

Recrystallization of Patterned Silicon-Thin-Films by AC-Magnetic Fields

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We report on new experimental results that confirms the role of eddy-currents in thin silicon-film during recrystallization by AC-magnetic fields. Clear difference was observed in surface morphology between the recrystallized silicon network-rectangles and the isolated-rectangles. According to the results, it has been shown that we could produce thin-film silicon-patterns with no grain boundary at specified locations on glass substrates, and that we could produce silicon-layer rectangles large enough to fabricate high-performance devices within them.

1. INTRODUCTION

Demand for giant micro-electronics, such as liquid-crystal displays and image-sensors, continues to increase for greater size and higher performance. Limiting factors in the further development of such devices have been the reduction of their power consumption and the reduction of connections between the devices and drive LSIs. A solution to these problems is a large-area, high-quality silicon-on-glass (SOG) structure that permits built-in CMOS drive-circuits.

We have previously proposed a recrystallization-technique referred to as an "Selective Recrystallization by Magnetic-field" technique for producing a large-area high-quality SOG. We have reported that we succeeded in producing a recrystallized silicon layer with a grain size of some hundred microns.¹⁻⁴ In this paper, we report on new experimental results obtained in the recrystallization of a patterned silicon-layer. The results confirm the role of eddy-currents in the thin silicon-film during recrystallization, and also show basic device-applicability of the SRM technique.

2. NETWORK AND ISOLATED SILICON RECTANGLES

We reported that induced eddy-currents in a thin silicon-film were expected to serve to heat and to recrystallize the silicon-film with the SRM technique. However, clear evidence for the role of

the eddy-currents was yet to be obtained. On the other hand, we used SOGs with plane silicon-layers, i.e. as-deposited silicon-layers, in our previous experiments. Silicon-droplets, created by the surface tension of molten silicon, were often observed after the recrystallization, since large volume of silicon melts at a time. In point of device-fabrication, however, we do not need recrystallized silicon-layer with so much volume, but with large area. Therefore, we performed the recrystallization of a patterned silicon-layer in order to confirm the role of eddy-currents in recrystallization and to suppress the generation of silicon-droplets.

Eddy-currents induced by AC-magnetic fields flow dense in poly-silicon rectangles connected in wafer scale two-dimensionally with poly-silicon paths since the induced voltage along a closed loop is proportional to the number of magnetic flux in the loop. Induced eddy-currents, however, flow sparse in isolated small poly-silicon rectangles. Figure (1) shows a conceptual diagram for the network rectangles, "A", and the isolated rectangles, "B", used in this experiment. We expect the rectangles "A" will be recrystallized easier than the rectangles "B" if the eddy-currents in the silicon layer serve to heat the silicon-layer. We also expect that successful recrystallization of the silicon pattern at a designed location will show device-applicability of the SRM technique.

3. EXPERIMENT

Poly-silicon with 2 [μm] thickness was deposited on 100 [mm]-diameter quartz substrates by conventional LP-CVD. The poly-silicon had the grain size of about 100 [\AA], and had a rough surface. The poly-silicon layers were patterned using conventional photo-resist and etching processes. Poly-silicon network rectangles with unit cell dimension of 100~2000 [μm] were patterned on different substrates. Isolated poly-silicon rectangles were also laid out adjacent to each network rectangles as shown in Figure (1). After cap-CVD SiO_2 layer was deposited, the recrystallization was performed for 120 [sec]. DC supply voltage and current for used rf-oscillator were 260~270 [V] and 20~22 [A], respectively. Recrystallized silicon surfaces were observed with SEM and phase-contrast optical microscope.

Figure (2) shows a photograph of the recrystallized area with unit cell dimension of 100 [μm] and connection path-width of 10 [μm]. In SOGs with larger unit cell dimensions, we used wider silicon connection-paths proportionally, and we could not suppress the droplet creation in SOGs with wider paths than about 100 [μm]. The whole area shown in Figure (2) looks to be recrystallized well. Clear difference was, however, observed in surface morphology between the recrystallized network rectangles "A" and the isolated rectangles "B". Figure (3) shows a SEM view of the poly-silicon before recrystallization. The silicon surface was Secco-etched and observed with SEM. The surface had a fine columnar structure as shown. Figure (4) shows a SEM view of a network-rectangle "A" shown in Figure (2), and no grain boundary was observed. Figure (5) shows a SEM view of an isolated rectangle "B" that locate adjacent to the network rectangle shown in Figure (4). Many grain boundaries were observed as shown in Figure (5). This difference shows the silicon network-rectangles "A" were heated more than the isolated silicon rectangles "B", and clearly means that induced dense eddy-currents served in melting the network silicon-rectangles.

Network silicon rectangles with about 100 [μm] side-dimension have been obtained successfully with the SRM technique. This size is large enough to fabricate ordinary-size thin-film-devices within them. This result means that silicon-layer patterns at designed locations could

be recrystallized successfully, and also means that we can remove grain boundaries from the area in which devices are going to be built.

The SRM technique uses AC-magnetic fields produced by induction coils.^{1,2} Therefore, the magnetic field distribution primarily determines the temperature distribution if the SOG wafer is static to the coil. The temperature distribution is also affected by the quantity and frequency of the induction-coil current. Therefore, optimization for the coil geometry is an important factor to obtain a large recrystallization area without grain boundaries. We believe that the SRM technique is a strong candidate for rapid thermal processing of silicon-on-quartz wafers and of bulk-silicon wafers considering our experimental results for SOGs with quartz-substrates. However, cheaper glass-substrate usage is yet to be tested in order to confirm practical applicability to very large SOG panels.

