Characteristics of Surface Roughness as a Film Thickness and Planarization of SLS Poly-Si Films

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Abstract

We report on a surface planarization process that produces more planar surface than previous sequential lateral solidification crystallized poly silicon films. By applying the single shot laser irradiation with optimum energy density (817mJ/cm²) on the ridge area after SLS crystallization, the ridge height can be decreased.

1. Introduction

The Sequential lateral solidification (SLS) process is based on the super-lateral growth (SLG) phenomenon [1, 2] and is expected to produce material capable of performance rivaling that of single-crystal silicon in the near future.[3]

In general, the device performance of poly-Si TFTs depends on the grain size, microstructure and orientation of super lateral growth. The TFT characteristics of devices fabricated on SLS-processed films with channels parallel to the grain boundaries have very superior performances.[4]

However, the surface roughness of the ridge shape is always found in the perpendicular direction of the lateral grain with the direction of solidification. The ridge can cause a large number of defect states in SLS crystallized poly-Si films and decrease the device performance of TFTs.

In this study, we report the characteristics of surface roughness as a film thickness and the ridge height control method by the specific excimer laser energy with new masking process.

2. Experimental

The amorphous-Si films of various thickness (500, 800, 1000, 1500 and 2000 Å-thick) were deposited on Si substrate with a 3000 Å thick SiO_2 buffer layer using a LPCVD process. The samples were crystallized using 308nm XeCl excimer laser with 25ns pulse duration at the complete melting energy density.

3. Results and discussion

Figure 1 shows the surface ridge height within SLS crystallized poly-Si films versus the film thickness, where it can bee seen that the ridge height increases linearly with increasing film thickness from 500 to 2000 Å-thick. The variations of surface ridge height is shown to increase with increasing film thickness.

