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400 °C Formation of poly-SiGe on SiO_2 by Au-induced lateral crystallization

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Abstract

Au-induced low-temperature (400 °C) crystallization of amorphous-$Si_{1-x}Ge_x$ (x: 0–1) thin films on SiO_2 has been investigated. Although the growth velocity decreased with increasing Ge fraction, growth velocity exceeding 20 μm/h was obtained in all Ge fractions. As a result, strain-free poly-$Si_{1-x}Ge_x$ with large areas (>20 μm) were obtained at a low temperature (400 °C). These new polycrystalline SiGe films on insulator could be used for advanced system in display and three-dimensional ULSI.

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1. Introduction

Low-temperature (<500 °C) formation of polycrystalline silicon–germanium (poly-SiGe) films on insulator has been expected to realize advanced system-in-display and three-dimensional ultra large-scale integrated circuit (ULSI). To achieve this, recrystallization processes of amorphous SiGe (a-SiGe) on SiO_2 have been widely investigated. However, in order to induce solid-phase crystallization (SPC) of a-SiGe, high-temperature annealing (>550 °C) is required [1,2]. Melt-grown process such as laser annealing achieved poly-SiGe with large grains (~5 μm), however Ge atoms were not distributed uniformly in the films and surface ripples with ~15 nm height were observed [3].

Recently, low-temperature metal-induced lateral crystallization (MILC) of a-Si was realized by using the catalytic effect of Ni [4,5], as Ni reacts with Si at a low temperature and forms silicide, which acts as a seed for solid-phase epitaxial growth. We have examined the possibility of this technique to crystallize a-$Si_{1-x}Ge_x$ (x: 0–1) and achieved poly-SiGe with large grains (~10 μm) [6]. However, the lateral growth velocity (1 μm/h at 550 °C) is not fast. In addition, uniform crystallization was obtained for only samples with low Ge fractions (<30%). This is because formation probability of $NiSi_2$ decreases with increasing Ge fraction [7].

One possible solution is the utilization of other types of reactants such as Ag, Al and Au. This is because these metals form eutectics with a-Si and a-Ge at a low temperature [8–10]. We selected Au, since its eutectic points with Si and Ge are very close (Au–Si: 363 °C, Au–Ge: 361 °C). The present paper reports our findings on the important role of Au on MILC, which success-

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fully enables enhancement of growth velocity as well as uniform crystallization for SiGe samples with all Ge fractions (0–100%).

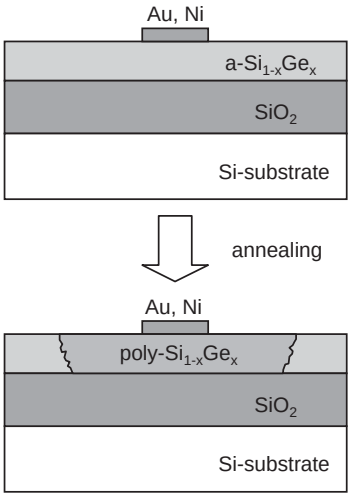

Fig. 1. Schematic experimental procedures for metal-induced lateral crystallization of a-$Si_{1-x}Ge_x$ on SiO_2.

2. Experimental procedures

In the experiment, p-type Si substrates with (1 0 0) orientation were used. They were covered with SiO_2 films (160 nm thick) by dry oxidation and then a-$Si_{1-x}Ge_x$ (x: 0–1) layers (50 nm thickness) were deposited on SiO_2 films by using a molecular beam epitaxy system (base pressure: 5×10^{-11} Torr). Here, Si and Ge were evaporated using Knudsen cells at a rate of 0.1 nm/s by keeping the substrates at room temperature. The composition ratio (x) in a-$Si_{1-x}Ge_x$ was controlled by monitoring Si and Ge fluxes, and confirmed by Auger electron spectroscopy. Subsequently, Au films (15 nm thickness) or 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, these samples were annealed at 400 or 550 °C in a furnace under a dry nitrogen ambient. Such experimental procedures are schematically shown in Fig. 1.

After MILC processing, the crystal structure and quality of the grown $Si_{1-x}Ge_x$ layers were evaluated with Nomarski optical microscopy, energy dispersive X-ray spectroscopy (EDX), and microprobe Raman spectroscopy (spot diameter: ~1 μm). All measurements were carried out at room temperature.

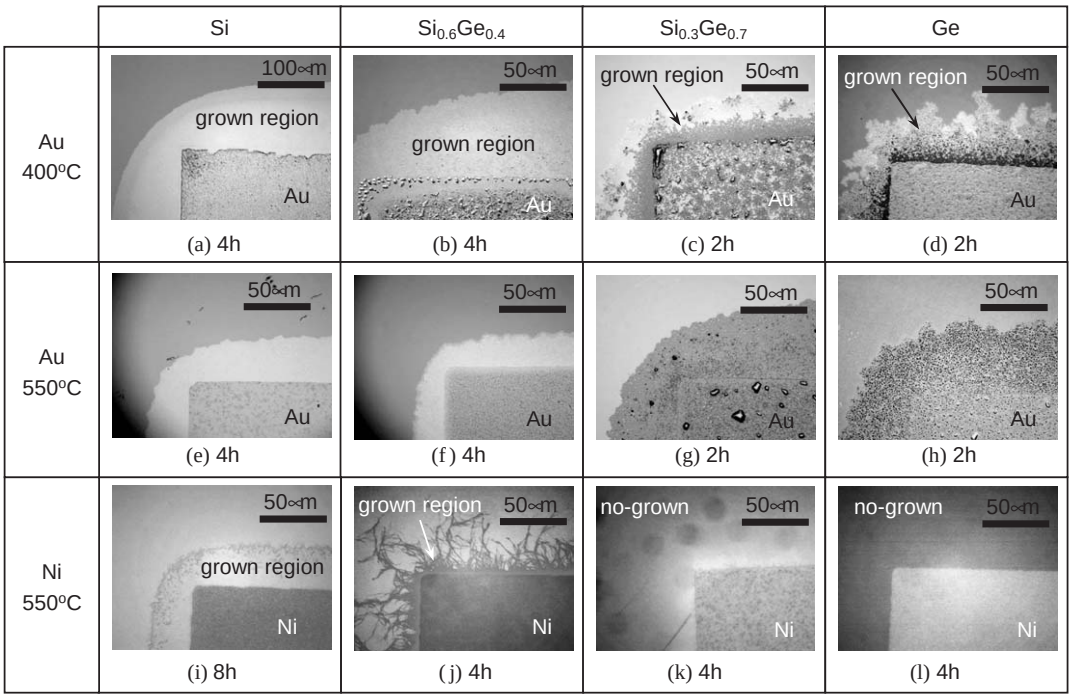

Fig. 2. Nomarski optical micrographs of samples with different Ge fraction. (a)–(d) Au-induced lateral crystallization at 400 °C, (e)–(h) Au-induced lateral crystallization at 550 °C, and (i)–(l) Ni-induced lateral crystallization at 550 °C.