4. SUMMARY

We recrystallized thin-film silicon-patterns with the SRM technique, which patterns are two-dimensionally connected in wafer-scale. We have achieved thin-film silicon-patterns with no grain boundary at designed locations on glass substrates, and we could produce silicon rectangle-patterns with about 100 [μm] side-dimension. This dimension is large enough to fabricate devices within them.

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5. REFERENCES

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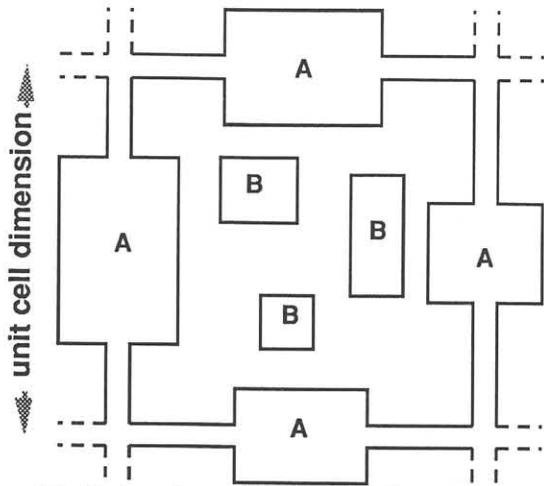


Figure (1) Network and isolated silicon patterns. Rectangles shown as "A" are network silicon-patterns. Rectangles shown as "B" are isolated silicon-patterns.

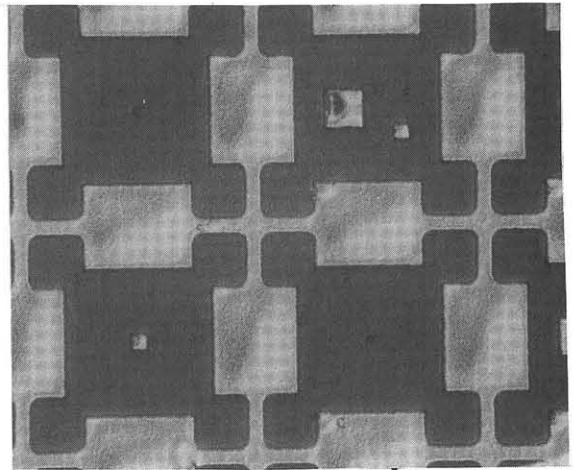


Figure (2) A phase-contrast photo-micrograph for the recrystallized area. The unit cell dimension is 100 [μm].

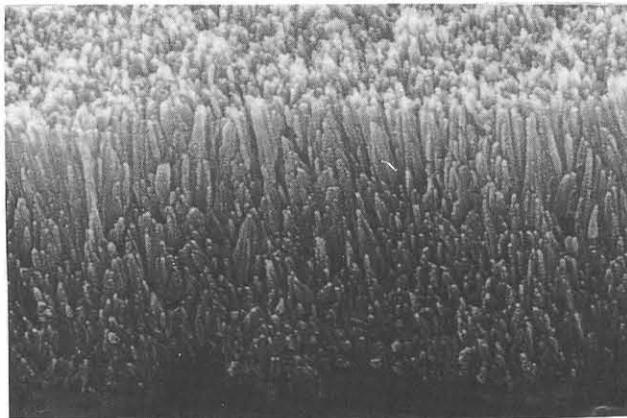


Figure (3) A SEM view for the poly-silicon before recrystallization. A columnar structure and a lot of grain boundaries are observed.

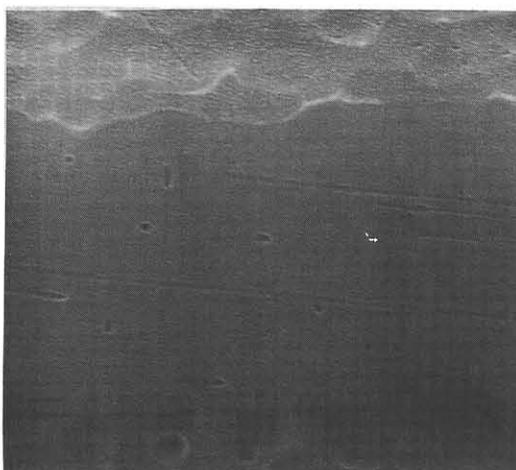


Figure (4) A SEM view for a recrystallized network-rectangle "A". No grain boundaries are observed.

Silicon top surface
 Silicon side surface
 Quartz substrate

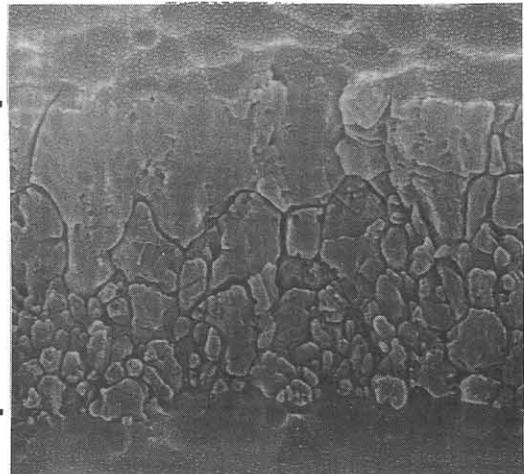


Figure (5) A SEM view for a recrystallized isolated-rectangle "B" adjacent to the network-rectangle shown in Figure (4). Grain boundaries are still observed.