Contents

Acknowledge (in Chinese)……………………………………………………...…..I

Abstract (in Chinese)…………………………………………...………II

Abstract (in English)………………………………………………………III

Figure Captions……………………...………………………………………IX

Chapter 1. Introduction……………………….......………………………..1

1.1 General Background and Motivation……………….…………………………..……1

1.2 Outline of the Dissertation……………………………………………………………2

Chapter 2. Use of Si^+ pre-ion-implantation on Si substrate to enhance the strain relaxation of the Ge_xSi_{1-x} metamorphic buffer layer for the growth of Ge layer on Si substrate……………………………………………………………………6

2.1 Introduction…………………………………………………………………...………..6

2.2 Experimental…………………………………………………………..……..……7

2.3 Results and discussion……………………………………………..……..…….8

2.4 Conclusions…………………………………………………………….…..……12

Chapter 3. Growth of epitaxial GaAs on Si substrates for high-speed electronic applications………………………………………………………………….…21

3.1 Introduction……………………………………………………………...…….21

3.2 Experimental……………………………………………………………..……..…23

3.3 Results and discussion…………………………………………….……..….24

3.4 Conclusions……………………………………………………………..……..…29

Chapter 4. An AlGaAs/InGaAs HEMT's on Si substrates with Si^+ pre ion implantation and $Ge_{0.95}Si_{0.05}/Ge_{0.9}Si_{0.1}/Ge_{0.8}Si_{0.2}$ metamorphic buffer...............41

4.1 Introduction……………………………………………………………...…….41

4.2 Experimental……………………………………………………………..……..43

4.3 Results and discussion……………………………………………….……..…44

4.4 Conclusions……………………………………………………………...……..49

Chapter 5. Growth of InAs channel HEMT on Si substrates for high-speed electronic applications………………..……………………………………62

5.1 Introduction…………………………………………………………...…….62

5.2 Experimental……………………………………………………………..……..63

5.3 Results and discussion……………………………………………….……..…64

5.4 Conclusions……………………………………………………………...……..72

Chapter 6. Self-assembled $In_{0.22}Ga_{0.78}As$ quantum dots grown on metamorphic $GaAs/Ge/Ge_{1-x}Si_x$ /Si substrates……………………….……..……….83

6.1 Introduction…………………………………………………………...…….83

6.2 Experimental……………………………………………………………..……..84

6.3 Results and discussion……………………………………………….……..…85

6.4 Conclusions……………………………………………………………...……..91

Chapter 7. Conclusions………………………………………………………104

Vita (in Chinese)

Publication List

Figure Captions

Chapter 2

Fig. 2-1. The layer structure and the growth conditions for the Ge film grown on the Si substrate with Ge_xSi_{1-x} metamorphic buffer layers. Note that Ge_xSi_{1-x} was grown at two growth rates ,the Ge composition set at 80% and 90%, and the Si substrate implanted with high dose Si^+ ions.

Fig. 2-2. Cross-sectional TEM images of sample (a) with a Si^+ pre-ion implantation into the Si substrate; the inserted image is the high-resolution TEM image at the interface between the Ge_xSi_{1-x} metamorphic layer and the Si substrate. (b) the Ge_xSi_{1-x} metamorphic grown on the Si substrate without a Si^+ pre-ion implantation into the Si substrate.

Fig. 2-3 (a) Double crystal x-ray data indicating variations at a [004] orientation for the Ge_xSi_{1-x} metamorphic buffer layer on the Si substrate with a Si^+ pre-ion-implantation. (b) Double crystal x-ray difference data indicating variations at [004] orientation for the Ge_xSi_{1-x} metamorphic buffer layer on the Si substrate without a Si^+ pre-ion-implantation.

Fig. 2-4 (a) Reciprocal Space Map data of [004] orientation of Ge_xSi_{1-x} metamorphic buffer layer on Si substrate with Si^+ pre-ion-implantation. (b) Reciprocal Space Map data of [224] orientation of Ge_xSi_{1-x} metamorphic buffer layer on Si substrate with Si^+ pre-ion-implantation.

Fig. 2-5 AFM image of the surface morphology of the sample with a Si^+ pre-ion implantation. The root mean square (RMS) of the roughness is 0.38nm.

Fig. 2-6 Nomarski image of the etched Ge film, the etch pits arise from threading dislocations.

Chapter 3

Fig. 3-1 Schematic diagram of GaAs MESFETs on Si substrate

Fig. 3-2 The different low growth temperature GaAs buffer layers grown on the composite substrate structure with Ge/Si_xGe_{1-x}/Si substrate (Si substrate without off angle). (a)550℃ (b)500 ℃(c) 450℃. The scanned area is 25 μm×25 μm .

Fig. 3-3 AFM image of the GaAs grown on the composite structure with Ge/Si_xGe_{1-x}/Si (Si substrate with 6° off toward <110>). The scanning area is 25 μm×25 μm .

Fig. 3-4 SIMS profiles of As, Ga and Ge in a 2 μm thick GaAs layer grown on Si with different off angle toward [110] direction. (a) 0 off (b) 4° off (c) 6° off.

Fig. 3-5 Transmission electron micrograph of grown structure with from Si to Ge buffer layer to GaAs transitions. (a) GaAs layer grown on Si substrate with 6^0 off (100) toward <110> direction. (b) GaAs layer grown on Si substrate without off angle.

