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Atmospheric In-situ Arsenic-Doped SiGe Selective Epitaxial Growth for Raised Extension NMOSFET

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1. Abstract

We propose a technique using atmospheric in-situ arsenic-doped SiGe selective epitaxial growth to deposit a high concentration of arsenic on film at a high growth rate for a raised extension NMOSFET. This film has a lower resistivity than that produced by conventional techniques.

2. Introduction

Suppressing the short channel effect by shrinking transistor dimensions is difficult. Reducing the extension junction depth is an effective approach to this problem. One promising technique that has been developed is raised extension structure. An in-situ arsenic-doped Si selective epitaxial growth process has been researched for the purpose of creating this structure [1-4]. However, depositing a high arsenic-concentrated film at a high growth rate for NMOSFET using the conventional in-situ arsenic-doped Si selective epitaxial growth process is difficult. We developed an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth technique that can deposit a high concentration of arsenic on film at a high growth rate.

3. Experimental

The substrate crystals were p-type doped CZ Si(100) wafers. The specimens were cleaned by HF treatment and H_2 anneal, followed by atmospheric in-situ arsenic-doped SiGe selective epitaxial growth. The film was analyzed by SEM, TEM, SIMS, sheet resistance, and XRD.

4. Results and Discussion

Figure 1 shows an SEM image of an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film for a pattern wafer. The selectivity on SiO_2 and Si_3N_4 is good. A cross-sectional TEM image and a SIMS profile are shown in Figs. 2 and 3, respectively. An atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film is a good crystalline and has a very sharp profile for arsenic and germanium. Figure 4 shows the arsenic and germanium concentrations as functions of the GeH_4 flow rate. Adding GeH_4 to the conventional atmospheric in-situ arsenic-doped Si selective epitaxial growth gas atmosphere leads to a definite increase in concentrations of arsenic and germanium. Furthermore, Fig. 5 shows the resistivity and the growth rate as functions of the GeH_4 flow rate. The resistivity decreases and the growth rate increases with an increase in the GeH_4 flow rate. This suggests that high arsenic and germanium concentrations lead to a low resistivity and a high growth rate.

XRD measurements around the (004) diffraction order for an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film and a conventional atmospheric non-doped SiGe selective epitaxial growth film and a reciprocal space mapping measurement around the (224) diffraction order for an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film were used to investigate the lattice strain from the angular separation of the Si substrate peak, the crystalline quality from a well-defined layer peak together with interference fringes, and the strain relaxation from the separation of the Si substrate peak as shown in Figs. 6(a) and (b), respectively. The lattice strain of an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film with no strain relaxation is larger than that of an atmospheric non-doped SiGe selective epitaxial growth film. Figure 7 shows the arsenic and germanium concentrations as functions of the AsH_3 flow rate. The arsenic and germanium concentrations increase with the AsH_3 flow rate. This suggests that the presence of more arsenic and germanium in the film leads to a larger strain of the atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film than that of the conventional atmospheric non-doped SiGe selective epitaxial growth film. Consequently, we speculate that chemical bonding between AsH_3 and GeH_4 leads to the higher arsenic concentration and a higher growth rate in the atmospheric in-situ arsenic-doped SiGe selective epitaxial growth process than those in the conventional atmospheric in-situ arsenic-doped Si selective epitaxial growth process.

Finally, the relationship between the resistivity and the arsenic concentration is shown in Fig. 8. Atmospheric in-situ arsenic-doped SiGe selective epitaxial growth process has a lower resistivity than that of the conventional atmospheric in-situ arsenic-doped Si selective epitaxial growth process.

5. Conclusion

A high arsenic concentration and a high growth rate have been achieved using an atmospheric in-situ arsenic-doped SiGe selective epitaxial growth process technique. This process produces film with a lower resistivity than that produced with the conventional atmospheric in-situ arsenic doped Si selective epitaxial growth process technique.

References

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[3] N. Yasutake, VLSI Tech. Dig. (2004) 84.

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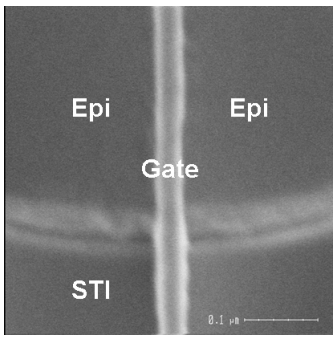


Fig. 1 SEM image of atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film for pattern wafer

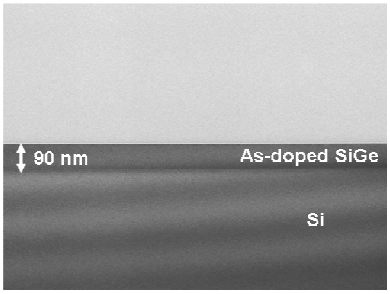


Fig. 2 Cross-sectional TEM image of atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film

