Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp902-903

Au induced low temperature formation of (111) preferential oriented crystalline Ge on insulator

Hayato Okamoto [a)], Kohei Kudo, Tatsushi Nomitsu, Kenichiro Takakura and Isao Tsunoda

National Institute of Technology, Kumamoto College
2659-2 Suya, Koshi-shi, Kumamoto, 861-1102 Japan
Phone: +81-96-242-6081 E-mail: isao_tsunoda@kumamoto-nct.ac.jp

Abstract

We have investigated the solid phase crystallization for amorphous Ge / Au / SiO_2 / Si-substrates. In the case of high temperature annealing above 300 °C, crystalline Ge has random grains due to the crystal nucleation occurred in the whole region of amorphous Ge. On the other hand, both of Ge and Au atoms were localized at initial position after annealing below 250 °C for 20 hours. Moreover, highly (111) oriented crystalline Ge without Au contamination was formed. These results are speculated that crystal nucleation occurs at interface between Ge and Au, subsequently the nuclei growth progressed into amorphous Ge layer.

1. Introduction

Orientation-controlled crystalline Ge films on insulating substrates are essential to achieve high-speed thin film transistors and high-efficiency tandem solar cells. Many researchers have developed solid phase crystallization (SPC) techniques for high quality crystalline Ge [1-6]. The SPC process of amorphous Ge on SiO_2 proceeds via two processes, i.e., crystal nucleation and subsequent nuclei growth. The crystal nucleation randomly occurs in the whole region of amorphous Ge on conventional SPC process. The resulting crystalline Ge layer consists of random grains. Recently, the metal induced layer-exchange SPC process has been widely investigated. This process can control crystal orientation because the crystal nucleation occurs at interface of different materials, during inter-diffusion of catalytic metal and Ge atoms [3-6]. In line with this, we have expected that the suppression of atomic inter-diffusion by low temperature annealing is effective for the preferential crystal nucleation at interface without using layer-exchange SPC process. In this present study, low temperature SPC by using Au insertion has been investigated in order to control the position of crystal nucleation for oriented crystalline Ge.

2. Experimental Procedure

In the experiments, Au films (100 nm thick) were evaporated on SiO_2 / Si-substrates. Amorphous Ge (100 nm thick) films were deposited on Au / SiO_2 / Si-substrates by using magnetron RF sputtering system. Finally, these samples were annealed (~ 300 °C, 20 hours) in N_2 ambient.

The grown layers were evaluated by using Nomarski optical microscopy, Raman spectroscopy (laser wavelength: 457 nm), X-ray diffraction (XRD), Auger electron microscopy (AES), and electron backscatter diffraction (EBSD). All measurements were performed at room temperature.

3. Results and Discussion

First, the effect of the Au insertion on SPC for amorphous Ge / SiO_2 / Si-substrates was investigated. Nomarski optical micrographs of the samples before and after annealing at 300 °C for 20 hours are shown in Fig. 1(a) and (b), respectively. It is clearly noted that the metallic luster is confirmed at the sample surface after annealing at 300 °C. Figure 1(c) shows EDX spectra obtained from sample surface after annealing at 300 °C. The EDX spectra indicate that Au atoms highly diffuse into Ge region. Crystal orientation of Ge layer evaluated by using XRD method is shown in Fig. 1(d). The diffraction peaks corresponding to Ge (111) and (220) are observed at around 2θ = 27 ° and 47 °, respectively. These results speculated that the random nucleation occurred at whole amorphous Ge region after Au diffusion into amorphous Ge layer.

These results triggers off the following idea: In the case of the sample after low temperature annealing below 300 °C, it is expected the suppression of Au diffusion into amorphous Ge layer. This will enable the restriction of crystal nucleation position at interface for orientation controlling.

To examine this idea, low temperature experiments below 300 °C were performed. The concentration profiles of Ge and Au measured by AES for samples before and after annealing at several conditions are shown in Fig. 2. For the sample after annealing at 300 °C, Au atoms diffused into amorphous Ge regions. However, localization of Au atoms at initial position was found for the samples even after long-time annealing (20 hours) at 250 °C and 200 °C. Figure 3 shows Raman spectra for the samples, which are showed Au localization. As a reference, amorphous Ge / SiO_2 / Si-substrates samples were also shown. As a result, it is clearly observed the sharp peak originating from TO phonon mode of Ge-Ge (300 cm^{-1}) bond in crystalline Ge. These results indicated that the inserted Au layers between

---

a) Present address: Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, 6-1 Kasuga-koen, Kasuga, Fukuoka 816-8580, Japan.
E-mail: 2ES15011Y@s.kyushu-u.ac.jp

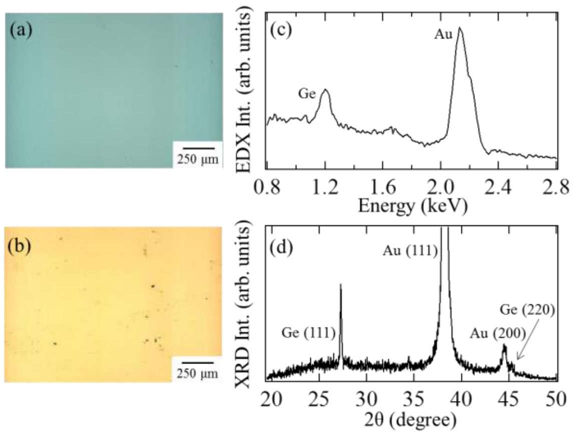

Fig. 1 Nomarski optical micrographs of sample surfaces (a) before and (b) after annealing. (c) EDX spectra of sample surface and (d) XRD patterns for the sample after annealing at 300 °C for 20 hours.

