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Enlargement of Crystal-Grains in Thin Silicon Films Using Continuous-Wave Laser Irradiation

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1. Introduction

Low-temperature polycrystalline-silicon (LTPS) thin film transistors (TFTs) are used in active-matrix liquid crystal display technologies, and are now becoming the key technologies for new applications, such as a system LCD. Large grains of thin Si films are needed to make high performance TFTs [1]. A diode pumped solid state (DPSS) continuous wave (CW) laser is effective for high-quality continuous crystallization of Silicon [2], [3]. The purpose of this work is to enlarge two-dimensional large grains using DPSS CW laser. The effects of the laser spot shape and the overlap of the laser irradiated region on the recrystallization of thin amorphous-Si (a-Si) films have been investigated.

2. Experiments

Figure 1 shows a schematic of sample structure for recrystallization experiments. A buffer SiO_2 film with a thickness of 900 nm was formed on a Si(100) wafer by thermal oxidation and PECVD. An a-Si film with a thickness of 150 nm was deposited by LPCVD. Finally, a cap SiO_2 film was deposited by PECVD to prevent surface reflection of laser beam. The thin a-Si films were irradiated by CW laser with a wavelength λ = 532 nm as shown in Fig. 2. An overlap ratio was defined by a ratio between an overlap width and a laser beam width. Laser spot shapes are shown in Fig. 3, where (a) is a conventional one, (b) is an elongated one toward a scanning direction. The elongated laser spot shape toward a scanning direction was designed to realize gradual slope of temperature in a laser irradiated region, which makes the recrystallization time longer than conventional one. Crystallization of thin Si films was investigated by X-ray diffraction (XRD) and electron back-scattering diffraction pattern (EBSP) measurements.

3. Results and Discussions

Figure 4 shows XRD spectra of the recrystallized thin Si films. By changing a laser spot shape from a conventional one to an elongated one, all peaks in the out-of-plane spectra decreased. Also, (220) and (400) peaks in the in-plane spectra dramatically increased and other peaks in the in-plane spectra greatly decreased. In addition, by changing the laser scanning from zigzag scanning to raster scanning, all peaks in the out-of-plane spectra further decreased, and (220) and (400) peaks in the in-plane spectra further increased and other peaks in the in-plane spectra were decreased also. It was found that a laser recrystallization with an elongated laser spot and raster scanning effectively enhanced crystallization of thin Si films.

Figure 5 shows in-plane XRD spectra of recrystallized thin Si films as a function of overlap ratio. The overlap ratio was changed from 0 % to 90 %. A laser recrystallization was carried out with an elongated laser spot and raster scanning. As overlap ratio was increased, (220) and (400) peaks increased, and other peaks decreased. This means that crystallization of the thin Si films was enhanced by overlapping the laser beam.

Figure 6 shows EBSP mappings. Figures 6 (a), (b), and (c) are the results of laser recrystallization by a conventional spot with zigzag scanning, an elongated spot with zigzag scanning, and an elongated spot with raster scanning, respectively. Figure 7 shows grain size distributions calculated from EBSP mappings. By using an elongated spot with raster scanning, (100) well-oriented thin Si film with an average grain size of 1.60 μm was achieved.

Figure 8 shows AFM images of recrystallized thin Si films. By using an elongated spot with raster scanning, surface roughness dramatically decreased.

It was found that crystal-grains of thin Si films depend on laser-irradiated time and gradual cooling. The zigzag scanning makes the crystallization direction irregularly due to the forward and the backward scannings induced by in-depth thermal gradient. The raster scanning makes crystallization direction regularly and increases crystallization of thin Si films.

4. Conclusion

Low temperature crystallization of thin amorphous silicon (a-Si) films using a diode-pumped solid state (DPSS) continuous wave (CW) laser was investigated. A laser beam spot was designed to be elongated toward a scanning direction in order to form a gradual slope of temperature in a laser irradiated region. The elongated laser spot with a raster scanning successfully enhanced crystallization of thin Si films. Consequently, a, large (100) well-oriented crystal-grains of thin Si films have been obtained.

5. Acknowledgment

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References

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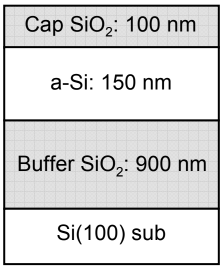

Fig.1 Schematic illustration of sample structure.

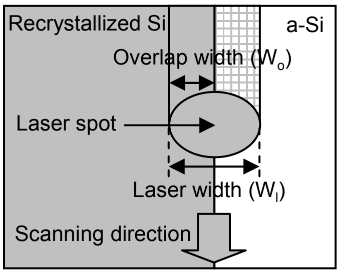

Fig.2 Schematic image of a laser spot on thin Si film in the recrystallization experiments.

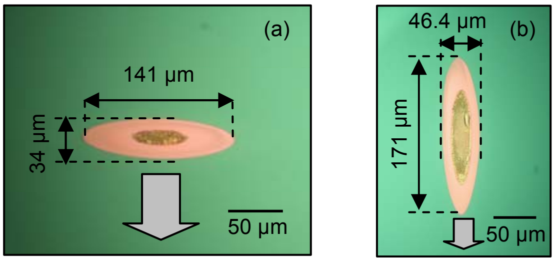

Fig.3 Photograph of laser spot shapes for 5 seconds exposure.
(a) a conventional spot shape,
(b) an elongated spot shape to a scanning direction.

