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The Characteristics of Single-pulse Excimer laser beam profile on the Low Temperature Poly-Si TFTs

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ABSTRACT

Laser crystallization has been the most promising technology to manufacture low temperature poly-silicon (LTPS) thin film transistors (TFTs), since LTPS technology can make LCD panels with integrated drivers. Higher mobility and lower leakage current than the solid-phase crystallization (SPC) counterparts can be obtained by laser crystallization. [1] Excimer laser emit in the UV region with a short pulse duration (10~30ns), and high temperature can be developed in the Si-surface region, causing melting, without appreciate heating (400℃) with the glass substrate. [2] Laser processes should provide uniform and stable laser beam profiles to obtain uniform distribution of electrical characteristics of TFTs.

In this study, the effects of laser beam profiles were investigated on the crystallization of poly-Si films. "One Pulse" laser crystallized poly-Si was analyzed by SEM and alpha-step to distinguish the effects of non-uniform laser beam profiles. Surface smoothness of poly-Si films with various laser-overlapping ratios was also measured to investigate the effects of laser beam profiles. Then the relationships of TFT characteristics and laser overlapping ratios will be discussed.

Keywords: Single-pulse excimer laser beam profile, Laser overlapping ratio

1. INTRODUCTION

We developed a methodology to investigate the effects of laser beam profiles on the crystallization of poly-silicon. By the analysis of "one pulse" laser crystallized poly-silicon films, the laser overlapping ratios can be related to the film qualities of poly-Si. Especially for the high energy densities at the two edges of a single-pulse laser beam, a high laser-overlapping ratio should be employed to manufacture high performance TFTs.

2. EXPERIMENTS AND RESULTS

Excimer laser beam passes through a homogenizer and irradiates on the glass substrate. In general, the optical module converts the laser beam from a quasi-gaussian intensity profile to a spatially uniform "top hat" profile with a beam uniformity of about less than $\pm 5\%$. In order to obtain uniform characteristics of TFTs, the laser beam profiles should be analyzed. Therefore, we set up a measuring system to monitor the beam profile, and discussed the effects on the crystallization of poly-Si. The dehydrogenated a-Si films were irradiated by excimer laser (253 mJ/cm2, beam size = $60.0 \times 1.73 mm^2$) with various overlapping ratios. The repetition rate of laser used in this study is 150 Hz.

2.1. The Characteristics of Single-pulse Excimer Laser Beam Profile

Figure 1 shows the laser beam profile of excimer laser system used in this study. The uniformity of top-hat is $\pm 7\%$, and FWHM is 1.73 mm. Before the amorphization occurring, the grain size of laser crystallized poly-Si increases as the increasing laser energy densities.

Figure 2 shows SEM image of single-pulse excimer laser crystallized poly-silicon. **Figure 3** shows the SEM photograph of the square region in figure 2 in a larger size. Very large grains and micro-crystalline grains can be seen in this region. As shown in this figure, 2~3 μm grains and micro-crystalline grains are due to the effects of super-lateral growth

(SLG) phenomena and amorphization phenomena, respectively. So it is hard to control the qualities of laser crystallized poly-silicon films by the non-uniform laser beam profiles, especially at the two edges of laser beam.

Figure 4 shows the surface topography of single-pulse excimer laser crystallized poly-Si film, which is measured by alpha-step. The RMS (root-mean square) surface roughness of SLG region and amorphization region are about 200Å and 30Å, respectively. In figure 4, the laser beam profile can correspond with the SEM photograph in the figure 2.

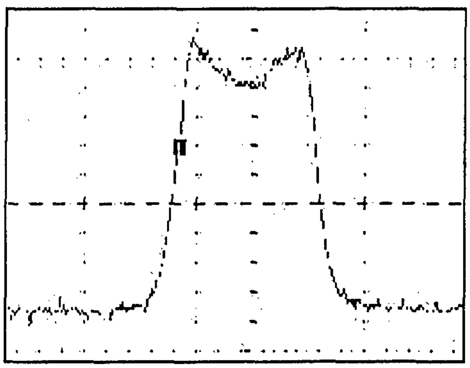

Figure 1 The laser beam profile of excimer laser system used in this study. The uniformity of top-hat is ±7%, and FWHM is 1.73 mm.

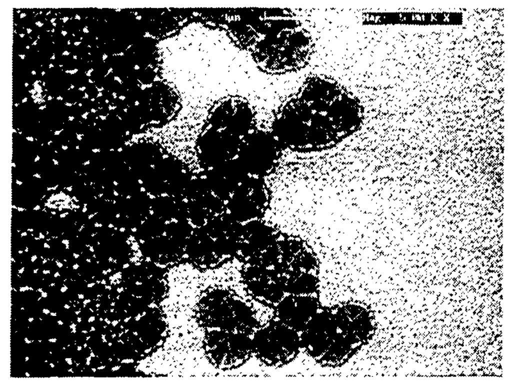

Figure 3 The SEM photograph of the square region in figure 2 in a larger size.

