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Selective Laser Annealing Technology for LTPS Thin Film Transistors Fabrications

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Abstract

Selective laser annealing system was developed to realize fabrications of low-temperature poly-Si (LTPS) thin film transistors (TFTs) even for large substrate, while the conventional excimer laser annealing system has the limitation in substrate size due to the difficulty in obtaining uniform beam line. The selective annealing has an additional important advantage that periodic grain structures can be practically introduced by optimizing the exposure method, which can suppress variation of the electrical properties TFTs.

1. Introduction

Low temperature poly-Si (LTPS) thin-film transistors (TFTs) fabricated using the excimer laser annealing (ELA) [1] is an important technology for fabricating flat panel displays such as active matrix liquid crystal displays as well as active matrix organic light-emitting diodes, owing to the merits against amorphous Si (α-Si) TFTs and the oxide semiconductor TFTs. The merits include higher mobility, ability to fabricate complementary metal–oxide–semiconductor (CMOS), and better stability. However, the applications of ELA to large substrate are a challenging issue, because of the difficulty in obtaining uniform long line beam. The substrate size for LTPS TFT production is commonly Gen. 6 (1.5 m × 1.85 m), while α-Si TFTs are widely produced using Gen.10 substrate (2.85 m × 3.05 m). To apply ELA to the large substrate, a new selective laser annealing (SLA) technology was proposed by V-technology [2], and applied to the LTPS TFT fabrications using Gen.10 substrate [3]. In the SLA, multiple beams can be generated to apply the SLA only to multiple TFT regions simultaneously. The SLA system also has a potential to precisely control grain structure, because scan pitch as well as the spatial distribution of laser fluence can be controlled with a distance scale comparable to a lateral grain growth distance of a few micron without degrading the productivity. Here, the grain growth control by the scan exposure with distance shorter than the single-pulse lateral solidification distance was previously proposed [5]. In this paper, results of grain structure control and the TFT results are presented.

2. Experimental

Figs. 1(a) –1(c) show a schematic view of laser exposure methods in SLA. KrF laser with a beam spot of 60 × 60 μm^2 was used. We performed three types of the laser exposure such as (a) the static exposure, (b) the scan exposure, and (c) the static exposure intentionally introducing the periodic distribution in the laser fluence using dot array mask pattern and a reduction lens (hereafter denoted as "dot mask exposure").

Fig. 2 shows a cross-sectional view of the top-gated LTPS TFT fabricated in this paper. Detailed process flow was described elsewhere [4]. A length (L) and a width (W) of the TFT channel were 20 and 30 μm, respectively.

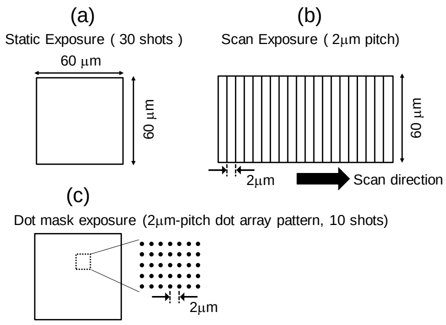

Fig. 1 Schematic view of laser exposure methods in SLA.

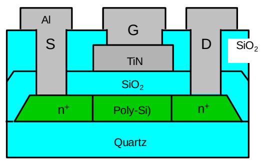

Fig. 2 Cross-sectional view of the top-gated LTPS TFT fabricated in this paper.

3. Results and discussions

Figs. 3(a)–3(c) shows the scanning electron microscope (SEM) images of the defect-etched SLA-treated 150-nm thick Si surfaces in the cases that E_L = 500, 600 and 700 mJ/cm^2 for the static exposure. Both the entire region and the edge regions of the annealed area were shown in each fluence. The grain size increased dramatically as E_L increased. At the same time, however, spatial variation of grain size become serious. It is noticeable that the periodic grain structure was observed at the edge region [suggested by arrows in Fig. 3], where the lateral grain growth might occur from the solid α-Si at the exposure edge toward the central region of the exposure.

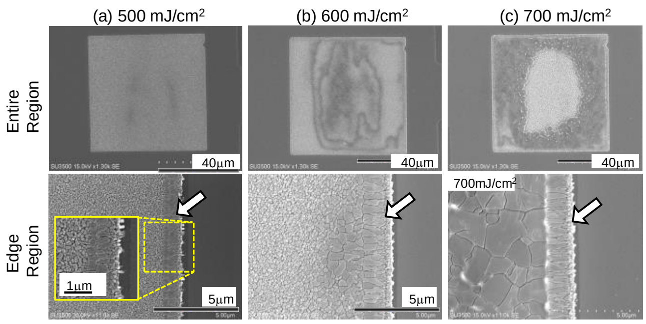

Fig. 3 SEM images of the defect-etched SLA-treated Si sur-faces in the cases that E_L = 500, 600 and 700 mJ/cm^2 for the static exposure.

