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Orientation Control of SOI Film by Laser Recrystallization

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We have studied the influence of the growth direction and the solidification speed on crystal quality of the SOI film. In a <100> direction on a {100} Si substrate, lateral epitaxial growth of single crystal regions from a seed extended as much as 1 mm. While it was found that the crystalline orientation of the SOI film changed continuously from {100} toward {110}. These results indicated that the quality of the SOI film was strongly affected by the crystallographic arrangement of the growth front relative to the composition of {111} faceted planes.

1. INTRODUCTION

To produce the high quality SOI (silicon on insulator) film by laser recrystallization, various techniques for controlling the thermal profile in the SOI film have been developed together with the seeded [1] or unseeded [2] sample structure. However, the {100} controlled single crystal SOI has elongated only about 100 μm from the seed openings, [1,3] and the SOI film has still contained crystalline defects such as twins and stacking faults as well as large or small angle grain boundaries. This is because former works have not taken into account the crystallographic arrangement, such as composition of growth front planes and growth direction. It is well known that the {111} faceted planes play a very important role for a stable {100} textured growth from molten silicon in the case of zone-melting recrystallization. [4] However, in the case of laser recrystallization, the {111} facet was hard to be formed because the transition zone was not sufficient for forming {111} faceted planes because of the high solidification speed as compared with that of zone-melting and the steep curvature of isothermal contours due to small size of the laser beam.

The purpose of this paper is to make clear the fundamental mechanism responsible for the crystal growth by laser recrystallization. In this study, the initial crystallographic arrangement was given by using the substrate single crystal as a seed, and the composition and its direction of the growth front planes were controlled with using the antireflecting stripes [5] formed in various directions on the {100} Si substrate.

2. SAMPLE PREPARATION

The sample structure used in this study was the combination of the seeding and the patterned antireflecting film for controlling the shape of liquid-solid interface. The starting material was 4-inch {100} Si wafer with a 1 μm thick thermally oxidized silicon dioxide (SiO_2) layer by LOCOS process. The 9 μm wide seed openings were arranged in <110> directions. A 0.6 μm thick polysilicon film was deposited by LPCVD technique. The 500 Å thick LPCVD silicon nitride (Si_3N_4) was deposited on that material system, as an antireflecting film, and photolithographically patterned and etched into stripes with lines and spaces of 6 μm and 10 μm, respectively. The nitride stripes were formed in various directions between <110> and <100> directions as shown in Fig. 1. The polysilicon film was then recrystallized with a cw argon laser. The laser beam with the diameter of about 100 μm was scanned parallel to the nitride stripes. Scan speeds varying from 5 to 25 cm/s were used. The substrate was heated to 450 ℃ during laser beam

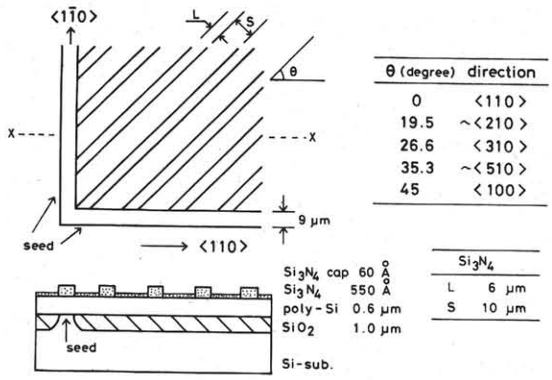

Fig.1 Schematic representation of a sample structure.

irradiation.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3-1 Growth Direction

Crystalline defects observed from the chemically etched. Sample surfaces were classified into three types shown in Fig. 2. They were (a) stacking faults, (b) grain boundaries originated from dislocations and stacking faults, and (c) twins. The latter two types of defects broke the continuity of single crystal growth.

