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The Characterization of P-MOS FET Fabricated on SOI with Controlled Crystal Orientation

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It has been studied how laser recrystallization conditions affect the rotation of crystal orientation in the seeded-lateral epitaxy. Thick Si, thick SiO_2, high substrate temperature and slow scanning speed have found to contribute to the reduction of the rotation. MOS transistors were fabricated on the recrystallized silicon, 100μm apart along the growth direction. Devices formed in a region whose deviation of the crystal orientation was less than 20 degrees shows good characteristics comparable to those built in bulk silicon.

1.INTRODUCTION

Laser recrystallization is the most promising technology for the formation of SOI (Silicon on Insulator) in fabricating three dimensional IC. In this technology, the crystal orientation control is important for the reduction in the variation of device characteristics caused by differences in gate oxide thickness and mobilities. In all directions, only (001)[010] growth produces defect-free crystal, which also contributes to the uniformity of device characteristics. The seeded-lateral epitaxy has been widely used in order to control crystal orientation. However, it has been pointed out that the crystal orientation of SOI continuously rotated [1][2].

This paper presents the approaches to suppress the rotation of crystal orientation, and the influence of the rotation on the characteristics of P-MOS FET fabricated on recrystallized silicon.

2.EXPERIMENTAL

A thermal oxide layer was grown on a 4-inch (001) Si wafer and 0.5μm deep stripes were formed in the SiO_2 film parallel to [010] direction of the substrate as shown in Fig. 1. Then dot seeds, 2μm square, were formed in order to control the SOI crystal orientation. Next, LPCVD polysilicon, where devices were fabricated, and a cap SiO_2 were deposited. Recrystallized silicon was obtained by irradiation of the M-shaped Ar laser beam parallel to the stripes[2]. The crystal orientation of SOI was characterized by electron channeling pattern. The examined parameters influencing on the rotation of crystal orientation in laser recrystallized SOI were (A)recrystallized silicon thickness, (B)insulator thickness, (C)substrate temperature, (D)laser scanning speed. Thirty P-MOS FETs were fabricated along the lateral epitaxial growth direction at intervals of 100μm with a conventional

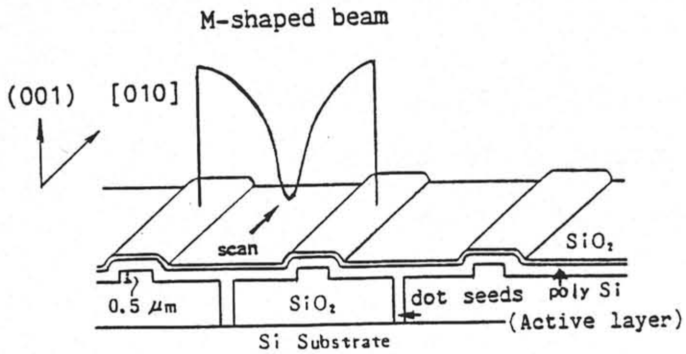

Fig.1 Schematic representation of a sample structure

P-MOS technology and the influence of the rotation on device characteristics was evaluated.

3.RESULTS AND DISCUSSION

3.1 Suppressing the rotation of the crystal orientation

The rotation of the crystal orientation in laser recrystallized SOI is affected by various parameters as shown in Fig. 2.

The rotation of crystal orientation was suppressed when the four parameters were changed as follows:

Thickness of the laser recrystallized silicon layer was increased(A). Thickness of the insulating layer was increased(B). Substrate temperature was increased(C). Laser scanning speed was slowed(D).

These results are summarized in Table 1.

