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Parametric Study for Excimer Laser-induced Crystallization in the a-Si thin film

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Abstract

Integrating the driver circuitry directly onto the glass substrate would be one of the advantages of polycrystalline Si (poly-Si) TFT-(LCD). Low-temperature poly-Si TFT(LTPS) is well-suited for higher-definition display applications due to its intrinsically superior electrical characteristics. In order to improve LTPS electrical characteristics, currently the excimer laser-induced crystallization (ELC) processes and sequential lateral solidification method were developed. Grain size of the poly-Si is mainly affected by beam pitch and energy density. Key parameter for making a larger poly-Si using excimer laser annealing(ELA) and increasing a throughput is due to increase in beam pitch and energy density to a certain degree. Furthermore, thin SiO_2 *capping is effective to suppress the protrusion of the poly-Si thin films and to reduce the interface state density. From the ELA process, we are able to control grain size by varying different parameters such as number of shots and energy density.*

1. Introduction

Recently manufacturers have made efforts to make a polycrystalline Si:H(poly-Si:H) using a-Si:H to integrate circuitry display devices on glass.[1-3] The a-Si is normally transformed into polycrystalline silicon(poly-Si) by thermal annealing at around 600□. In order to use glass substrate, all thermal steps in the TFT process must remain below the strain temperature of the glass substrate. It is, therefore, important to decrease the crystallization temperature and crystallization time.

We have focused our study on the large grain type poly-Si using an excimer laser to know its effect on grain size with the variation in number of shots and beam pitches.[4]

Despite considerable effort towards imprvement in laser crystallization process, Excimer Laser-induced Crystallization(ELC) is still considered as a "bottleneck" of the LT poly-Si TFT process .[5-7] To increase the throughput and improve the surface roughness, capping oxide was introduced on top of the a-Si thin film and studied by parametric method focused on varying energy density and pitch of beam shots.

In this paper, we have introduced capping oxide on the top of a-Si thin film and the study about crystallization of amorphous silicon with capping oxide on top of a-Si layer by XeCl Excimer laser irradiation method.

2. Experimental

Low Temperature polysilicon(LTPS) process is crystallized by 308nm XeCl excimer laser irradiation as shown sequence in figure 1.