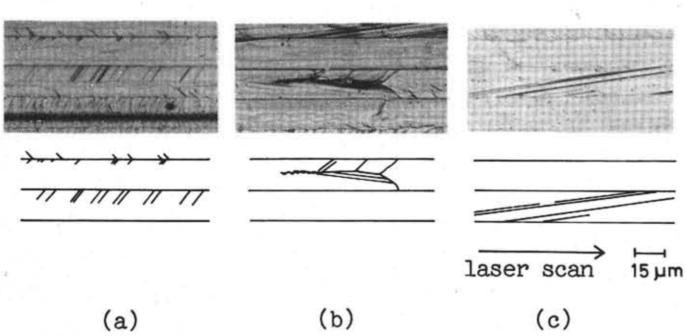

Fig.2 Micrograph of crystalline defects after etching SOI films in a Secco etch.

Figure 3 shows the length of the single crystal region epitaxially grown from a seed as functions of growth direction and scanning speed. The slower scan speed contributed the longer single crystal growth. This is considered to be due to the wider transition zone responsible for melt-resolidification caused by longer dwell time, providing capability of forming {111} facets as growth front.

The further increase of the growth length was found in the investigation of the growth orientation. The growth length increased gradually from 100-200 μm at <110> direction to <310> direction, and drastically increased between <310> and <510>. The longest crystal growth was obtained in a <100> direction. Figure 4 shows the optical micrograph of the SOI film recrystallized in the <100> direction with the scan speed of 12.5 cm/s. The sample surface was chemically etched for revealing crystalline defects. The single crystal was epitaxially grown more than 1 mm from a seed without having any crystalline defects

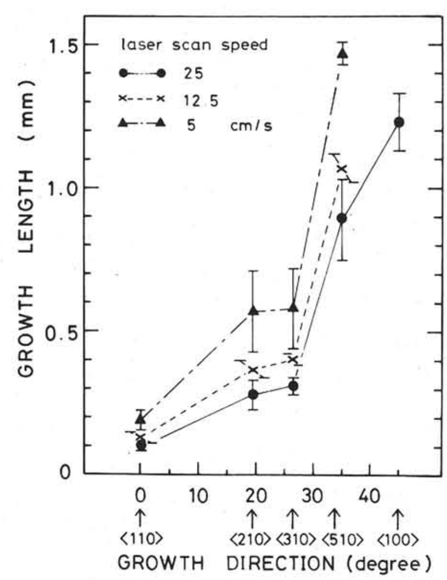

Fig.3 Growth length of SOI film from the seed as functions of growth direction and solidification speed.

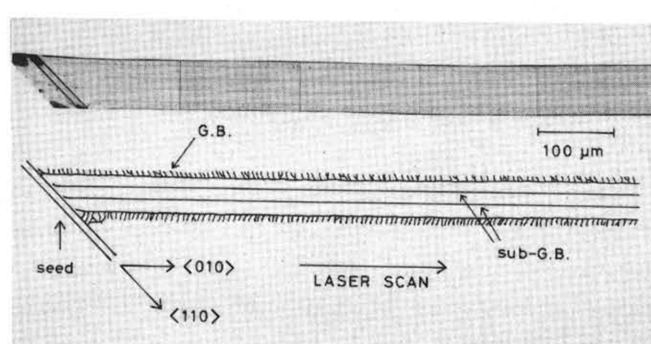

Fig.4 Microscopic view of a SOI film recrystallized in the <100> direction with scan speed of 12.5 cm/s.

except controlled subgrain boundaries beneath antireflecting stripes. These results indicated that the crystallographic orientation of the growth front achieved the important role for growing the high quality SOI film.

Figure 5 shows the optical micrograph of the partially recrystallized silicon film revealing the liquid-solid interface by chemical etching. Although the laser beam was scanned perpendicular to the antireflecting stripes, in stead of parallel scanning, the composition of this liquid-solid interface was considered to be similar to the actual shape of the growth front. The relations between this chevron-shaped growth front and the {111} faceted planes controlled with the {100} seed are illustrated in Fig. 6 for 2 types of representative crystallographic arrangements, <100> direction and <110> direction on {100} plane. This illustration clearly shows that the shape of the growth front become close to the {111} faceted plane at <100> direction, and that the result is consistent with the case of zone melting recrystallization.