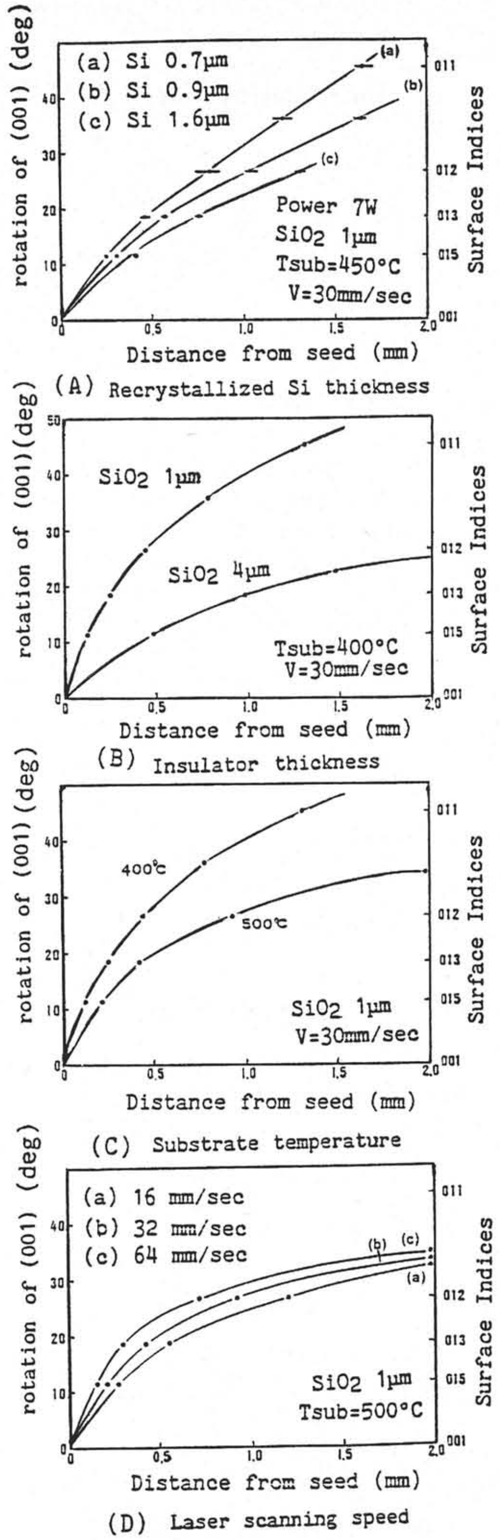

Fig.2 Dependence of recrystallization conditions on crystal rotation.

Parameters	(Rotation) increase	↔	decrease
Recrystallized Si thickness	Thin	↔	Thick
Insulator thickness	Thin	↔	Thick
Substrate temperature	Low	↔	High
Laser scanning speed	Fast	↔	Slow

Table 1 Dependence of recrystallization condition on crystal orientation.

Three dimensional temperature profile simulations show the solid-liquid interface becomes almost perpendicular to the wafer surface in the above four cases. The rotation may be suppressed by keeping the solid-liquid interface perpendicular to the wafer surface.

3.2 Characteristics of P-MOS FET/SOI

The relationship between the distance from the seeds and the P-MOS FETs' characteristics (threshold voltage:Vth, effective mobility:μeff, subthreshold swing:S) was investigated. Fig. 3 shows the arrangement of P-MOS FETs fabricated at intervals of 100μm and Fig. 4 shows the rotation of (001) axis in the sample shown in Fig. 3. The recrystallized silicon orientation rotated about 20 degrees from the axis of (001) at a distance of 400μm from the seeds. The further away the transistors were from the seeds, the more the electrical characteristics of the transistors degraded and the variation increased. The relationship between the distance from seeds and P-MOS FET(L/W=4/6μm) is shown in Fig. 5. The difference of device characteristics was small between the transistors fabricated on bulk silicon and those on SOI within a distance of 400μm from the seeds. The variations in P-MOS FETs characteristics fabricated at a distance of 250μm from the seeds are shown in Fig. 6. As the crystal propagated away from the seeds, the threshold voltage and subthreshold swing gradually increased and effective mobility decreased. The reason for the increase in threshold voltage was attributed to the increase of the gate oxide thickness, as the crystal orientation rotated. Decrease in effective mobility was due to the increase in the gate oxide thickness and the decrease in mobility itself, depending on the crystal orientation. Increase in subthreshold swing was affected not only by the rotation of the crystal orientation but also by micro-defects in the SOI layer. It appeared that increase in the variation of device characteristics was caused by degradation of crystal quality.