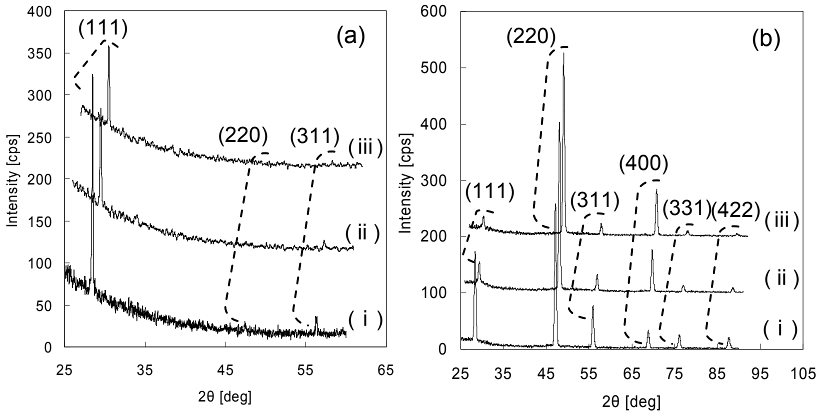

Fig 4. XRD spectra. (a) is the out-of-plane spectra, (b) is the in-plane spectra.
(i) a conventional spot shape with a zigzag scanning,
(ii) an elongated spot shape to a scanning direction with a zigzag scanning,
(iii) an elongated spot shape to a scanning direction with a raster scanning.

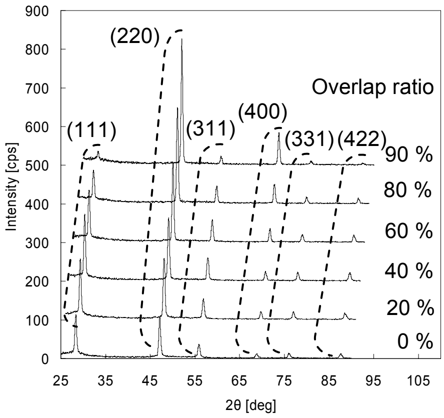

Figure 5. In-plane XRD spectra as a function of overlap ratio. Laser annealing was carried out with an elongated spot shape and a zigzag scanning.

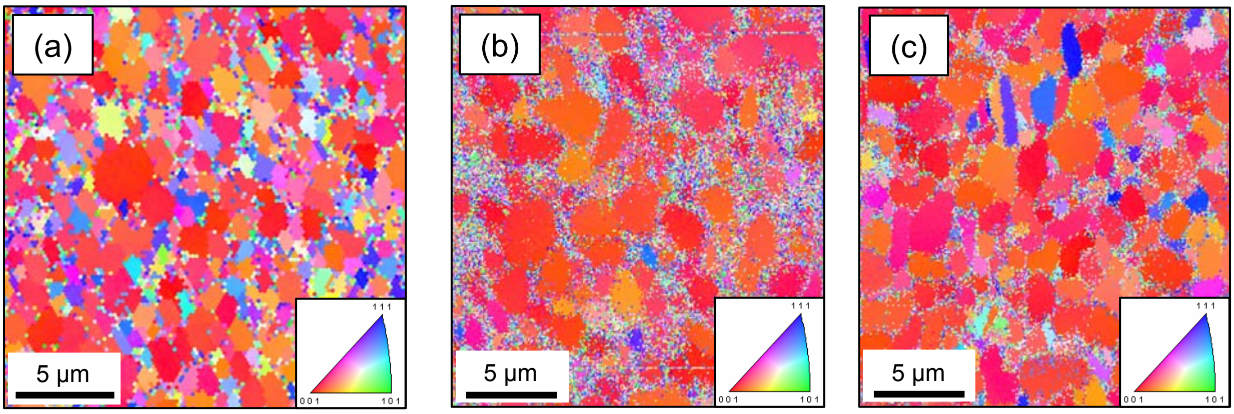

Fig 6. EBSP mappings. (a) a conventional spot shape with a zigzag scanning, (b) an elongated spot shape with a zigzag scanning, (c) an elongated spot shape with a raster scanning.

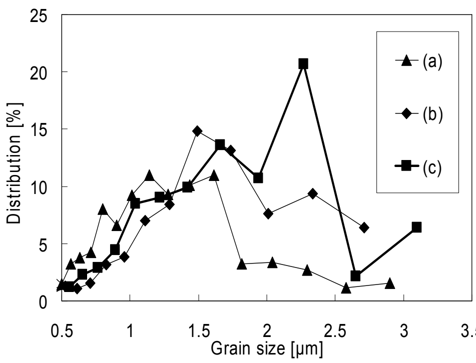

Fig 7. Grain size distributions calculated from EBSP mappings.
(a) a conventional spot shape with a zigzag scanning,
(b) an elongated spot shape with a zigzag scanning,
(c) an elongated spot shape with a raster scanning.

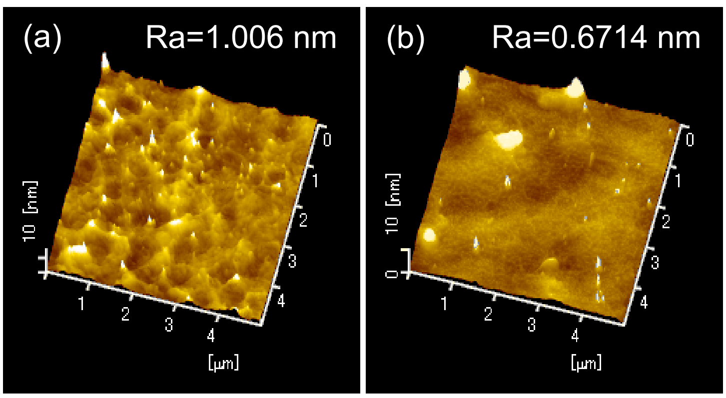

Fig 8. AFM images of recrystallized thin Si films.
(a) a conventional spot shape with a zigzag scanning,
(b) an elongated spot shape to a scanning direction with a raster scanning.