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Silicon Film Recrystallization by Line Electron Beam

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Ion implanted Si and SOI films were recrystallized by using a line electron beam annealing system, operated in a CW-mode. In annealing ion implanted Si films, an area about 3.5 mm wide was uniformly annealed in one beam scan. In the seeded SOI recrystallization case, SOI islands 200 μm square over an area 1.6 mm on a side were recrystallized without any grain boundaries in one beam scan.

1. Introduction

Beam annealing technology[1], such as laser[2-3] and electron beam (e-beam)[4-6], is effective in growing crystalline silicon films on amorphous insulating materials (SOI), which is one of the key points in the formation of 3-dimensional ICs, because the influence of heat flow below the SOI films can be neglected in a short processing time. e-beam annealing technology, compared with laser annealing technology, for SOI crystal growth has the followir, advantages; 1) Formation of desired beam shape, 2) High output power and 3) High flexibility and good controllability in beam scanning, heating depth and time etc. Radiation damage on devices underlying SOI films was considered to be a major problem in e-beam annealing. However, it was found that radiation damage was not a crucial problem[7]. Use of line e-beam[4,6] is very attractive for large area SOI formation, since a relatively large area, such as a chip-size area, can be melted in one scan.

This paper reports results obtained by using a line e-beam annealing system to recrystallize ion implanted Si and SOI films.

2. Experiment

A line e-beam annealing system was used in this experiment. This system is operated in the cw-mode. The line e-beam, emitted from a strip-cathode, is accelerated and scanned on a sample by electromagentic lens and deflection systems. The line e-beam is approximately 0.3 mm wide and up to 3.5mm long on a sample surface. Figure 1 shows an example of a line e-beam profile in the longitudinal direction. This figure shows that e-beam measures about 2 mm long with a uniform current density.

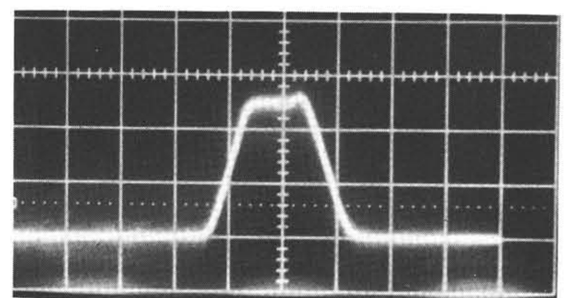

Fig. 1 A line e-beam profile. H; 1.7 mm/div, V; 0.13 A/cm^2/div.

Samples used in this experiment were ion impalnted Si and SOI films. 2~3 Ω·cm p-(100)Si substrates were implanted with 1 x 10^{15} As atoms/cm^2 at 150 keV. SOI films were formed without and with a seeding area. The unseeded samples were 1 μm thick poly-Si films on 1 μm thick SiO_2 films grown on Si(100) substrates. In the seeded samples, square SOI islands surrounded by a 5 μm wide seeding strip were formed in various sizes (5 to500 μm). After opening the 5 μm wide windows (seeding area) in 1 μm thick SiO_2 films gown on Si(100) substrates, 0.5 μm thick poly-Si films were deposited. These unseeded and seeded samples were capped with CVD SiO_2 films 1 μm and 0.5 μm thick, respectively, and pre-annealed at 1000 °C for 20 minutes in N_2 gas. A seeded sample cross sectional view is shown in Fig.2. e-beam annealing was

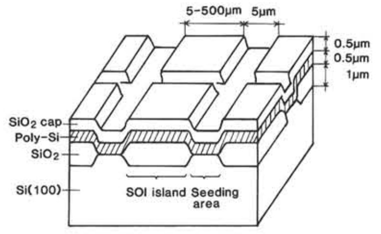

Fig. 2 Seeded SOI cross sectional view

carried out under conditions involving 15 kV accelerating voltage, 4.2~30 mA beam current, 4.2~20 cm/sec scan speed and 320~500 °C substrate heating temperature.