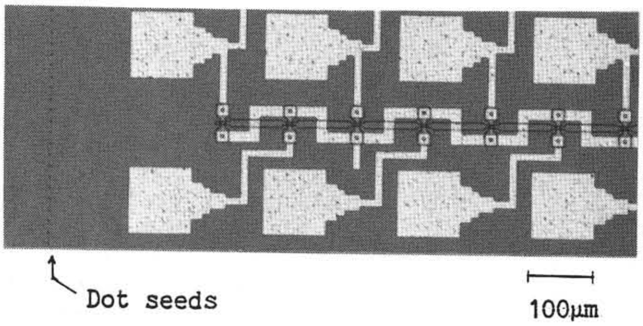

Fig.3 Optical micrograph of P-MOS FET/SOI

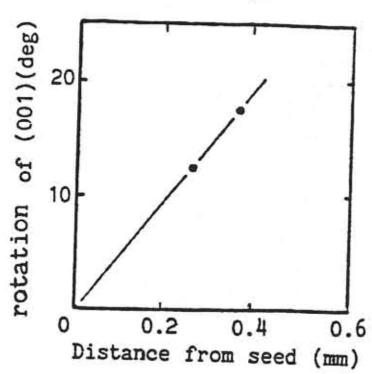

Fig.4 Rotation of crystal orientation

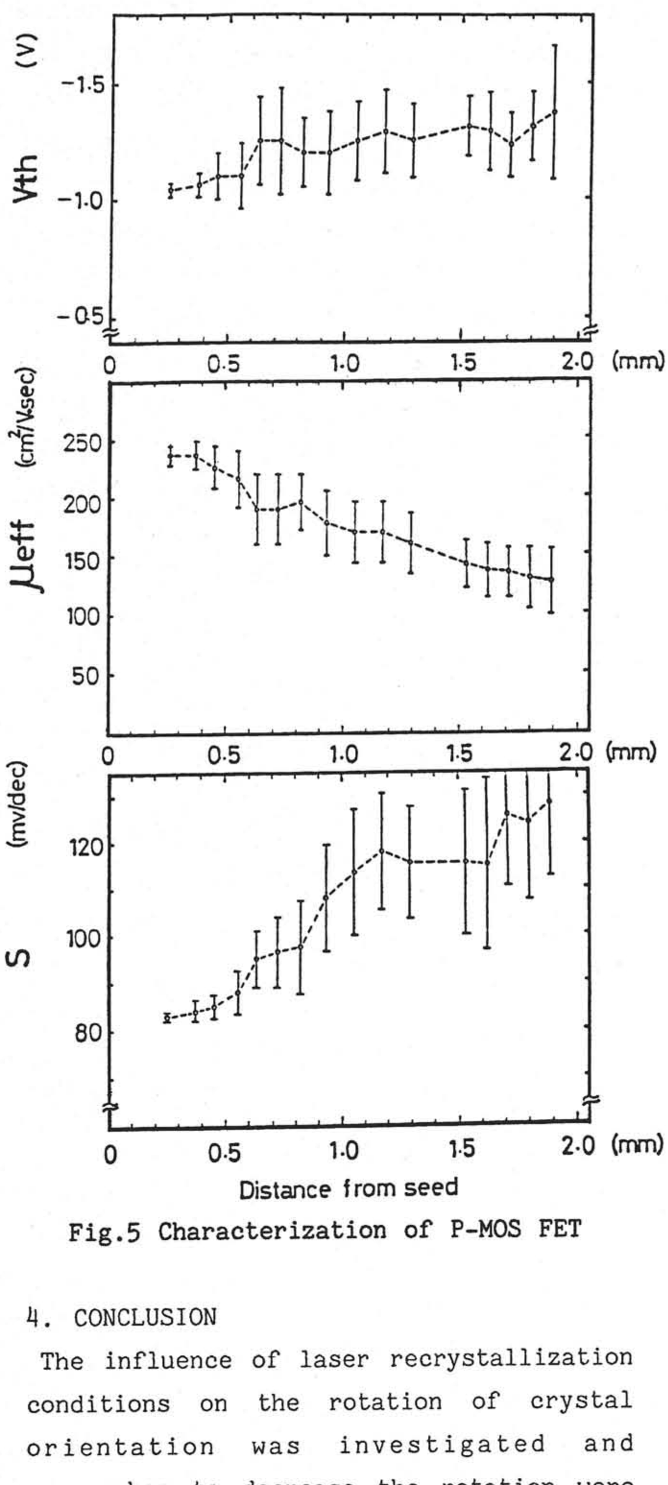

Fig.5 Characterization of P-MOS FET

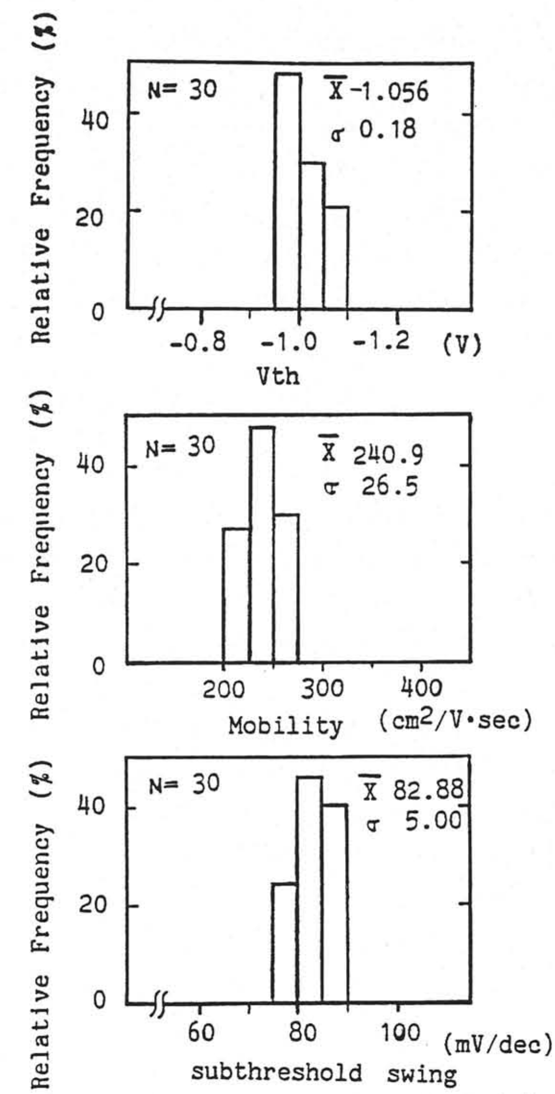

Fig.6 Characteristics of transistor fabricated at a distance of 250μm from seeds.

4. CONCLUSION

The influence of laser recrystallization conditions on the rotation of crystal orientation was investigated and approaches to decrease the rotation were presented. The relationship between the degree of the rotation of crystal orientation and the characteristics of P-MOS FETs fabricated on SOI were evaluated. Consequently, the variation of device characteristics was small enough when the degree of rotation was less than about 20 degrees, and the difference of device characteristics between the transistors fabricated on bulk silicon and those on SOI was small.

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References

[1]C.I Drowly et al., Mat. Res. Symp. Pros. 23(1984) P.456

[2]M.Maekawa, 5th Symposium on Future Electron Devices, P.215(1986) in Japanese