Therefore, since the laser recrystallization process lacks the alternative driving forth for the {111} facet formation which corresponds to the constitutional supercooling criterion for zone-melting recrystallization using carbon strip heater,[6] it is indicated that the appropriate arrangement of the growth front to the {111} faceted plane by using the seed and the control method of the lateral thermal profile was the key issue for laser recrystallization.

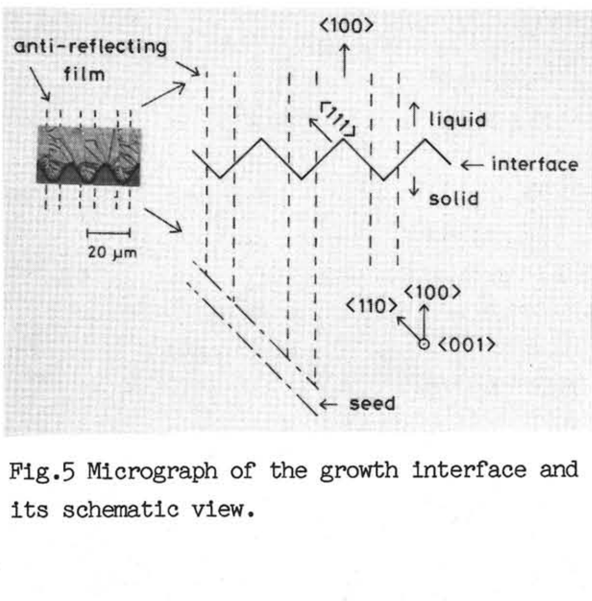

Fig.5 Micrograph of the growth interface and its schematic view.

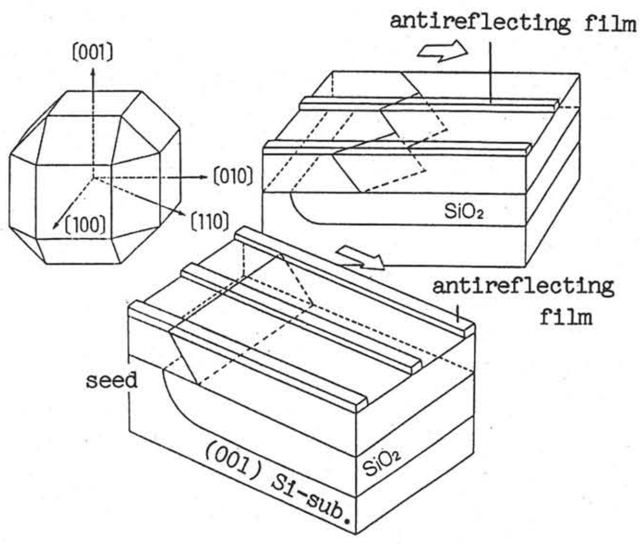

Fig.6 Illustration of {111} planes in [110] and [010] directions.

3-2 Orientation of the SOI film

Figure 7 shows the crystallographic orientation of the similar SOI film as shown in Fig. 4 revealed by the grid of etch-pits technique. The square pits exhibiting {100} texture were found near the seed opening, but their shapes were gradually modified to a hexagon exhibiting {110} texture in a distance about 600 μm without any defects. This change in crystallographic orientation, or slanting of the main axis was readily illustrated in Fig. 8, and clearly explained the rotating motion of {111} faceted plane. In the case of zone-melting recrystallization, it has been speculated that the