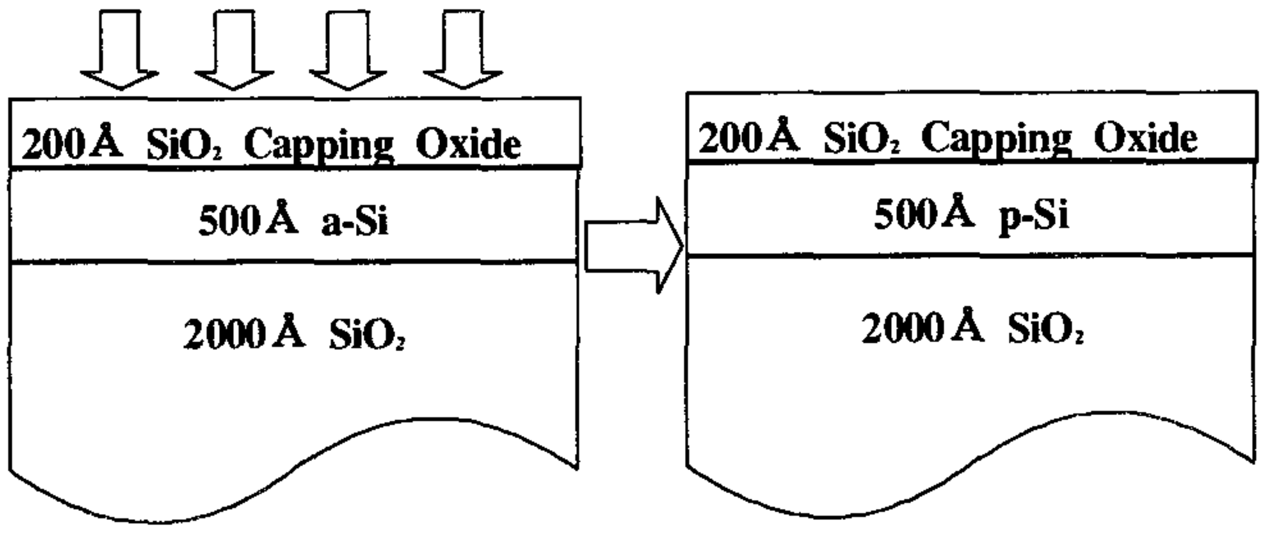

Figure 1. Excimer Laser Irradiation procedure

Capping Oxide on the a-Si layer is used as an anti-reflection coating and heat sink and reservoir of a number of shots are critically induced to the substrate.

Using a 200□ thickness of oxide on top of a-Si (500□, PECVD), the excimer laser was irradiated on the a-Si with several conditions(Table 1). Firstly, different beam pitches of 20μm, 40μm, 60μm and 80μm, each pitch of 20shots, 10shots, 7shots and 5shots respectively were used. These samples were irradiated by the laser energy density ranging from 300mJ/cm^2 to 400 mJ/cm^2 in 30 mJ/cm^2 in steps.

Table 1 The grain size of the poly-Si with energy density and beam pitch

Substrate temperature	〈 400 □
Condition of the as-Deposited a-Si film	Low-H content PECVD
Pulse Width(FWHM)	~ 20μs
Capping Oxide Thickness	200 □
Wavelength	308nm(XeCl Gas)
Laser Energy	300~400mJ, 30mJ step
Pitch to Pitch of Shot	20μm40μm,60μm,80μm

The samples were irradiated at various energy densities and beam pitches between shot to shot as shown in figure.2.