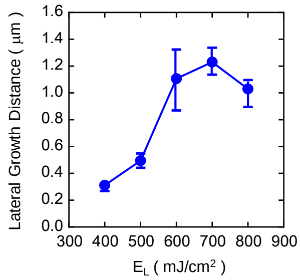

Fig. 4 Lateral growth distance as a function of the fluence E_L.

Fig. 4 shows the lateral growth distance as a function of the fluence E_L evaluated from the SEM images shown in Fig. 3. It was found that the lateral growth distance saturated at approximately 1 μm at around E_L = 500 mJ/cm^2 or more. This suggested that periodic grain structure can be obtained by introducing spatial pattern with characteristic distance comparable to the lateral growth distance. In order to do this, scan exposure with a 2 μm pitch and the dot mask exposure (2 μm pitch at the Si surface using the reduction projection lens) were introduced.

Figs. 5(a)–5(c) show the SEM images of the defect-etched SLA-treated Si surface for (a) the static exposure (b) the scan exposure, and (c) the dot mask exposure. In the case of the static exposure without mask pattern, significant variation of grain size was observed. However, in the cases of the scan exposure as well as introducing the dot mask pattern, both introduced periodic structure could be obtained. Lateral solidification might occur at the exposure edge and dot region in the static exposure and the dot mask exposure, respectively.

Figs. 6(a)–6(c) show the transfer curves of the TFTs for (a) the static exposure (b) the scan exposure, and (c) the dot mask exposure. Results for eight TFTs were shown in each case. By introducing periodic structure, variation of the mobility, threshold voltage could be dramatically suppressed.

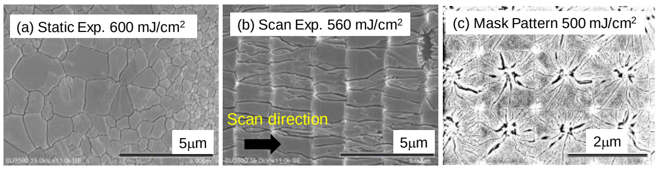

Fig. 5 SEM images of the defect-etched SLA-treated Si surface for (a) the static exposure (b) the scan exposure, and (c) the dot mask exposure.

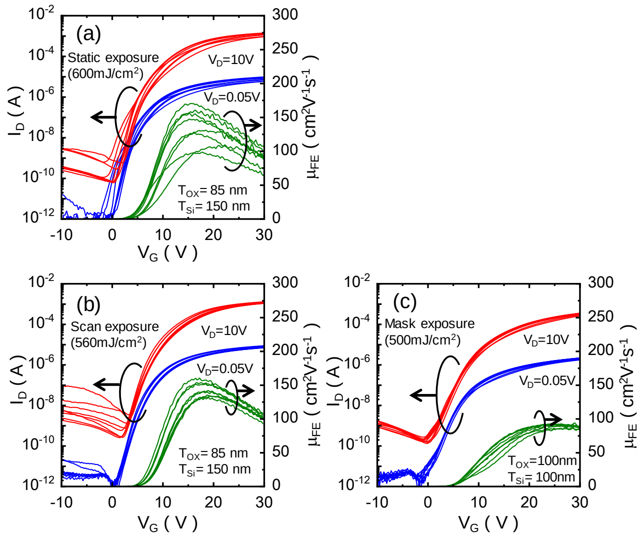

Fig. 6 transfer curves of the TFTs for (a) the static exposure (b) the scan exposure, and (c) the dot mask exposure.

3. Conclusions

SLA was developed to realize fabrications of LTPS TFTs even for large substrate such as Gen. 10 substrate. It was demonstrated that SLA is quite useful to precisely control the grain structure, by introducing the scan pitch and/or intentional periodic laser fluence pattern with a small characteristic distance (e.g., few micrometers) comparable to the lateral grain growth distance. This is essential to obtain the lateral-solidification-induced periodical grain structure. In this condition, variations of electrical properties of TFT could be reduced compared to the case of the static exposure. SLA will greatly contribute to further developing the flat panel display with high productivity.

Acknowledgements

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References

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