Thin Solid Films 518 (2010) S57–S61

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Electrical characteristics of thermal CVD B-doped Si films on highly strained Si epitaxially grown on Ge(100) by plasma CVD without substrate heating

Katsutoshi Sugawara, Masao Sakuraba, Junichi Murota *

Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

ARTICLE INFO

Available online 19 October 2009

Keywords:
Electron cyclotron resonance (ECR) plasma
Chemical vapor deposition (CVD)
Epitaxial growth
Strained Si
Carrier mobility

ABSTRACT

Using an 84% relaxed Ge(100) buffer layer formed on Si(100) by electron cyclotron resonance (ECR) plasma enhanced chemical vapor deposition (CVD), influence of strain upon electrical characteristics of B-doped Si film epitaxially grown on the Ge buffer have been investigated. For the thinner B-doped Si film, surface strain amount is larger than that of the thicker film, for example, strain amount reaches 2.0% for the thickness of 2.2 nm. It is found that the hole mobility is enhanced by the introduction of strain to Si, and the maximum enhancement of about 3 is obtained. This value is higher than that of the usually reported mobility enhancement by strain using $Si_{1-x}Ge_x$ buffer. Therefore, introduction of strain using relaxed Ge film formed by ECR plasma enhanced CVD is useful to improve future Si-based device performance.

1. Introduction

Atomically controlled heterostructure growth of group IV semiconductor is important to improve Si-based device performance [1,2], because nanometer-order thick film with atomically flatness and uniformity are necessary to achieve highly strained heterostructures. For example, strained Si is an attractive material to enhance channel mobility in Si MOSFET [3], and it is obtained by lattice matching of Si to $Si_{1-x}Ge_x$ buffer using heteroepitaxial growth. Using $Si_{1-x}Ge_x$ ($x<0.8$) buffer layer, hole mobility enhancement was observed [6]. In our previous work, we have reported that, using electron cyclotron resonance (ECR) plasma enhanced chemical vapor deposition (CVD) without substrate heating, epitaxial growth of relaxed Ge on Si(100) [4] and undoped highly strained Si on 84% relaxed Ge/Si(100) (u-sSi/rGe/Si(100)) [5] with atomically flat surface was achieved by suppression of incident ion energy. In this work, using a relaxed Ge buffer layer formed by ECR plasma enhanced CVD, introduction of higher strain to epitaxially grown B-doped Si and mobility enhancement in B-doped strained Si (B-sSi) was investigated.

2. Experimental

Substrate used was p-type Si(100)-on-insulator (SOI) wafer. The resistivity and thickness of SOI are 20–30 Ω cm and 50–70 nm, respectively. Therefore, sheet resistance of SOI was about 4 MΩ/□. Epitaxial growth of u-sSi/rGe on the SOI was performed by ECR plasma CVD system shown in Fig. 1 [4,5]. The relaxed Ge and undoped strained Si were grown by GeH_4 and SiH_4 reaction, respectively, under ECR Ar plasma irradiation from a plasma generating chamber. For the 53 nm-thick relaxed Ge deposition, ion flux density and peak energy of the incident Ar ions were about $2\times10^{16}cm^{-2}\ s^{-1}$ and 3 eV,

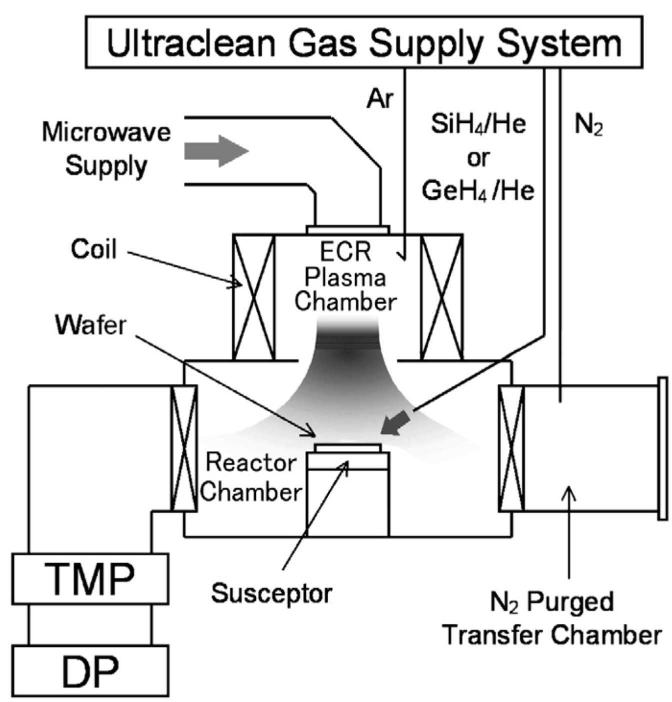

Fig. 1. Schematic of ultraclean ECR Ar plasma enhanced CVD system for epitaxial growth of u-sSi/rGe on SOI. Vacuum pumping was done by a turbo-molecular pump (TMP) and a dry pump (DP).

* Corresponding author. Tel.: +81 22 217 5548; fax: +81 22 217 5551.
E-mail address: murota@riec.tohoku.ac.jp (J. Murota).