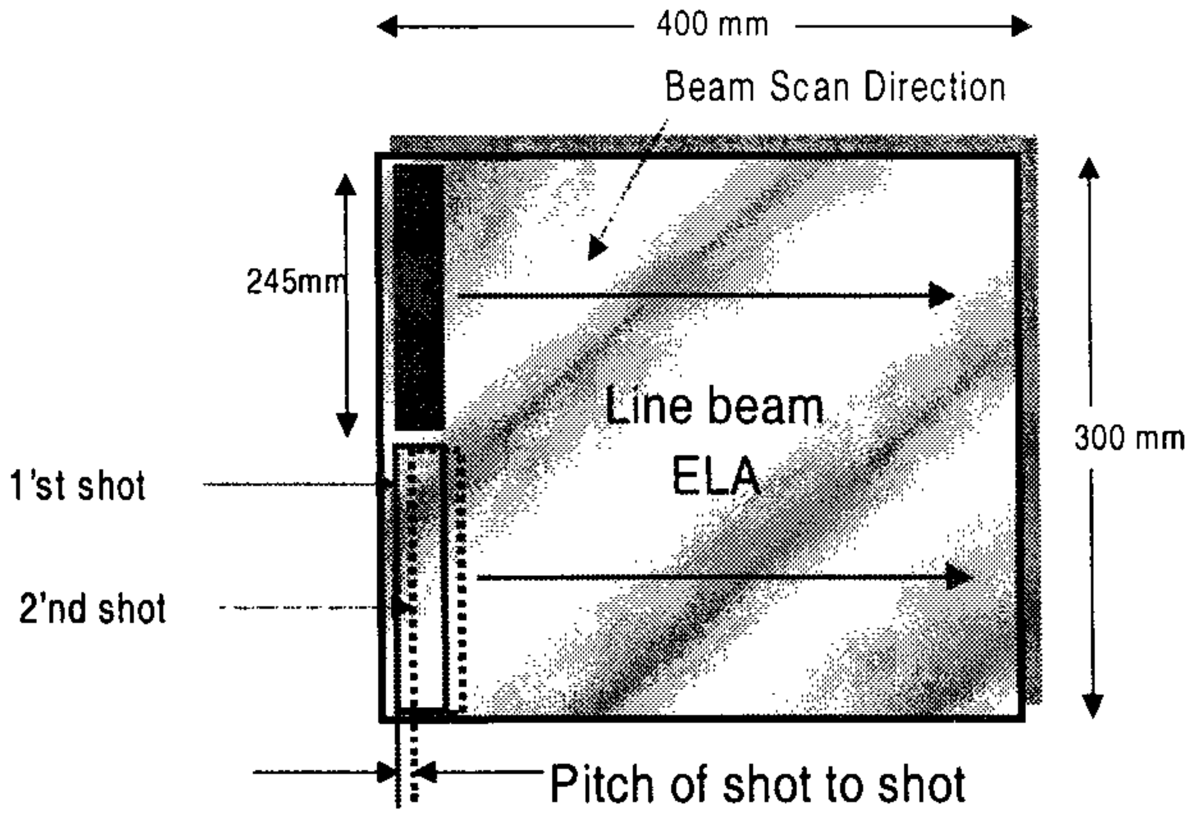

Figure 2. ELA process with 300 × 400 glass substrate

Multiple pulse irradiation process is implemented by XeCl Excimer Laser with different energy densities and pitches, from 300mJ to 400mJ and 20 micron pitch to 80 micron pitch. Each of the conditions has a capping oxide on the a-Si layer with 200□ thickness. The microstructure of irradiated films were analyzed using scanning electron microscope after the films were subjected to a defect etching process.

3. Results and discussion

Multiple pulse irradiation process was implemented with various energy densities and pitches. Figure 3-(a) shows the typical small-sized grain of poly-Si films that are obtained when the incident energy density corresponds to the required energy density to meet the melting energy.