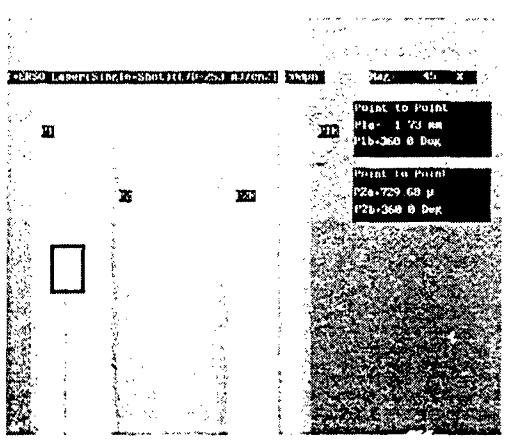

Figure 2 The SEM photograph of single-pulse excimer laser crystallized poly-silicon.

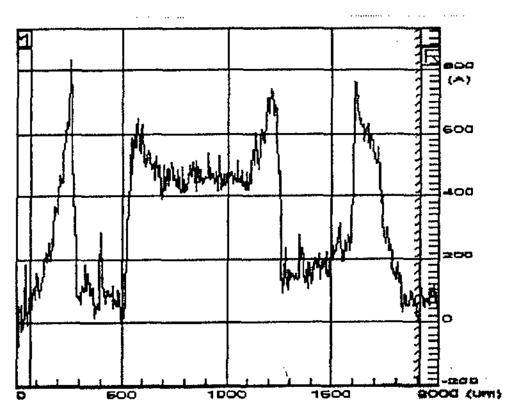

Figure 4 The surface topography of single pulse excimer laser crystallized poly-Si film.

2.2. SEM photographs of poly-Si film with various laser-overlapping ratios

Figure 5~Figure 7 show SEM photographs of the laser crystallized poly-Si film with various laser-overlapping ratios of 75%, 90%, and 99%. The overlapping ratio means the percentage of the overlapping distance between one laser pulse and its next pulse along the direction of the laser beam scanning.

From the observations of SEM photographs, the SLG and amorphization regions will not disappear until the overlapping ratio is higher than 90%. If the dehydrogenated a-Si films are irradiated by a higher energy density, which is at the two edges of the laser beam, the SLG and amorphization phenomena will occur. This is the reason why the overlapping ratio of laser scanning should be larger than 90% for the manufacturing of uniform laser crystallized film.

2.3. Alpha-step Analysis of excimer laser crystallized poly-Si film

Figure 8 shows the surface topography of the poly-Si films when the overlapping ratio is 75%. There are 4 peaks with-in the distance of 1600 μm due to the higher energy densities at the edges of the laser beam. The 4 peaks are caused due to the SLG and amorphization regions when the overlapping ratio is 75%.

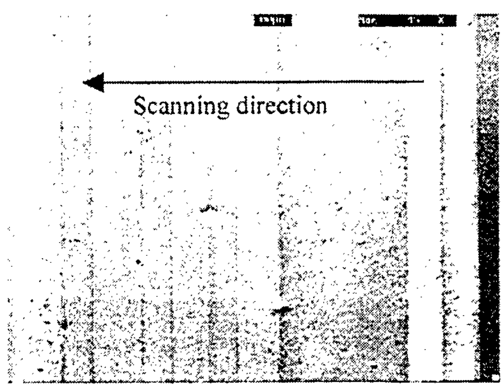

Figure 5 The SEM photograph of the laser crystallized poly-Si film with 75% laser overlapping ratio.

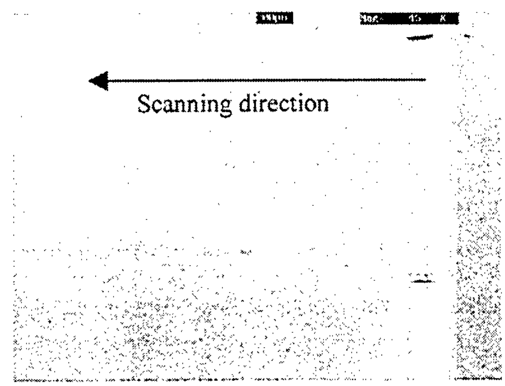

Figure 7 The SEM photograph of the laser crystallized poly-Si film with 99% laser overlapping ratio.

