

# Hetero-epitaxial growth of SiCGe on SiC

Z.M. Chen \*, H.B. Pu, L.M. Wo, G. Lu, L.B. Li, C.X. Tan

*Department of Electronic Engineering, Xi'an University of Technology, Xi'an, 710048, China*

Available online 18 November 2005

## Abstract

SiCGe/SiC heterojunction structure is required in development of SiC optoelectronic devices and light-activated switching devices. We present in this paper a primary attempt to grow the ternary alloy SiCGe on SiC substrates under varied growth conditions in a conventional hot-wall CVD system. SiH<sub>4</sub>, GeH<sub>4</sub> and C<sub>3</sub>H<sub>8</sub> were employed as silicon, germanium and carbon sources, respectively. The samples were measured by means of SEM, XPS, XRD, optical absorption, etc. Two different growth modes i.e., island growth and porous growth were observed. It has been shown that germanium atoms can be effectively incorporated into the ternary alloys, which makes their optical gaps to be narrowed with increasing Ge content. However, incorporation of Ge induces a heavy lattice mismatch, which limits the film thickness by the formation of mismatch defects. It has been shown that use of a buffer layer can effectively improve the growth quality of the ternary alloy.

© 2005 Elsevier B.V. All rights reserved.

*Keywords:* SiCGe; SiC; Heterojunction; Optoelectronics; LPCVD

## 1. Introduction

Although the ternary alloy SiGeC grown on Si has attracted much attentions of the semiconductor device engineers and the material researchers who are interested in Si-based HBT [1], MOSFET [2] or optoelectronic devices [3], growing SiGeC on SiC in CVD process is less studied up to now. Only a few papers reported the SiGeC/SiC heterojunction that was formed by the ion implantation of Ge into SiC and a subsequent annealing [4].

We are interested in the SiC-based heterojunction because of its potential applications to the optoelectronics and power electronics fields where silicon devices cannot effectively complete. These include light sensors and light-activated high-power switching devices to be used at high temperature [5,6]. However, SiC is not sensitive to most of the visible lights and all the near-infrared lights, and essentially sets a limitation to its application in these fields. A promising way to solve this problem is to adopt a SiCGe/SiC heterojunction structure, in which the ternary alloy SiCGe with appropriate composition is used as a

light-absorption layer. This way may be available to make SiC devices to be optically activated in the wavelength range where light sources are readily available for present optical communication. For example, in order to realize a light-activation of SiC power switches for anti-EMI (electromagnetic interference) applications, we proposed a SiC light-activated Darlington transistor, in which a SiCGe/SiC pn heterojunction is employed to produce a light-induced base current for triggering the transistor [7].

We present in this paper, a primary attempt to grow the ternary alloy SiCGe films on SiC substrates in a conventional hot-wall CVD system and the characteristics of the experimental samples prepared under varied growth conditions.

## 2. Growth of the ternary alloy SiCGe on SiC

Fig. 1 shows the schematic diagram of the hot-wall LPCVD apparatus employed to grow the SiCGe on SiC substrates. The graphite reactor is a tube with rectangular cross-section, which is inductively heated to produce a hot-wall CVD circumstance. There is no thermal isolator between the reactor and the quartz tube when the growth temperature is not over 1000 °C. Frequency of the inductive

\* Corresponding author. Tel./fax: +86 29 82312136.  
E-mail address: [chenzm@xaut.edu.cn](mailto:chenzm@xaut.edu.cn) (Z.M. Chen).

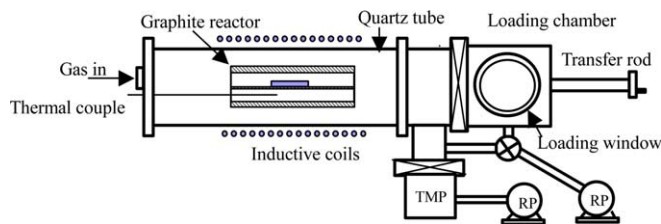


Fig. 1. Schematic diagram of the hot-wall CVD apparatus for growth of SiCGe on SiC.

power source is 2.5 kHz. Gas source used in this work was a mixture of silane ( $\text{SiH}_4$ ), germane ( $\text{GeH}_4$ ) and propane ( $\text{C}_3\text{H}_8$ ). The mixing ratio was adjusted by changing their flow rates. Hydrogen with high purity was used as a carrier gas. Base pressure in the growth chamber can be achieved to  $1 \times 10^{-3}$  Pa by the turbo-molecular pump (TMP). However, the growth pressure is maintained by the rotary pump (RP). In a typical case, the total pressure during growth was 260 Pa when the flow rates of  $\text{SiH}_4$  (10% in  $\text{H}_2$ ),  $\text{GeH}_4$  (5% in  $\text{H}_2$ ),  $\text{C}_3\text{H}_8$  (10% in  $\text{H}_2$ ) and  $\text{H}_2$  were set at 30, 20, 10 and 1000 SCCM, respectively.