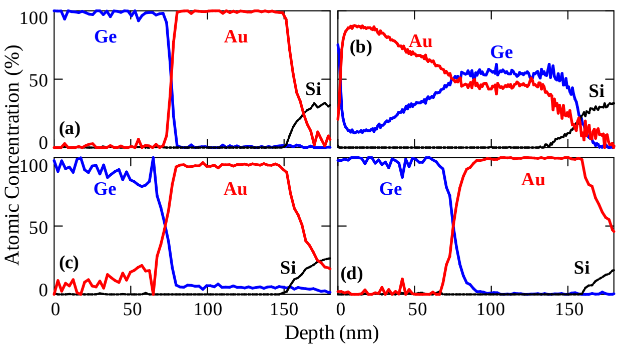

Fig. 2 Concentration profiles of Ge, Au and Si evaluated by AES measurements for the samples (a) before and after annealing at (b) 300 °C, (c) 250 °C, (d) 200 °C for 20 hours.

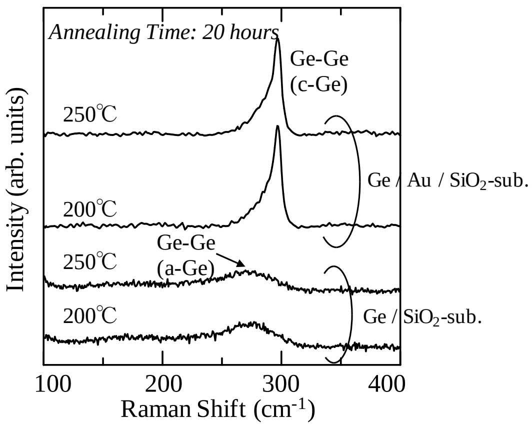

Fig. 3 Raman spectra of the samples after annealing at 250 °C and 200 °C for 20 hours.

amorphous Ge and insulator acted as preferential nucleation sites by low temperature annealing.

Figure 4 shows the EBSD images along the normal direction relative to annealing temperature are respectively shown in Fig. 4(a)-(c). Figure 4(a) indicates the randomly grains for the sample after annealing at 300 °C. By contrast, (111) oriented grains were achieved for the low temperature annealing sample (~250 °C), as shown in Fig. 4(b) and (c). These results suggest that formation of (111) oriented crystalline Ge without Au contamination is caused by interface nucleation.

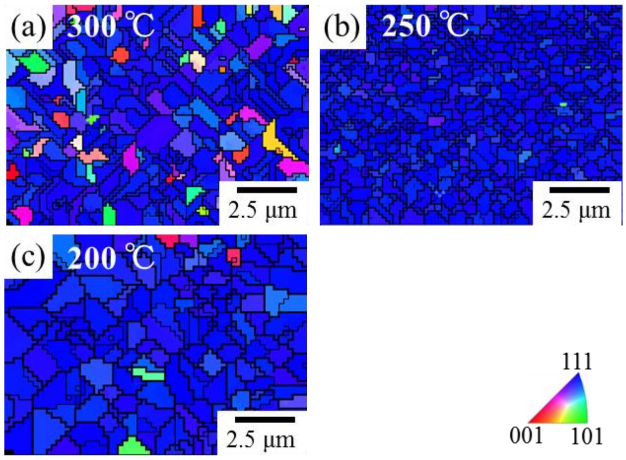

Fig. 4 EBSD images in the normal direction of Ge films after annealing at (a) 300 °C, (b) 250 °C, (c) 200 °C for 20 hours.

4. Conclusions

Low temperature formation of (111) oriented Ge / Au / SiO_2 was investigated from the viewpoint of nucleation position controlling. In the case of high temperature annealing (300 °C), crystalline Ge has random grains by highly atomic diffusion. By contrast, both of Ge and Au atoms were localized at initial position by low temperature annealing (~250 °C). Furthermore, (111) oriented Ge without Au contamination was formed. It is speculated that oriented nuclei growth propagates from interface to amorphous Ge region by restricting the crystal nucleation site in low temperature. This new method will be a powerful tool to fabricate high speed thin film transistors and high efficiency tandem solar cells.

Acknowledgements

The authors thank Professor M. Miyao and Assistant Professor T. Sadoh of Kyusyu University for providing the opportunity to use the AES measurement system. This work was partly supported by Grant-in-Aid for Young Scientists (B) (No. 26870815) from The Japan Society for the Promotion of Science (JSPS).

References

[1] K.Toko *et al.*, Solid-State Electronics **53** (2009) 1159.
[2] H.Kanno *et al.*, Appl. Phys. Lett. **89** (2006) 182120.
[3] M. Kurosawa *et al.*, Solid-State Electronics **60** (2011) 7.
[4] R. Numata *et al.*, Thin Solid Film **557** (2014) 143.
[5] K.Toko *et al.*, Appl. Phys. Lett. **101** (2012) 072106-1.
[6] K.Nakazawa *et al.*, Jpn. J. Appl. Phys. **53** (2014) 04EH01.