Fig. 3-6 Double crystal x-ray diffraction pattern of (a)Ge and SiGe metamorphic layer grown on a Si.substrate (b)GaAs layer grown on a Ge/Si_xGe_{1-x}/Si substrate.

Fig. 3-7 Transmission electron micrograph of a structure grown with Si to Ge buffer layers and a transistion to GaAs transitions with AlGaAs/GaAs superlattice in the GaAs layer.

Chapter 4

Fig. 4-1. The layer structure and the growth conditions for InGaAs channel HEMT grown on Si substrate with Ge_xSi_{1-x} metamorphic buffer layers. Note that Ge_xSi_{1-x} was grown with two step growth with the Ge composition set at 80%, 90% and 95%.

Fig. 4-2 (a) Double crystal x-ray difference data at [004] orientation for a HEMT structure grown on a Si substrate (b) Double crystal x-ray difference data at [004] orientation for a HEMT structure grown on a Ge substrate.

Fig. 4-3(a) The cross section TEM image of a HEMT structure grown on Si substrate. (b) The cross section TEM image of the interface between the GaAs layer and $Ge_{0.95}Si_{0.05}/Ge_{0.9}Si_{0.1}/Ge_{0.8}Si_{0.2}$ metamorphic buffer layer.

Fig. 4-4 The AFM image of HEMT structure grown on Si substrate. The root mean square (RMS) of the roughness is 0.38nm.

Fig. 4-5 SIMS profiles of As, Ga and Ge in a 2 μm thick GaAs layer grown on Si with 6^0 off angle toward [110] direction.

Fig. 4-6 Leakage current as a function of the bias voltage. The data was measured on a pad pattern of 300 μm wide with a spacing of 10 μm between pads.

Fig. 4-7 (a) I-V characteristics of a 0.35 μm × 100μm AlGaAs/InGaAs HEMT on a Si substrate with Ge/GeSi metamorphic layer. (b) Transconductance and drain-source current vs. V_{GS} of a 0.35 μm × 100μm AlGaAs/InGaAs HEMT on the Si substrate with Ge/GeSi metamorphic layer.

Fig. 4-8 (a) I-V characteristics of a 0.35 μm × 100μm AlGaAs/InGaAs HEMT on the Ge substrate.(b) Transconductance and drain-source current vs. V_{GS} of the 0.35 μm × 100μm HEMT on the Ge substrate.

Chapter 5

Fig. 5-1 (a) Schematic diagram of InAs MHEMT on GaAs substrate.
(b) Schematic diagram of InAs MHEMT on Si substrate

Fig. 5-2 Cross-sectional TEM image of InAs MHEMT epilayer structure on Si

Fig. 5-3 (a) The cross-section TEM image of antiphase boundary formation at GaAs layer on Si without off angle. (b) The suppression of antiphase boundary formation by Si substrate 6° off angle toward to [110].

Fig. 5-4 (a) The comparison double crystal x-ray [004] orientation of crystalline quality of InAs MHEMT structure on GaAs substrate and Si substrate. (b)The detail comparison of InAs MHEMT structure on GaAs substrate and Si.

Fig. 5-5 High resolution TEM image of AlSb nucleation on (a)GaAs substrate (b) Si substrate

Fig. 5-6 High resolution TEM image of InAs channel on Si substrate

Fig. 5-7 (a) Reciprocal Space Map data [004] orientation of InAs/AlGaSb on GaAs substrate (b) Reciprocal Space Map data [004] orientation of InAs/AlGaSb on Si substrate 6° off angle toward to [110]

Fig. 5-8 AFM image of InAs MHEMT on GaAs substrate

Fig. 5-9 AFM image of InAs MHEMT on Si substrate

Chapter 6

Fig. 6-1. Schematic diagram of InGaAs QDs on Si substrate.

Fig. 6-2. Cross-sectional TEM image of the epitaxial structure.

Fig. 6-3. (a)AFM image of the surface of the Ge layer. (b) The Quality of Ge layer of FWHM of X-ray rocking curves.

Fig. 6-4. AFM scans (10 μm×10 μm) of the typical GaAs grown on the composite structure with Ge/SiGe/Si sub with 6° off-degree toward [110] (b) The Quality of GaAs layer of FWHM of X-ray rocking curves.

Fig. 6-5. (a) AFM scans (10 μm×10 μm) of the typical GaAs grown on the composite structure with Ge/SiGe/Si sub with 6^{0} off-degree toward <110>. (b) The TEM micrograph of GaA layer grown on Si sub. with 6° off-degree toward <110> shows the APBs cross the GaAs layer.

Fig. 6-6. Bright-field cross-section TEM image of the $In_{0.22}Ga_{0.78}As$ QDs formed on GaAs/Ge/SiGe/Si.

Fig. 6-7. Distribution of InGaAs QDs grown on misorientated Si substrate. (a) 6° off-degree toward <110> (b) 0° off-degree toward <110>.

Fig. 6-8. PL measurement of the InGaAs QDs grown on misorientated Si substrate. (a) 6° off-degree toward <110> (b) 0° off-degree toward <110>

Fig. 6-9. AFM images of Self-assemble InGaAs QDs grown at different temperatures. (a) 450 ℃（b）480℃ (c) 520℃

Fig. 6-10. Average size distribution of the $In_{0.22}Ga_{0.78}As$ QDs grown at different temperatures. (a) 450℃（b）480℃ (c) 520℃