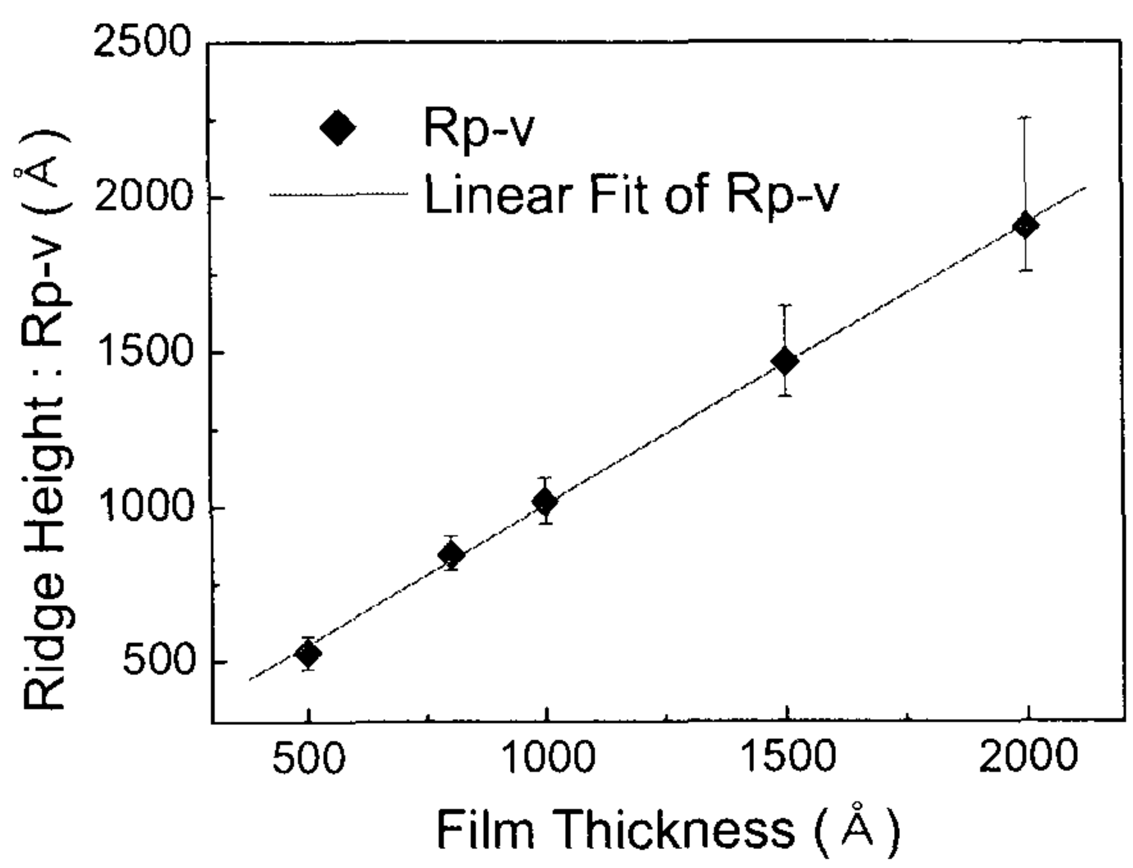
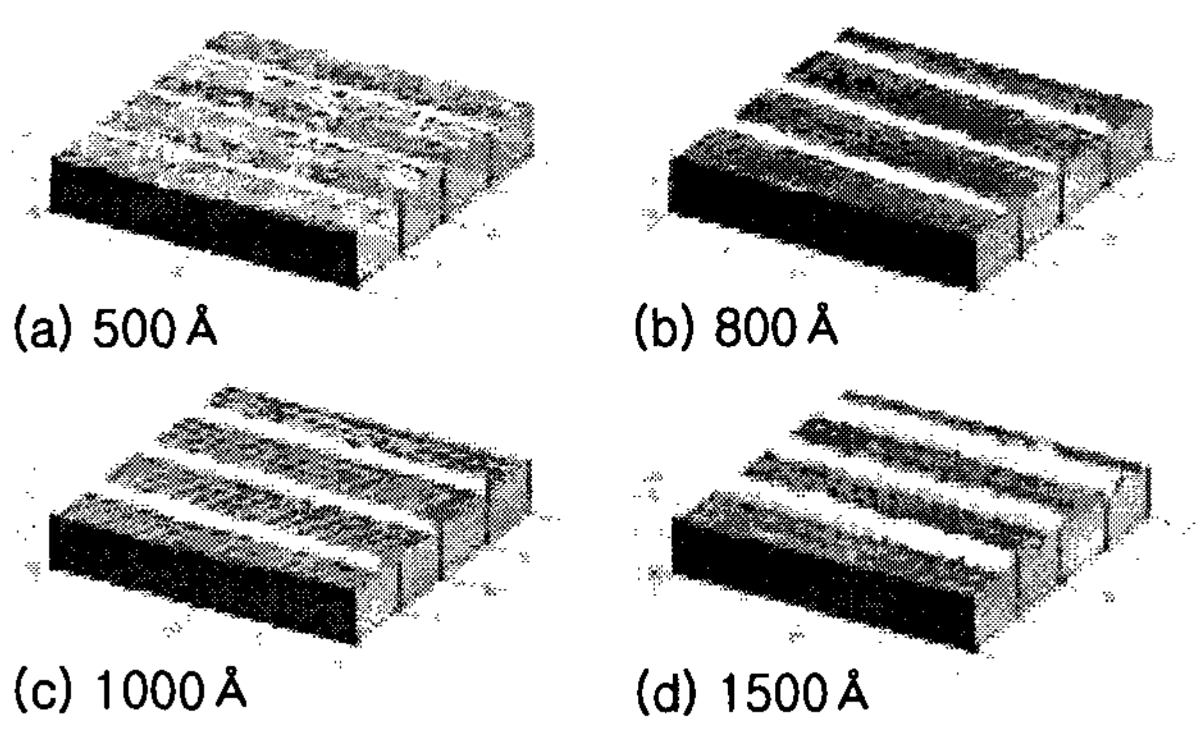
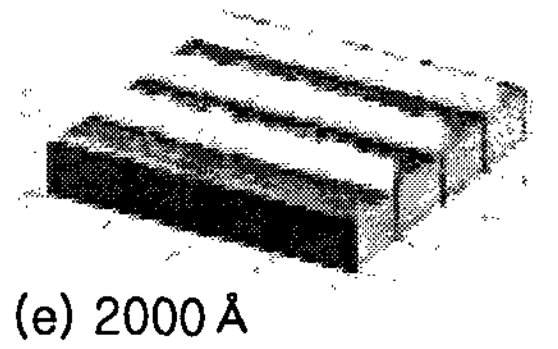


Figure 1. Variation of the ridge height as a function of silicon film thickness.