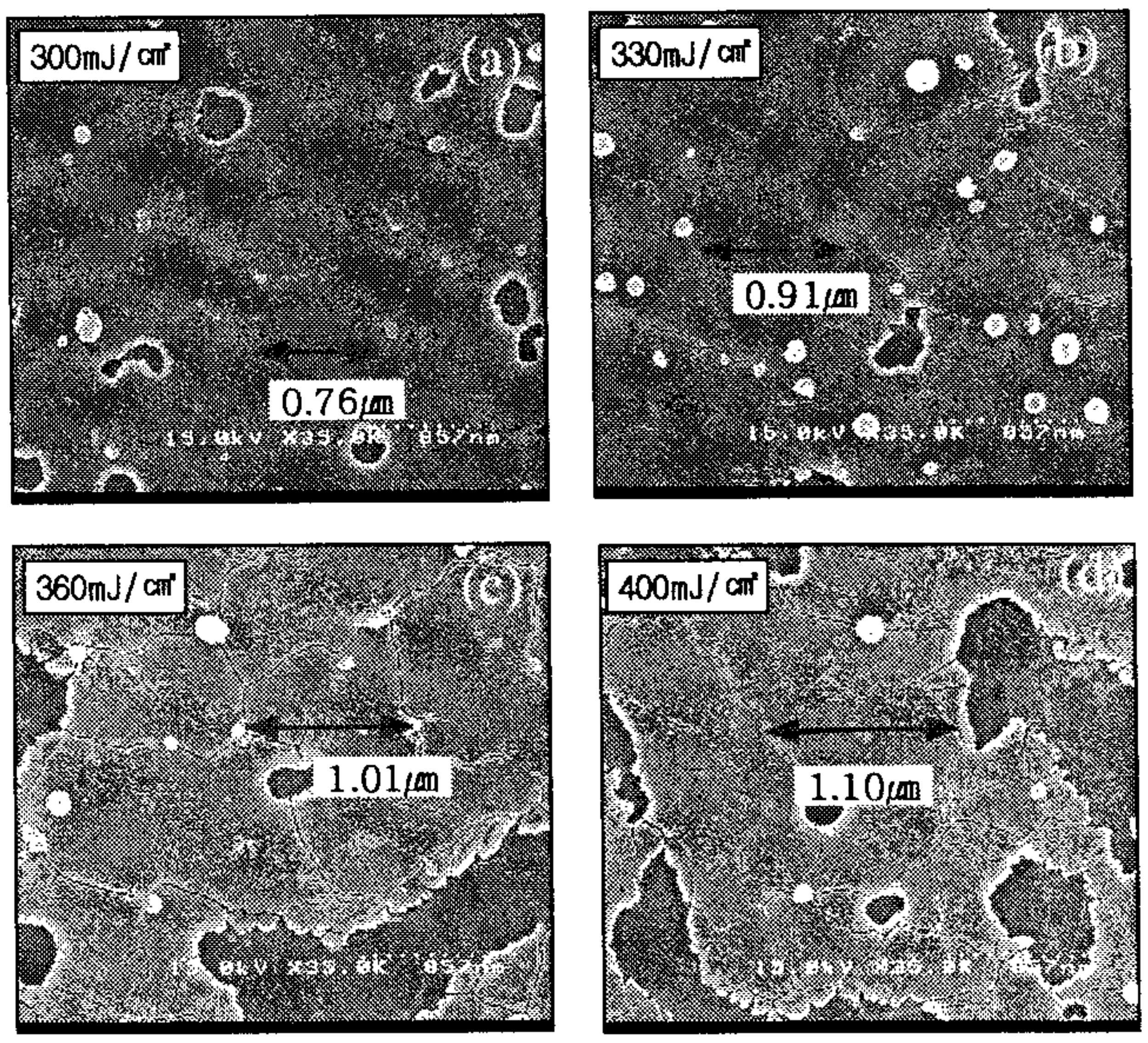

Figure 3. Planar-view SEM images of 20μm beam pitch multiple-pulse-laser-crystallized Si films at various energy densities 300~400mJ/cm^2 with 200□ Oxide thickness. (a) 300 mJ/cm^2 (b) 330 mJ/cm^2 (c) 360 mJ/cm^2 (d) 400 mJ/cm^2

Figure 3 shows the SEM images of excimer laser irradiated samples with 20μm beam pitch(It means 20 times shot on the surface). With the increase of Laser energy density, the grain becomes bigger. It is easy to expect that higher energy gives higher molten region.

In figure 4, we have shown the change in excimer laser beam pitch from 20μm to 40μm, which shown the decrease in grain size at the same energy density compared to 20μm shown in figure 3-(a).

But the increasing trend of grain size is in proportion to energy density increase as shown in figure 3. The similar result was observed with 40μm of beam pitch;that is the grain size was increased when energy density is increased.

