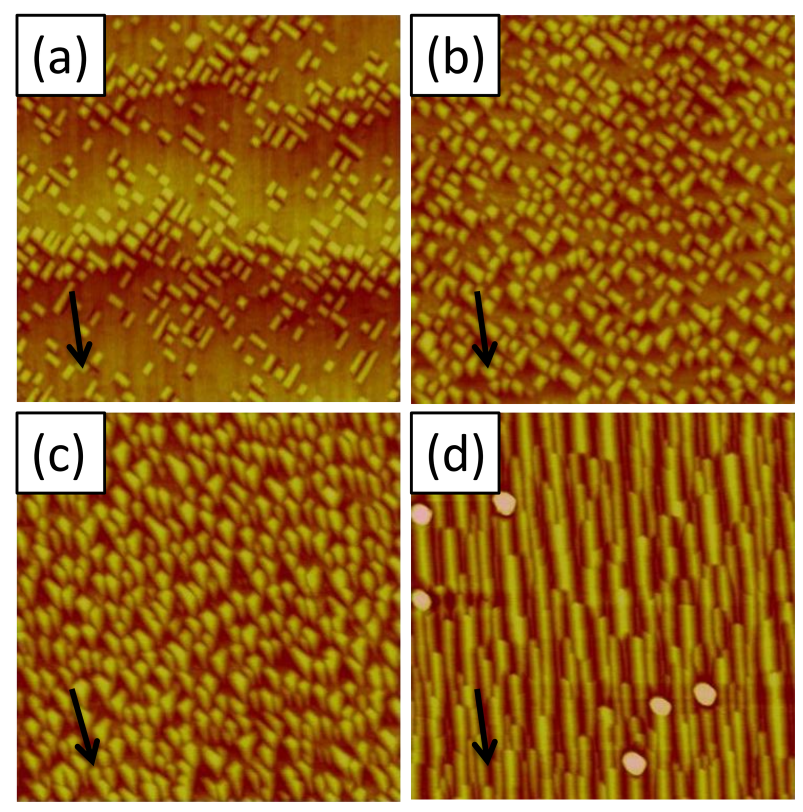

Fig 3. AFM image (1×1μm²) of 2.2-nm-thick $Si_{0.3}Ge_{0.7}$ layers on vicinal Si (001) substrates with (a) 0°, (b) 2°, (c) 4°, (d) 8 off toward <110>. The black arrows denote the miscut direction.

Ⅲ. Result

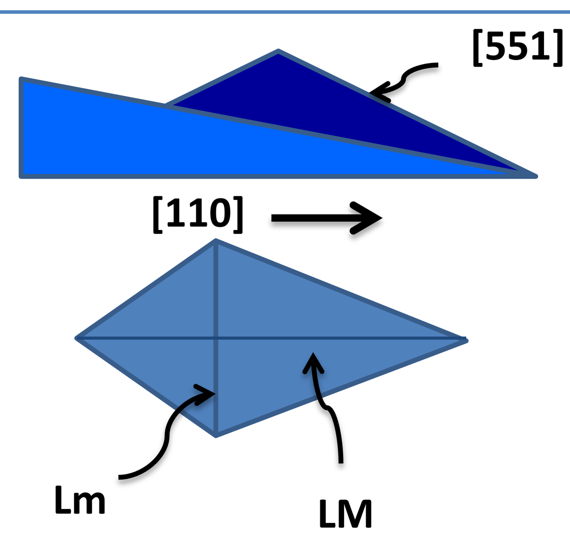

Fig 4. Schematic illustration of the morphology of QDs growth on miscut angles. The figure above is a top view and the following is a side view.