It is reported that the sub-grain boundary spacing depended approximately linearly on the film thickness [5]. The device performance of SLS crystallized poly-Si TFTs with more thick silicon film can be increased.

However, high surface roughness of SLS crystallized poly-Si films is due to more interface states formed between the poly-Si and gate insulator [6].





Film Thickness [Å]	Roughness RMS [Å]
500	80
800	128
1000	161
1500	239
2000	356

Figure 2. AFM images and RMS roughness of SLS crystallized poly-Si films at the film thickness (a) 500Å, (b) 800Å, (c) 1000Å, (d) 1500Å, and (e) 2000Å

Figure 2 shows the results of surface roughness difference with AFM images as a function of amorphous silicon film thickness. The RMS roughness is shown to increase with increasing film thickness. In Figure 1 and figure 2(e), an estimated above 2000Å surface ridge height was made of SLS crystallized poly-Si film.

The AFM image in Figure 3 (a) shows that multi-shot SLS crystallization process at 800Å-thick poly-Si film leads to forming of the ridge height above 1000Å-thick and RMS roughness of ~130Å.

Figure 4 shows the results of using a secondary laser irradiation process with AFM analysis as a function of laser energy density. It is possible to decrease the surface ridge height by applying the single shot laser irradiation with optimum energy density (817mJ/cm^2) on the ridge area after SLS crystallizations.

Figure 5 shows the AFM images of (a) original rough SLS poly-Si with a 800Å-thick, (b) surface ridge height controlled poly-Si with a planarization laser energy of 693mJ/㎠, (c) 776mJ/㎠, (d) 817mJ/㎠, (e) 858 mJ/㎠, and (f) 899 mJ/㎠, respectively.

Figure 6 shows the SEM images of microstructure resulting from single-pulse irradiation of 800Å-thick films irradiated at energy densities of (a) 693mJ/㎠, (b) 776mJ/㎠, (c) 817mJ/㎠, and (d) 899mJ/㎠, respectively.