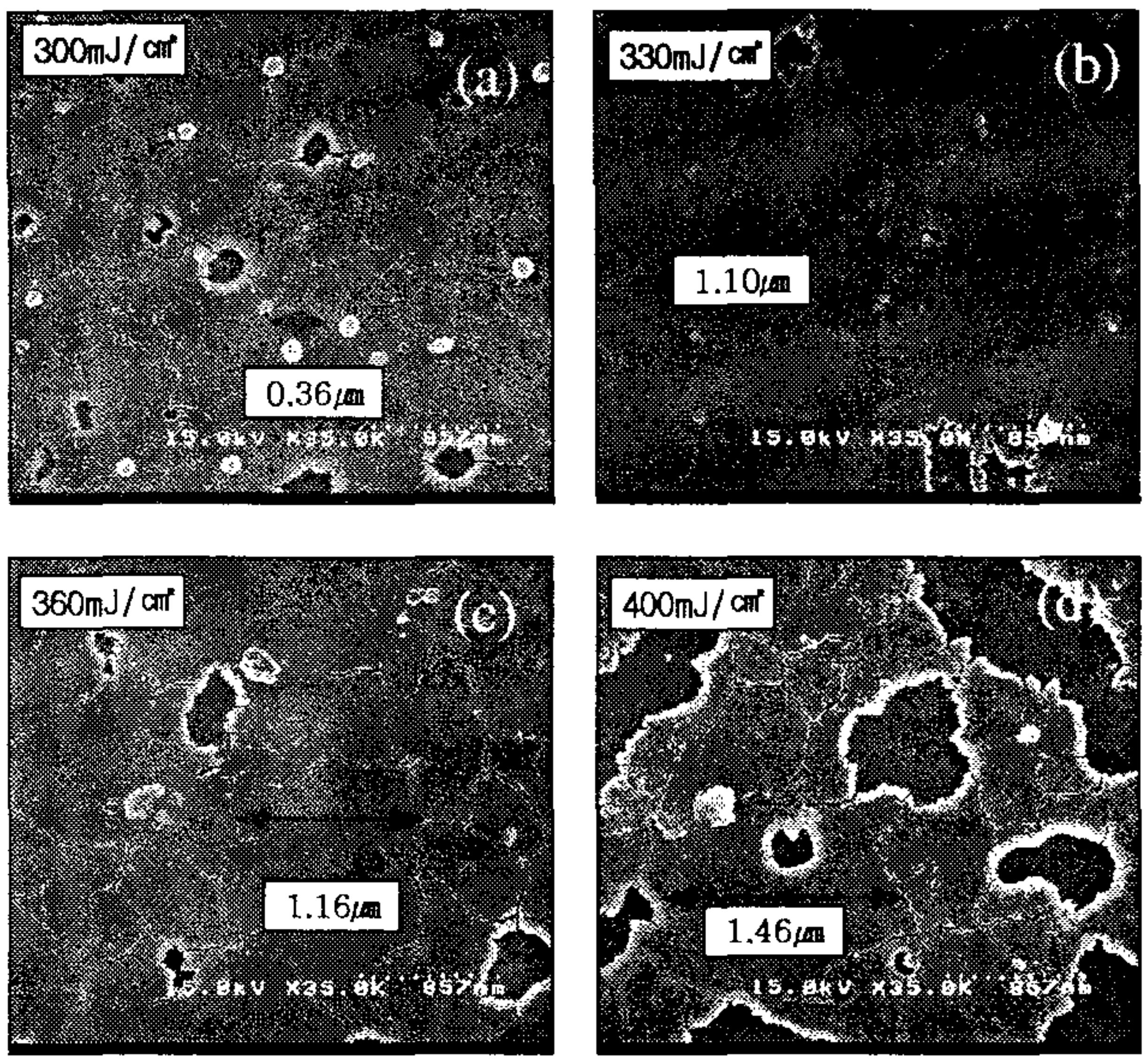

Figure 4. Planar-view SEM images of 40μm beam pitch. (a) 300 mJ/cm^2 (b) 330 mJ/cm^2 (c) 360 mJ/cm^2 (d) 400 mJ/cm^2

Figure 5 and 6 show the grains with irradiated beam pitch of 60μm and 80μm, respectively. As seen in figure 6, when the beam pitch reached 80μm, the a-Si layer was irradiated with nearly 5 shots. So grain size becomes smaller. With capping oxide much bigger grain can be observed than samples without capping oxide.[8-9] Capping layer acts as a surface stress suppressor and anti-reflection coating.

Also, Si film under the SiO_2 capping layer rises to a much higher temperature since it absorbs more of the incident energy and the thin capping layer of which the thickness is well within the characteristic thermal diffusion length and which initially acts as a heat sink during the heating period, eventually acts as a heat source during the conductive cooling period.[10-13]

The above mentioned results are summarized in figure 7, which shows the variation in grain size with energy density and pitch.