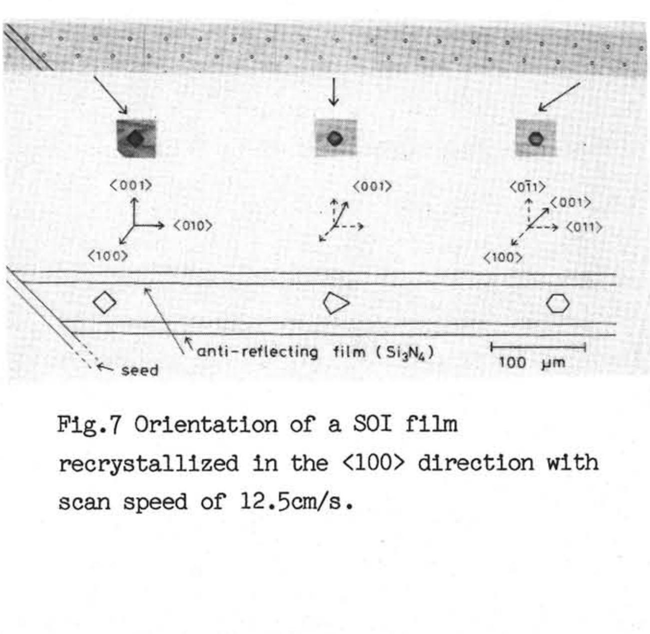

Fig.7 Orientation of a SOI film recrystallized in the <100> direction with scan speed of 12.5cm/s.

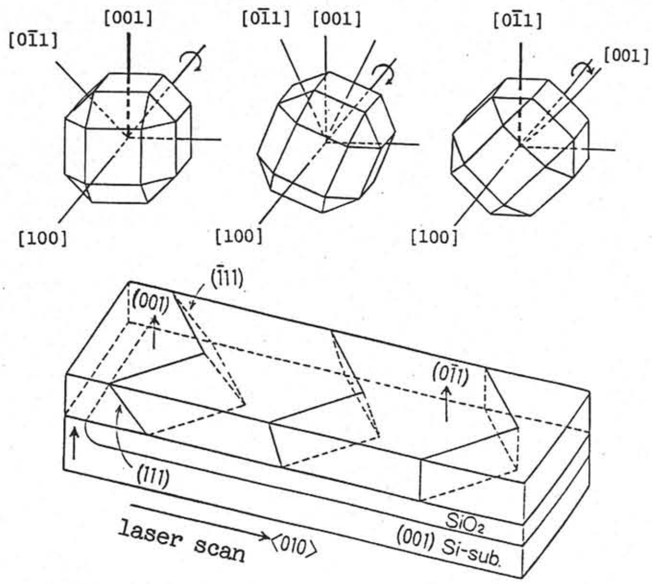

Fig.8 Schematic illustration of the rotation in crystallographic orientation and the composition of {111} planes.

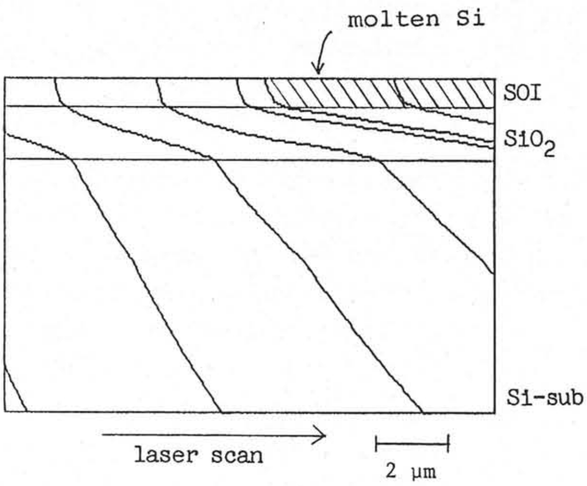

Fig.9 Cross-sectional thermal profile in the recrystallized silicon film.

{100} textured growth was preserved due to minimum interfacial tension for the {100} Si/SiO_2 interface, however this was not predominant for laser recrystallization.

The mechanism for the slanting of axis was not fully understood, but the major role was considered to be the actual slope of the growth front.

Figure 8 shows the cross sectional thermal profile in the recrystallized silicon film where the location is far apart from a seed. The calculation was achieved by the two-dimensional heat flow analysis simulation. The growth front was appeared as the composition of planes almost perpendicular to the film surface due to lower diffusivity of SiO_2 . Therefore, it was implied that the {111} faceted planes initially arranged in a {100} texture were gradually got up toward an arrangement in a {110} texture as facing the melt.

4. CONCLUSION

The quality of the SOI film was strongly affected by the crystallographic arrangement of the growth front relative to the composition of {111} faceted planes. In a <100> direction on a {100} Si substrate, single crystal regions from a seed extended as much as 1 mm. While the crystalline orientation of the SOI film changed continuously from {100} to {110}.

5. ACKNOWLEDGEMENT

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