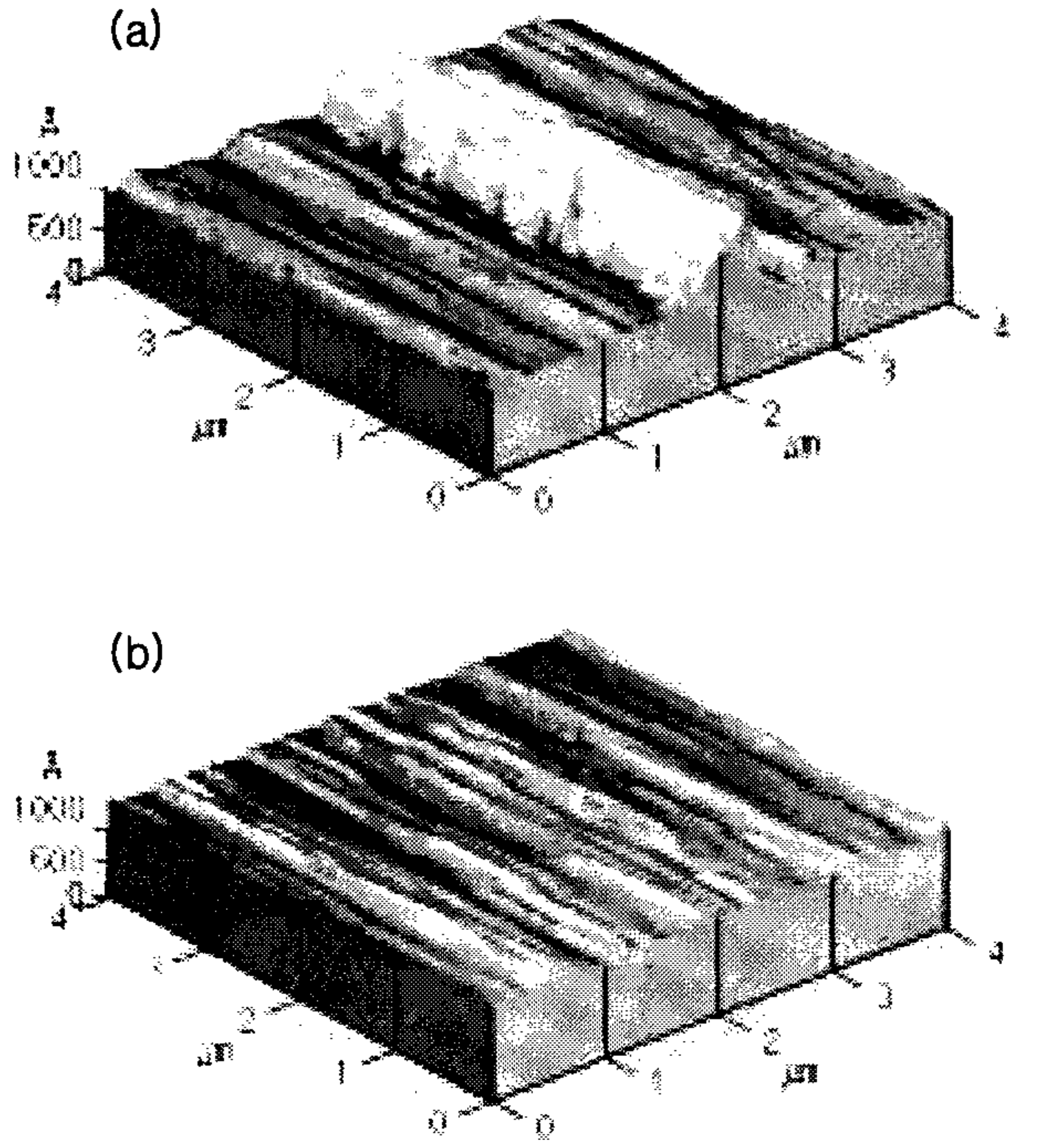


Figure 3. AFM images of 800Å-thick SLS crystallized polysilicon films. (a) 3D-image of ridge region with ridge height of ~1000Å and RMS roughness of ~130Å, (b) 3D-iamge of sub-boundary region with peak to valley roughness of ~230Å and RMS roughness of ~45Å.

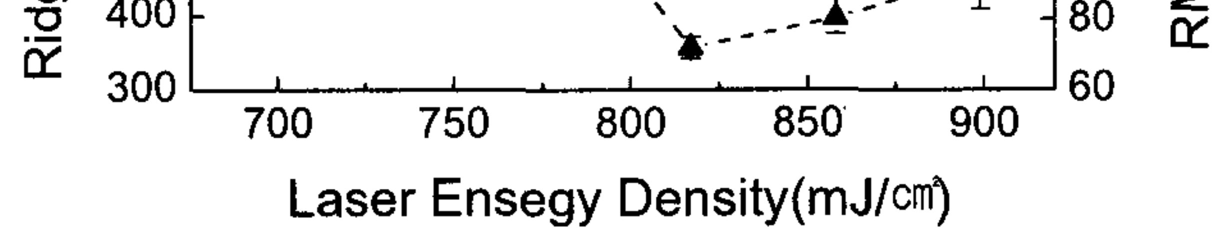


Figure 4. Ridge height and RMS roughness as a function of laser energy density for surface planarization process.