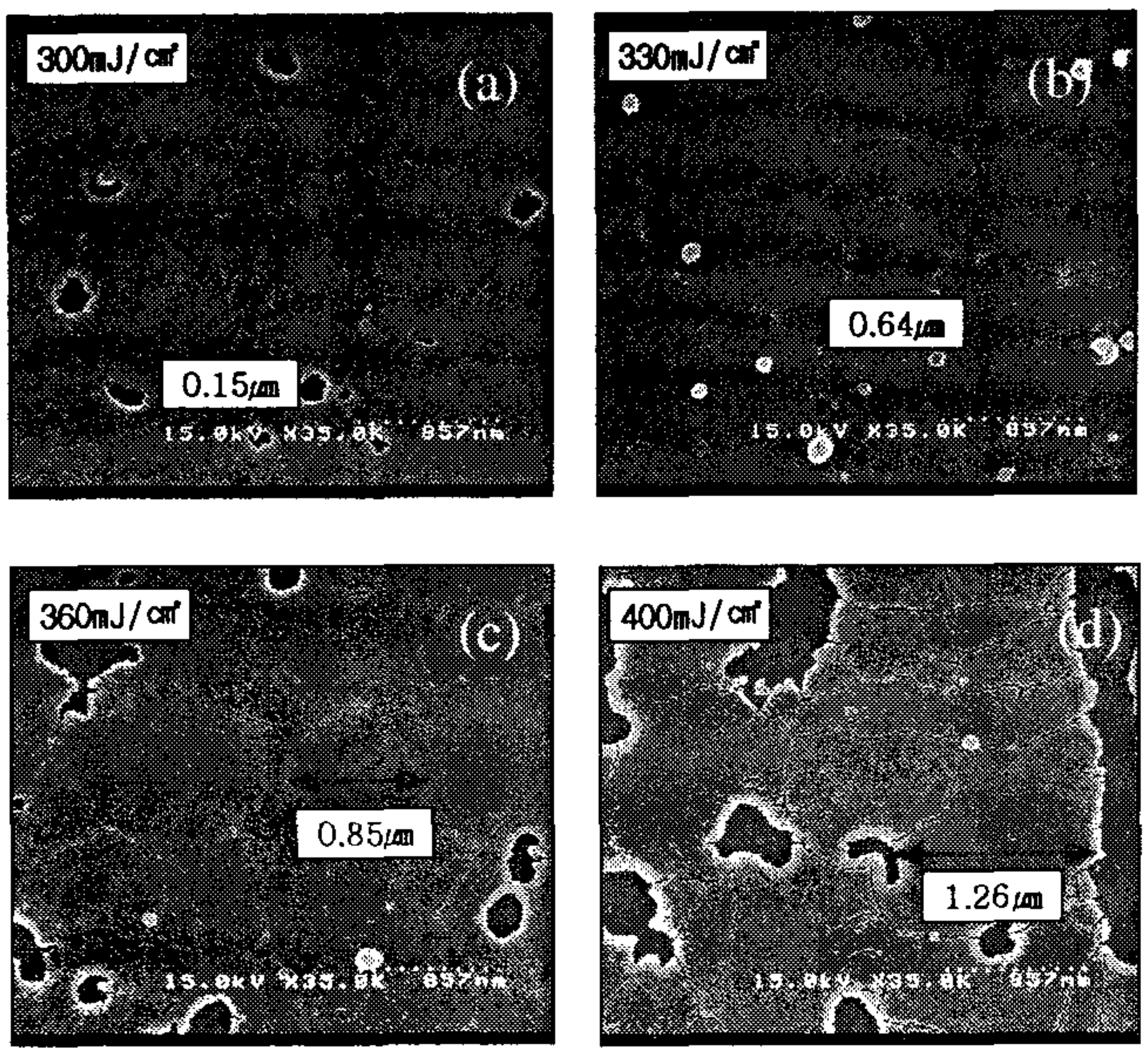

Figure 5. Planar-view SEM images of 60μm beam pitch. (a) 300 mJ/cm^2 (b) 330 mJ/cm^2 (c) 360 mJ/cm^2 (d) 400 mJ/cm^2