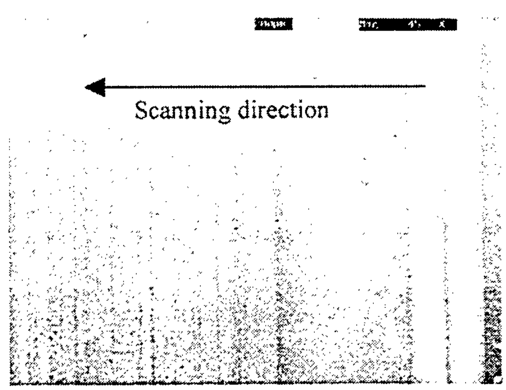

Figure 6 The SEM photograph of the laser crystallized poly-Si film with 90% laser overlapping ratio.

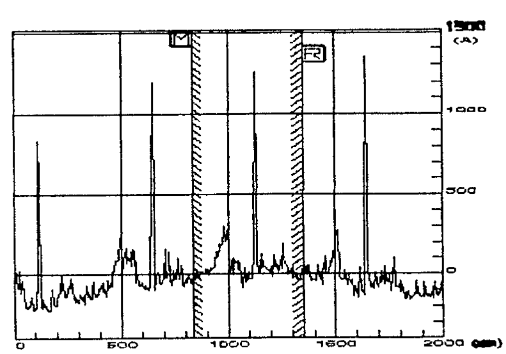

Figure 8 The surface topography of the poly-Si films when the overlapping ratio is 75%.

2.4. TFT Characteristics with various laser overlapping ratios

Figure 9 shows the typical Id-Vg curves (Vd=0.1volt, 10volt) of our n-type single-gate TFT (W/L=50/20um) with various laser overlapping ratios (96%~99%). **Table 1** shows the relationships of the mobility (μ), the threshold voltage (Vth), the sub-threshold swing (SS), and the minimum leakage current (Imin, Vd=10V) with laser overlapping ratios. It is obvious that the characteristics of TFTs with higher overlapping ratios are better.

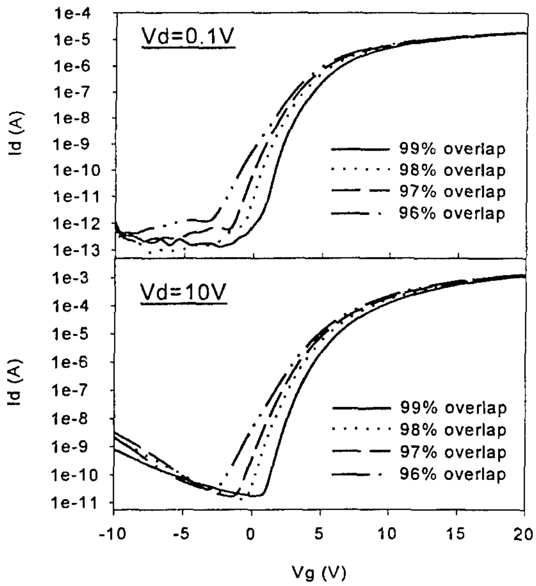

Figure 9 The typical Id-Vg curves (Vd=0.1 and 10 volt) of n-type single-gate TFT (W/L = 50/20um) with various laser overlapping ratios (96%~99%).

overlap	μ (cm2/Vs)	Vth (Volt)	SS (V/dec.)	Imin (pA)
99%	156	3.78	0.64	17.4
98%	148	3.06	0.73	13.7
97%	148	2.65	0.82	16.3
96%	148	2.20	1.11	30.2

Table 1 The TFT characteristics with various laser-overlapping ratios.

CONCLUSION

In this study, we investigated the effects of laser beam profiles on the crystallization of poly-Si films. "One Pulse" laser crystallized poly-Si was analyzed by SEM and alpha-step to distinguish the effects of non-uniform laser beam profiles. Surface smoothness of poly-Si films with various laser-overlapping ratios was also measured to investigate the effects of laser beam profiles. By the analysis of "one pulse" laser crystallized poly-silicon films, the laser overlapping ratios can be related to the film qualities of poly-Si. It is obvious that the characteristics of TFTs with higher overlapping ratios are better for the relationships of the mobility (μ), the threshold voltage (Vth), the sub-threshold swing (SS), and the minimum leakage current (Imin, Vd=10V). It is very important to prevent from the highest energy density area of the single-pulse laser shot to emit to amorphous-Si film. Therefore, it is useful to overcome this problem with higher overlapping ratios. Especially for the high energy densities at the two edges of a single-pulse laser beam, a high laser-overlapping ratio should be employed to manufacture high performance TFTs.

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