0040-6090/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2009.10.055

respectively, and for the 1.7 nm-thick undoped strained Si deposition, these values were about $4\times10^{15}\,cm^{-2}\,s^{-1}$ and 0.5 eV, respectively [5]. After u-sSi/rGe deposition, the samples were keeping in N_2 atmosphere due to minimization of the surface oxidation before B-doped strained Si growth. Epitaxial growth of B-doped strained Si was performed by ultraclean low-pressure CVD (LPCVD) in a SiH_4–B_2H_6–H_2 gas mixture at 500 °C [7]. The samples were dipped in 2% diluted HF and carried in LPCVD system through the N_2 purged transfer chamber at room temperature. Then, a reactor chamber was heated up to 500 °C. At 500 °C, strain relaxation of undoped strained Si and intermixing at heterointerface in u-sSi/rGe/Si structure were scarcely expected for the heat-treatment [5]. For all of B-doped strained Si deposition, partial pressure of H_2, SiH_4 and B_2H_6 were fixed at 24, 6 and 2×10^{-4} Pa, respectively.

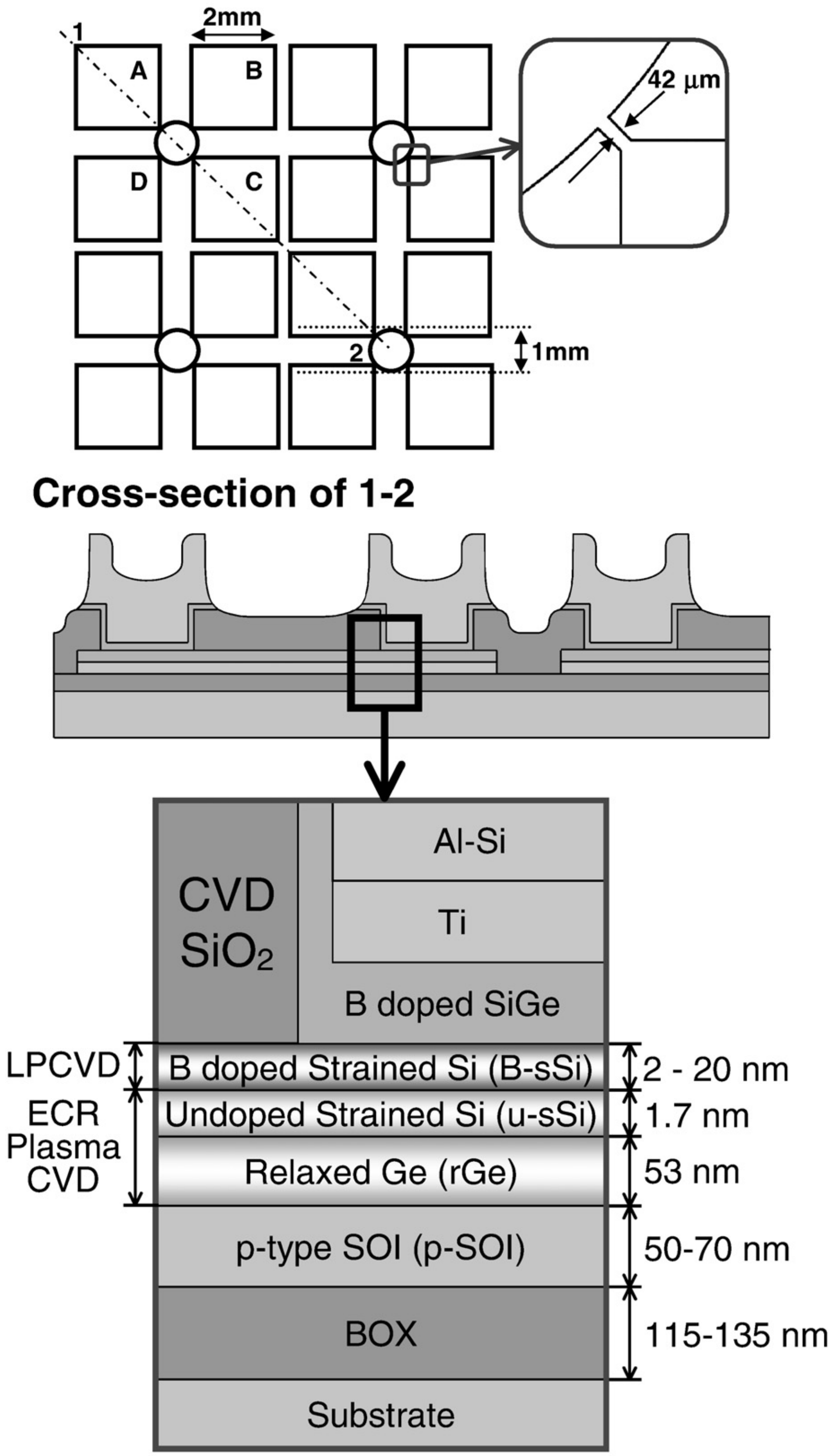

Fig. 2. Schematic of sample structure measured by van der Pauw method for Hall effects measurement.