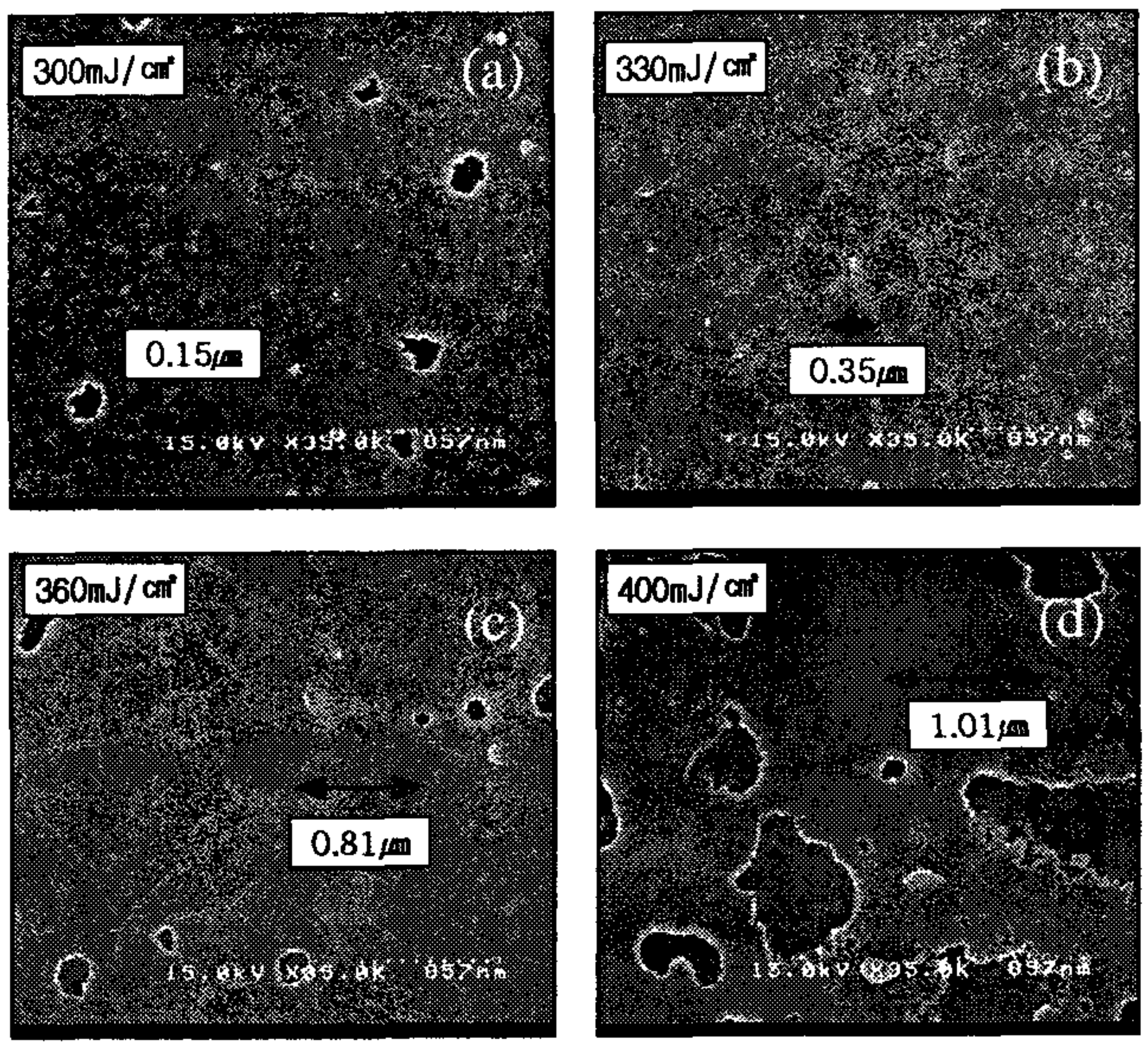

Figure 6. Planar-view SEM images of 80μm beam pitch. (a) 300 mJ/cm^2 (b) 330 mJ/cm^2 (c) 360 mJ/cm^2 (d) 400 mJ/cm^2

