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# Metal-induced solid-phase crystallization of amorphous SiGe films on insulator

Hiroshi Kanno, Isao Tsunoda, Atsushi Kenjo, Taizoh Sadoh,
Shinya Yamaguchi*, and Masanobu Miyao

Department of Electronics, Kyushu University, 6-10-1 Hakozaki, Fukuoka 812-8581, JAPAN
*Central Research Lab., Hitachi Ltd., Kokubunji, Tokyo 185-8601, JAPAN
TEL: +81-92-642-3951, FAX: +81-92-642-3974, E-mail: h_kanno@ed.kyushu-u.ac.jp

## 1. Introduction

Low temperature (≦550 ℃) formation of SiGe heterostructures on insulating films has been expected to realize advanced three-dimensional ULSI and system in display. To achieve this, recrystallization processes of amorphous SiGe (a-SiGe) on $SiO_2$ have been widely investigated. However, only poly-SiGe with small grains (≦0.1μm) was obtained by solid-phase recrystallization. Melt-grown process such as laser annealing achieved poly-SiGe with large grains (~5μm), however Ge atoms were not distributed uniformly in the films, and surface ripples with ~15 nm height were observed [1].

Recently, low temperature (~550 ℃) solid-phase recrystallization of a-Si was realized by using the catalytic effect of some metals [2]. This metal-induced lateral crystallization (MILC) achieved poly-Si with large grains (~10μm). In the present work, we have applied this technique to recrystallization of a-SiGe and report our findings of Ge-fraction dependence of MILC.

## 2. Experimental Procedures

In the experiment, a-$Si_{1-x}Ge_x$ layers (50 nm thickness, $0 \leqq x \leqq 1.0$) were deposited on $SiO_2$ films by using a MBE system (base pressure: $5x10^{-11}$ Torr). Subsequently, Ni films (5 nm thickness) were evaporated on top of the a-$Si_{1-x}Ge_x$ and then patterned by using the lift-off process with photolithography. Finally, the samples were annealed at 450-600℃ in a nitrogen ambient. The crystal structures and quality of the grown layers were evaluated with Nomarski optical microscopy, SEM, and Raman spectroscopy.

## 3. Results and Discussion

Figs.1 (a)-(f) show optical micrographs of the samples with different Ge-fractions after annealing. They are classified into three groups: (i) the samples with low Ge-fractions ((a) and (b)), which crystallized with plane morphology around the Ni-pattern, (ii) those with intermediate Ge-fractions ((c) and (d)), which show dendrite morphology, and (iii) those with high Ge-fractions ((e) and (f)), which scarcely crystallized. Statistical distribution of lateral growth-length for a typical sample ($Si_{0.6}Ge_{0.4}$) is shown in Fig.2, which shows plane-growth with 4μm length and dendrite-growth with wide distributed length. Maximum dendrite-growth-length is estimated to be 60μm.

Characteristics of plane-growth in MILC-SiGe are summarized in Figs.3 (a) and (b) as a function of annealing time and Ge fraction, respectively. Results indicate that the plane-growth progresses slowly with annealing time and reaches to 10~13μm. The growth velocity is enhanced by 50% by increasing Ge fractions from 0 to 20%, which is attributed to enhanced Ni-migration in locally strained a-SiGe films. The Raman spectra and shifts for annealed samples (550℃, 20hr) are shown in Figs.4(a) and (b), respectively. The data points of the shifts lie along a line obeying Vegard's law [3]. This clearly shows that the SiGe layers were completely strain free. This is the first report, which achieves low-temperature SiGe growth by MILC method. Electrical characterizations of these crystallized regions are now underway.

Maximum lateral-length of dendrite-growth is summarized in Figs.5 (a) and (b) as a function of annealing time and Ge-fractions, respectively. Results indicate that dendrite-growth progresses rapidly and saturates in a very short time. Significant long growth-length of 60μm is obtained for samples with Ge-fraction of 40%.

The growth direction became straight, and the width of dendrite regions became narrower with increasing Ge fraction and decreasing annealing temperature. The mechanisms of such phenomena are not clarified yet, however, very sharp needlelike crystals (width: 0.05μm, length: 10μm) were obtained by optimizing the growth condition (Ge fraction: 40%, annealing: 450℃, 20hr). A typical example of the sharp dendrites is shown in Fig.6. Such needlelike crystals might be used for unique devices such as one-dimensional wires in advanced ULSI.

## 4. Conclusion

Metal-induced low-temperature (≦ 550 ℃) recrystallization of a-SiGe on $SiO_2$ have been investigated. Growth velocity of MILC-SiGe can be enhanced by 50% by increasing Ge fraction from 0 to 20%, which achieved poly-SiGe with large grains (13μm). In addition, needlelike dendrite crystals were found for samples with intermediate Ge fractions. These new polycrystalline SiGe films on insulator should be used for advanced three-dimensional ULSI, system in display, and novel one-dimensional wires.