3. Results

3-1. Ion implanted Si layers regrowth

In order to regrow Si layers by solid phase epitaxy, arsenic implanted Si layers were annealed. e-beam annealing was performed under the conditions involving 15 kV accelerating voltage, 20 mA beam current, 12 cm/sec scan speed, 3.5 mm beam length and 320 °C substrate temperature. Figure 3 shows a photomicrograph of e-beam annealed areas in one scan. Figure 4 shows the spreading resistance measurement results for an e-beam annealed area, as shown in Fig. 3. These results indicate

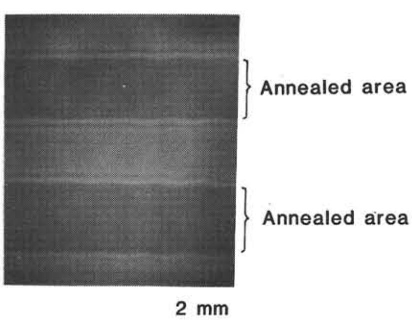

Fig. 3 Photomicrograph of e-beam annealed Si, implanted with 1×10^{15} As atoms/cm^2

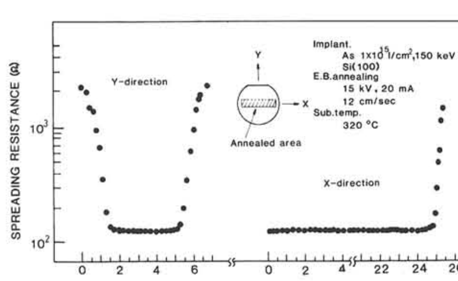

Fig. 4 Spreading resistance measurement results for e-beam annealed area.

that an area about 3.5 mm wide and up to 25 mm long can be uniformly annealed in one scan. It is also found that no slip lines are observed with an optical microscope.

3.2 SOI film recrystallization

SOI films were annealed in order to recrystallize Si films by liquid phase recrystallization. In the unseeded samples, e-beam annealing was performed under conditions involving 15 kV accelerating voltage, 4.2 mA beam current, 4.2 cm/sec scan speed, 3 mm beam length and 500 °C substrate temperature. Figure 5 shows a

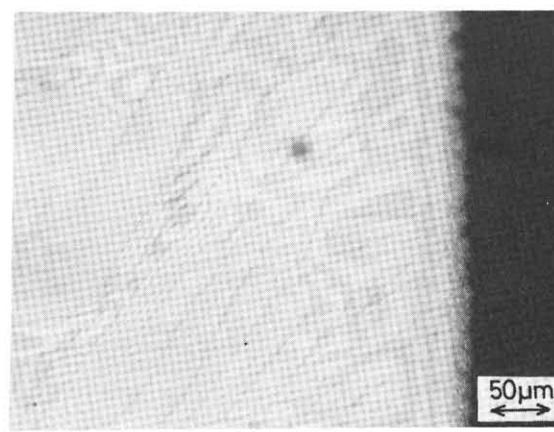

Fig. 5 Photomicrograph of the unseeded sample after the sample was Secco etched to delineate grain boundaries.

photomicrograph of the unseeded sample, after the sample was Secco etched to delineate the grain boundaries. This figure indicates that many grain boundaries, grown from the unannealed poly-Si area, are observed. However, grains as long as 500 μm are grown, although the width is narrow, about 50 μm.

In the seeded recrystallization case, e-beam annealing was carried out under conditions involving 15 kV accelerating voltage, 8 mA beam current, 7 cm/sec scan speed, 2 mm beam length and 500 °C substrate temperature. Figure 6 shows a photomicrograph of a seeded SOI sample, which has been Secco etched. This photograph shows that no grain boundaries exist in the seeded SOI islands 100 and 200 μm square over the area 1.6mm side in single scan. Moreover, it is found that square SOI islands, as large as 500 μm on one side, can be recrystallized without any grain boundaries, although protrusions are observed at the end of the beam sweeping in each SOI area.

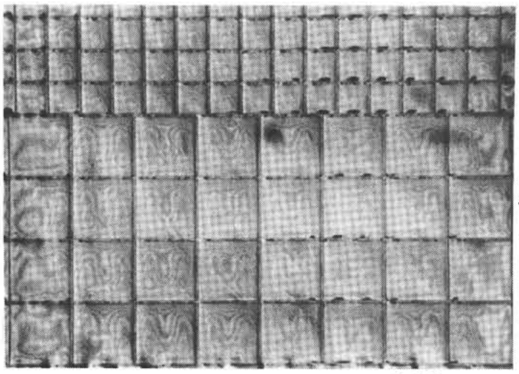

Fig. 6 Photomicrograph of the seeded SOI sample after the sample was Secco etched.

4. Conclusion

Si film recrystallization by line e-beam has been studied. Main results obtained are;

(1) A more than 3 mm wide implanted area can be annealed in one beam scan.

(2) Seeded SOI islands 200 µm square over on area 1.6 mm on a side can be rerystallized without any grain boundaries.

(3) Seeded square SOI islands, as large as 500 µm on one side, can be recrystallized without any grain boundaries.

These results verify the effetiveness of line e-beam annealing on recrystallizing large, i.e., chip-sized or larger, SOI islands.

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