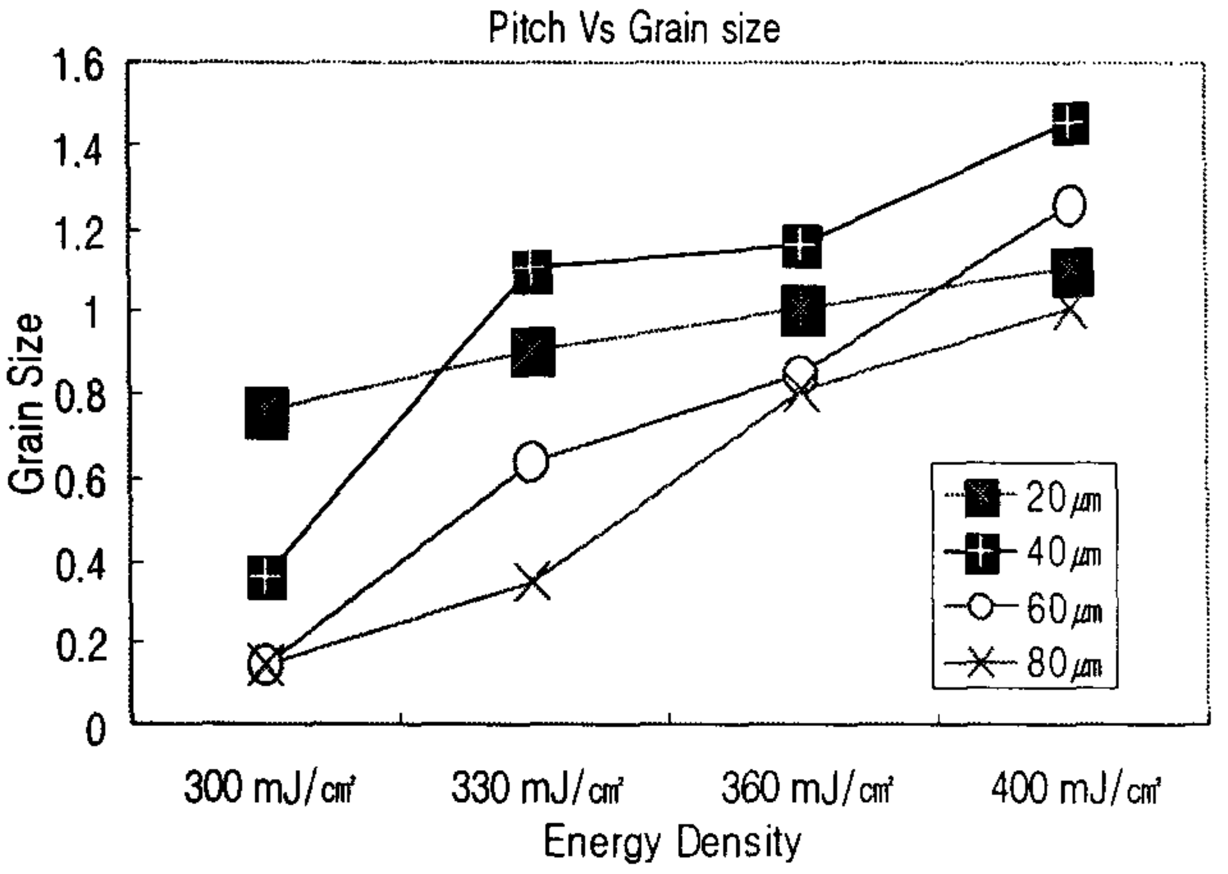

Figure 7. Increasing Trends of grain size versus energy density each pitches.

4. Conclusion

Using a Capping oxide, we got larger grain sized polycrystalline silicon in excimer laser crystallization. For this parametric study, beam pitch was of smaller overlap (i.e, number of shots was more strongly affected by grain size), a-Si received more energy and repeated poly silicon to liquid silicon melt and completed the crystallization cycle resulting much bigger grain size. The samples were irradiated with 20 shots for 20 micron beam pitch and only with 5 shots for 80 micron beam pitch. The grain size changed from 0.75μm to 1.10μm in 20 micron beam pitch, but the case of 80 micron, grain size changed from 0.15 micron to 1.01 micron. It shows that the trend of grain size versus energy density is same but if number of shots is increased and the energy density is kept low, then recrystallization is takes place even more times than that of 80 micron beam pitch. It gives the bigger grain size at 20 micron beam pitch low energy density.

So, If we choose higher beam pitch(80 micron) with the purpose of getting throughput faster and translation stage speed hight, we must select a higher energy density for large grain boundary.

Grain size of the poly-Si is mainly affected by beam pitch and energy density. Key parameters for making a larger poly-Si using ELA and increasing throughput are to increase beam pitch and energy density to a certain degree. Furthermore, thin SiO_2 capping is effective to suppress the protrusion of the poly-Si thin films and to reduce the interface state density. Thin capping oxide acts as a heat sink as well as heat reservoir. Also, the SiO_2 layer of certain thickness acts as anti-reflection coating.

Acknowledgement

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