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### References

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[2] J.S.Im et al., MRS Bulletin/March (1996) 39.
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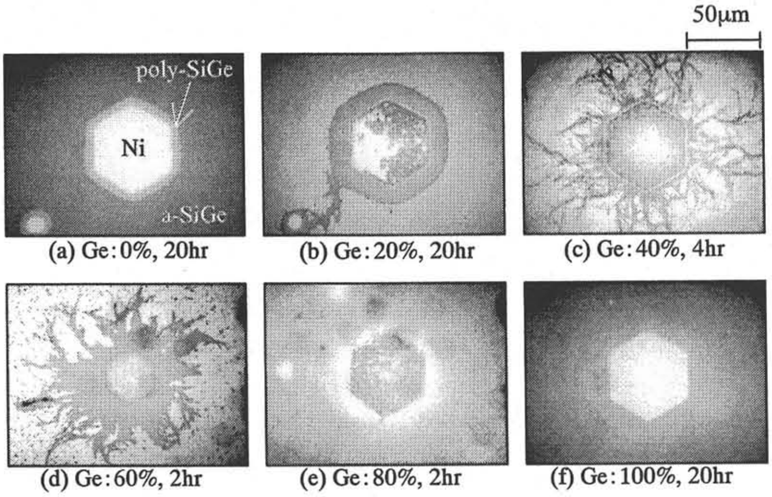


Fig.1 Nomarski optical micrographs of samples with different Ge-fractions after annealing at 550℃.

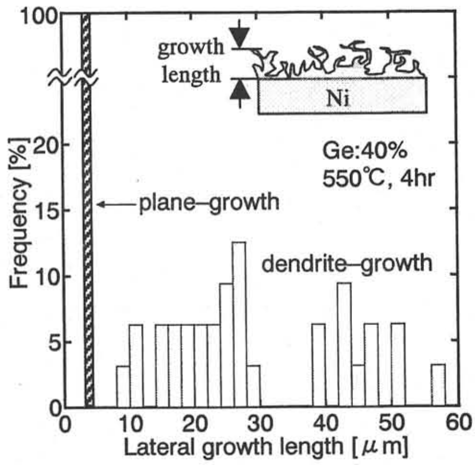


Fig.2 Statistical distribution of lateral growth-length after annealing at 550℃ for 4 hr.

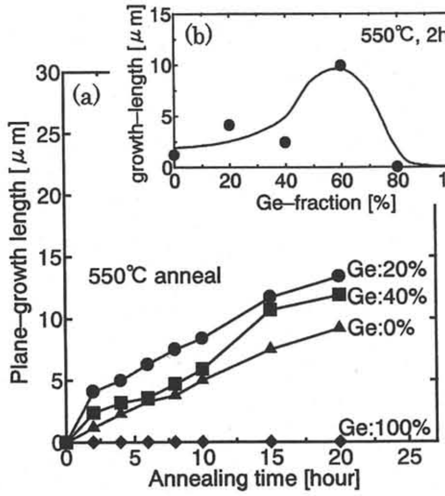


Fig.3 Lateral-length of plane-growth as a function of annealing time (a) and Ge-fraction (b).

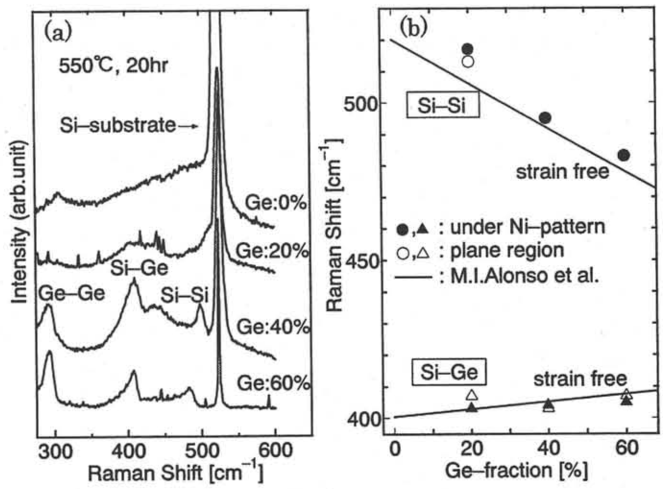


Fig.4 Raman spectra (a) and peak positions (b) for samples with different Ge-fractions.

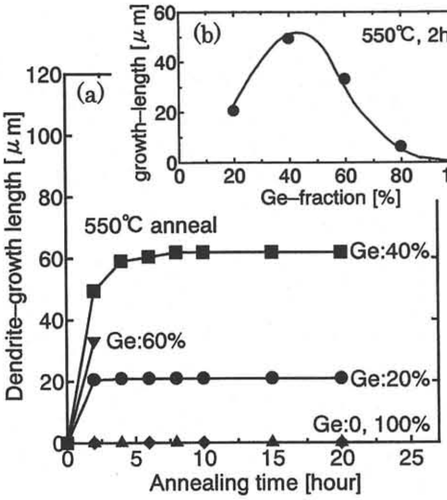


Fig.5 Maximum lateral-length of dendrite-growth as a function of annealing time (a) and Ge-fraction (b).

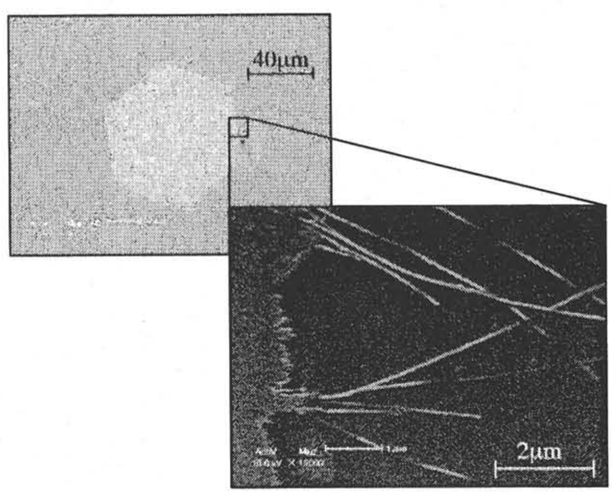


Fig.6 SEM photographs for sharp dendrite-growth of $Si_{0.6}Ge_{0.4}$ after annealing at 450℃ for 20 hr.