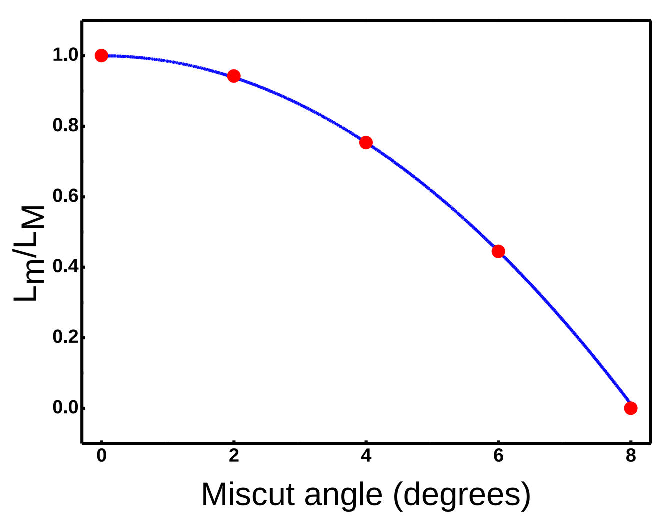

Fig 5. (Lm=LM) ratio as a function of the miscut angles. The red scatter dots represent the experimental data measured from AFM images and the blue line represents the calculated value.

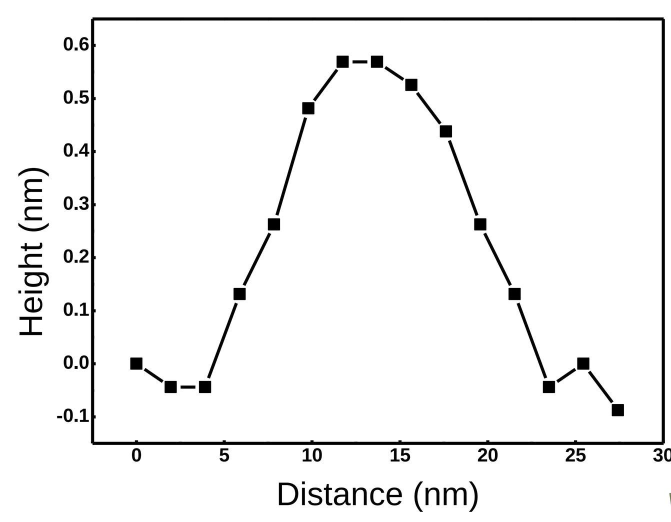

Fig 6. Height profile of the dot shown in fig 1.(d). The lateral distance is perpendicular to the miscut direction.

The band structure can be changed from an indirect band into a quasi-direct band when the height is less than 0.8nm due to mixing of the X and L bands[5].

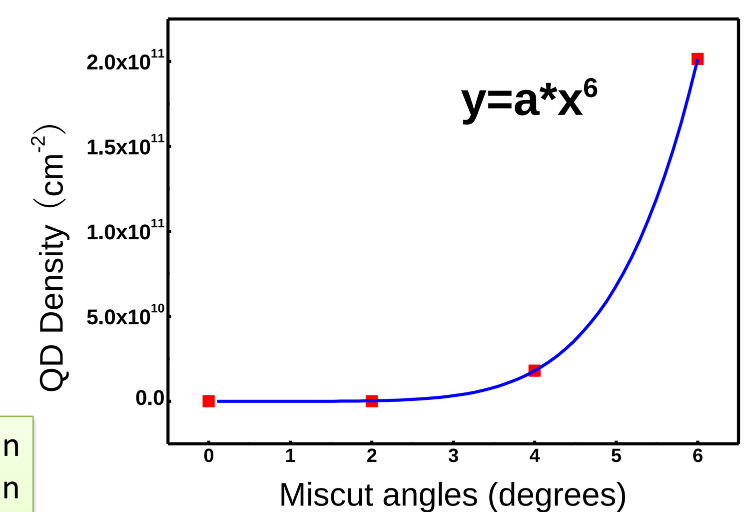

Fig 7. the QDs density vs the miscut angles. The red scatter dots represent the experimental data and the blue curve represents the fitting function.

Ⅳ. Conclusion

We present a novel and easy route for manipulating the density of GeSi QDs based on the mechanisms of epitaxial growth of misoriented substrates. The density of GeSi QDs show a striking increase from none of dots to 10^{11} cm^{-2} on the substrates misoritented by 0º,2º,4ºoff toward <110> under the same growth conditions. This results give an evidence to understand the mechanisms of Ge growth on misoriented substrates. There is an obviously influence on the mechanisms of nucleation on the different misoriented angles which play an important role in the competition between step-flow growth and island nucleation.

Reference

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