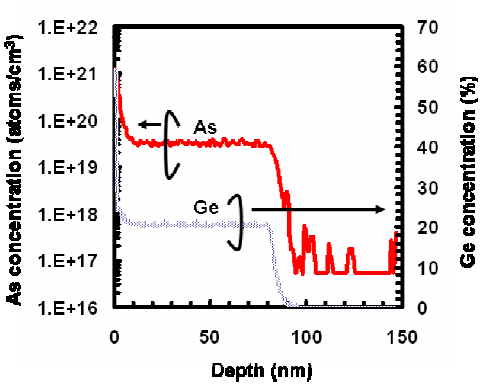


Fig. 3 SIMS profile of atmospheric in-situ arsenic-doped SiGe selective epitaxial growth film

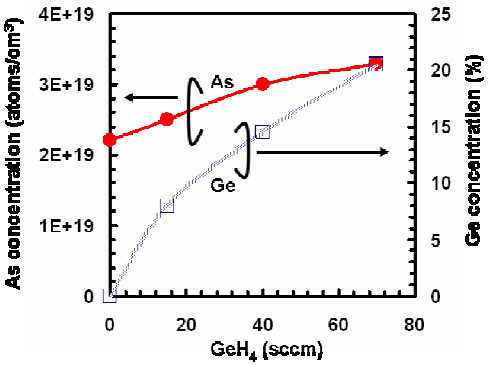


Fig. 4 Arsenic and germanium concentrations as functions of GeH_4 flow rate

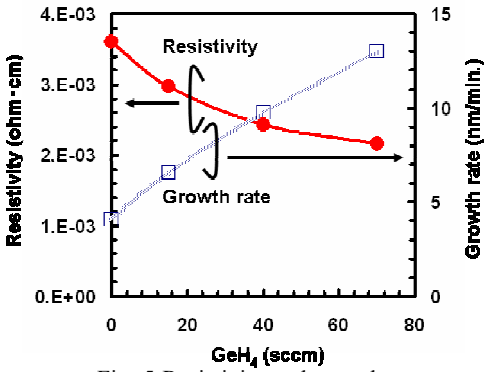
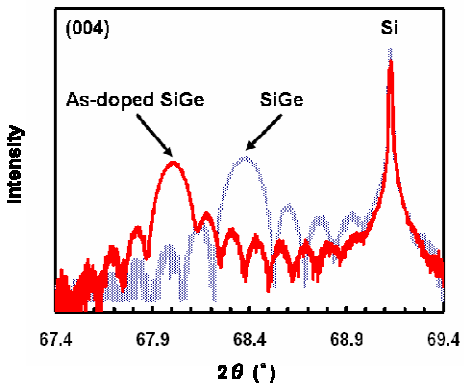
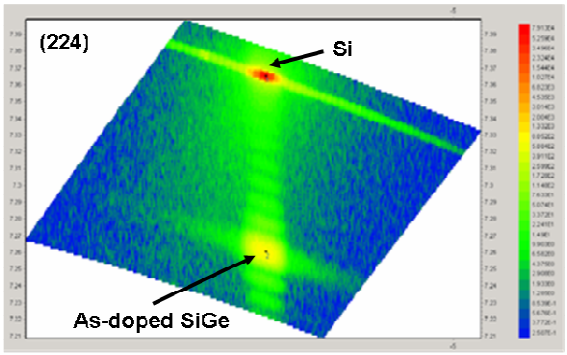


Fig. 5 Resistivity and growth rate as functions of GeH_4 flow rate



(a)



(b)

Fig. 6 (a) XRD measurements around (004) diffraction order for arsenic-doped SiGe epitaxial growth film and conventional non-doped SiGe epitaxial growth film (b) Reciprocal space mapping measurement around (224) diffraction order for arsenic-doped SiGe epitaxial growth film

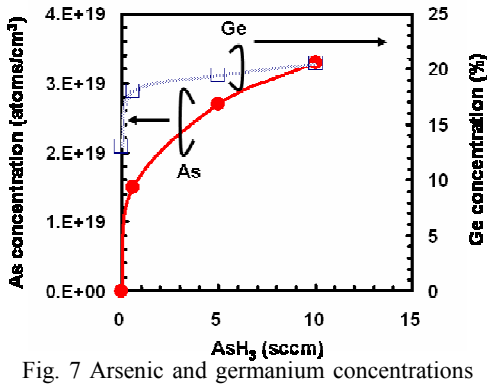


Fig. 7 Arsenic and germanium concentrations as functions of AsH_3 flow rate

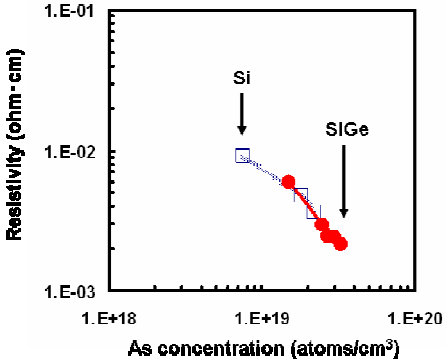


Fig. 8 Relationship between resistivity and arsenic concentration