The substrates used in this work were 200  $\mu\text{m}$  thick 6H-SiC purchased from II–VI Inc. During the growth, the substrates were mounted on a graphite sheet which acts as a sample holder when we load and unload the samples by means of the transfer rod in the loading chamber. All substrates were ultrasonically cleaned, and then dipped into a diluted (5%) HF to remove possible oxide before loading them into the loading chamber. To start a growth process, we always treat the substrates in  $\text{H}_2$  circumstance at a high temperature near 1000  $^\circ\text{C}$  for 10 min.

Owing to a very low solid solubility of C in either Si or Ge and the large size-differences among Si, C and Ge, synthesis of the ternary alloy SiCGe with stable composition and structure is very difficult. As shown in [8], several binary and ternary phases, such as  $\text{Si}_4\text{C}$ ,  $\text{Si}_3\text{GeC}_4$ ,  $\text{Ge}_4\text{C}$  and  $(\text{Si}_2\text{Ge})\text{C}_x$  have been found in CVD grown SiCGe on Si substrates. These phases may also be formed in that grown on SiC. However,  $\text{Si}_3\text{GeC}_4$  with a structure related to ZnS sphalerite is especially expectable because it is the most promising structure of the ternary alloy in terms of lower energy, which does not match dimensionally with Si but match rather well with SiC [8]. In order to find the well matched structures, the growth temperature was ranged from 650 to 1100  $^\circ\text{C}$  for a certain composition ratio, while the composition ratio was also changed for a certain growth temperature.

### 3. Key points to growth of the ternary alloy SiCGe

#### 3.1. Composition of the SiCGe

Composition of the ternary alloy SiCGe is a sensitive function of the growth conditions such as the growth temperature and the gas mixture ratio. Fig. 2 shows the composition ratios of Si, C and Ge in the samples grown at

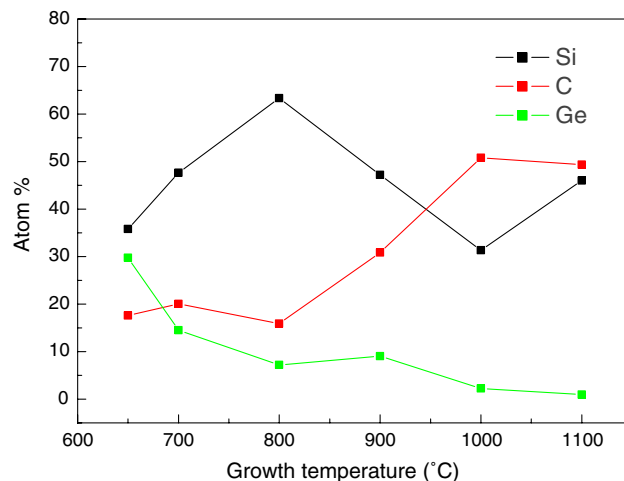


Fig. 2. Different variations of the Si, C and Ge composition ratios with growth temperature.

different temperatures but with the same gas flow rates mentioned above, which were taken from X-ray photoelectron spectroscopy (XPS) measurements. It is indicated by the limited experimental data that the Ge content decreases, while C content increases basically as the growth temperature goes up for a certain gas mixture ratio. In order to realize a  $\text{Si}_3\text{GeC}_4$ -like structure, we attempted to increase the C content in the samples prepared at a constant lower temperature by increasing the  $\text{C}_3\text{H}_8$  flow rate. But, it was not very effective as the films grown in a higher  $\text{C}_3\text{H}_8$  flow rate were found to be easily cracked.

#### 3.2. Growth modes of the SiCGe

Two growth modes were observed in this work. The first is so-called island growth. As shown in Fig. 3(a), the sample grown at a relatively high temperature exhibits a two-phase co-growth aspect, which consists of a relatively smooth background region and some separately distributed spherical islands. Materials in the two phases were identified by EDS (energy dispersion spectroscopy, a micro-probe for composition analysis) to have different compositions. For the sample demonstrated by Fig. 3, which was prepared for 150 min at 1100  $^\circ\text{C}$  with the gas flow rates mentioned above, the islands consist of a Ge-rich material with Ge content of more than 30%, while the Ge content of the background region is less than 1%. Cross-section SEM photographing shows that the two materials seem to have different growth rates. As shown in Fig. 3(b), the islands remarkably raise from the background. The background seems to be a defect-rich region, as shown in Fig. 3(c), where a high density of stocking faults is evident.

The second growth mode observed in this work is the porous growth. As shown in Fig. 4, the SEM morphology images of the other three SiCGe samples prepared at different lower temperatures but in the same gas flow rates with the sample exhibiting an island growth mode demonstrate

Download English Version:

<https://daneshyari.com/en/article/540247>

Download Persian Version:

<https://daneshyari.com/article/540247>

[Daneshyari.com](https://daneshyari.com)