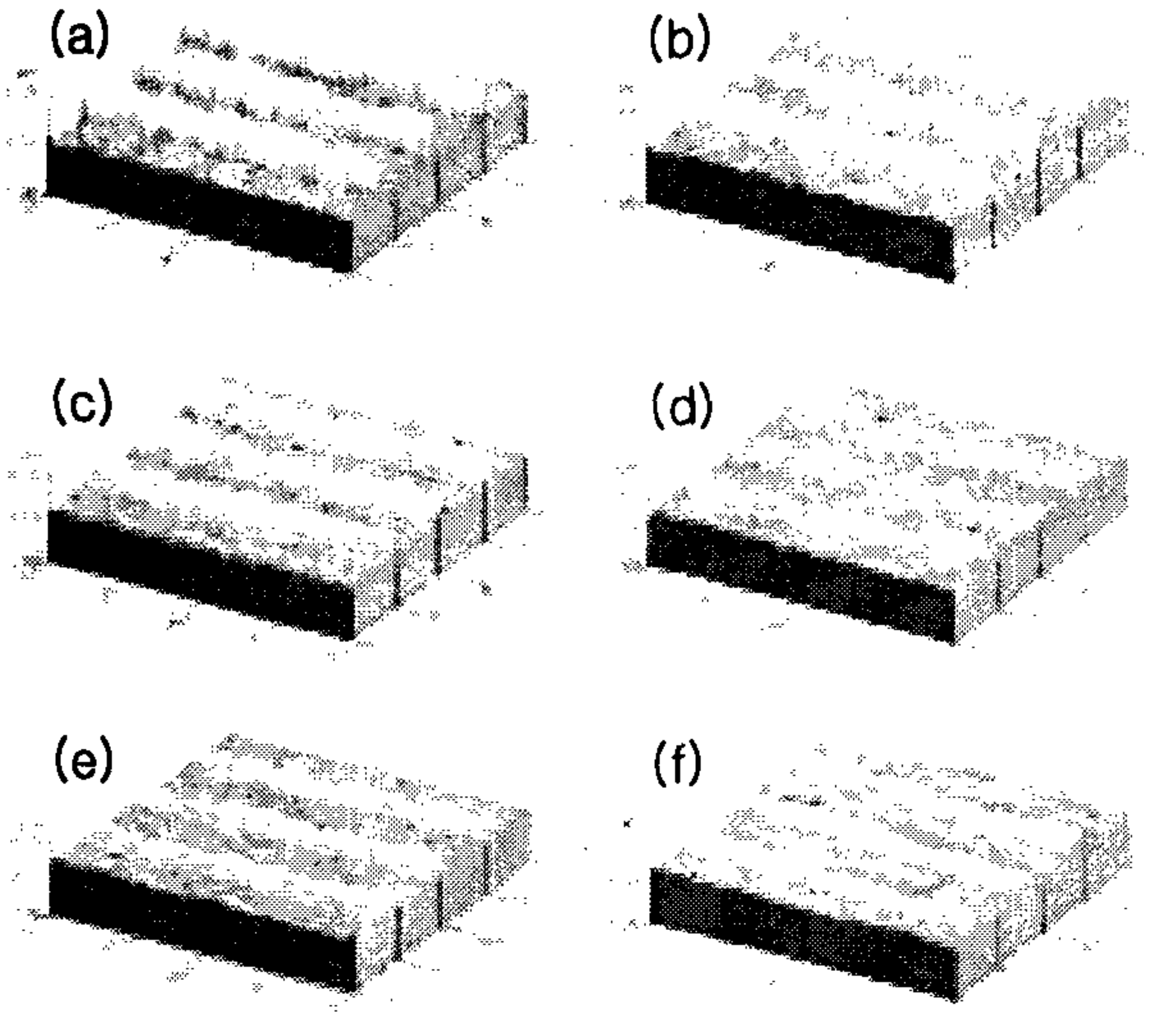


Figure 5. AFM images of (a) original rough SLS poly-Si with a 800Å-thick, (b) surface ridge height controlled poly-Si with a planarization laser energy of 693mJ/㎠, (c) 776 mJ/㎠, (d) 817 mJ/㎠, (e)858 mJ/㎠, and (f) 899 mJ/㎠.

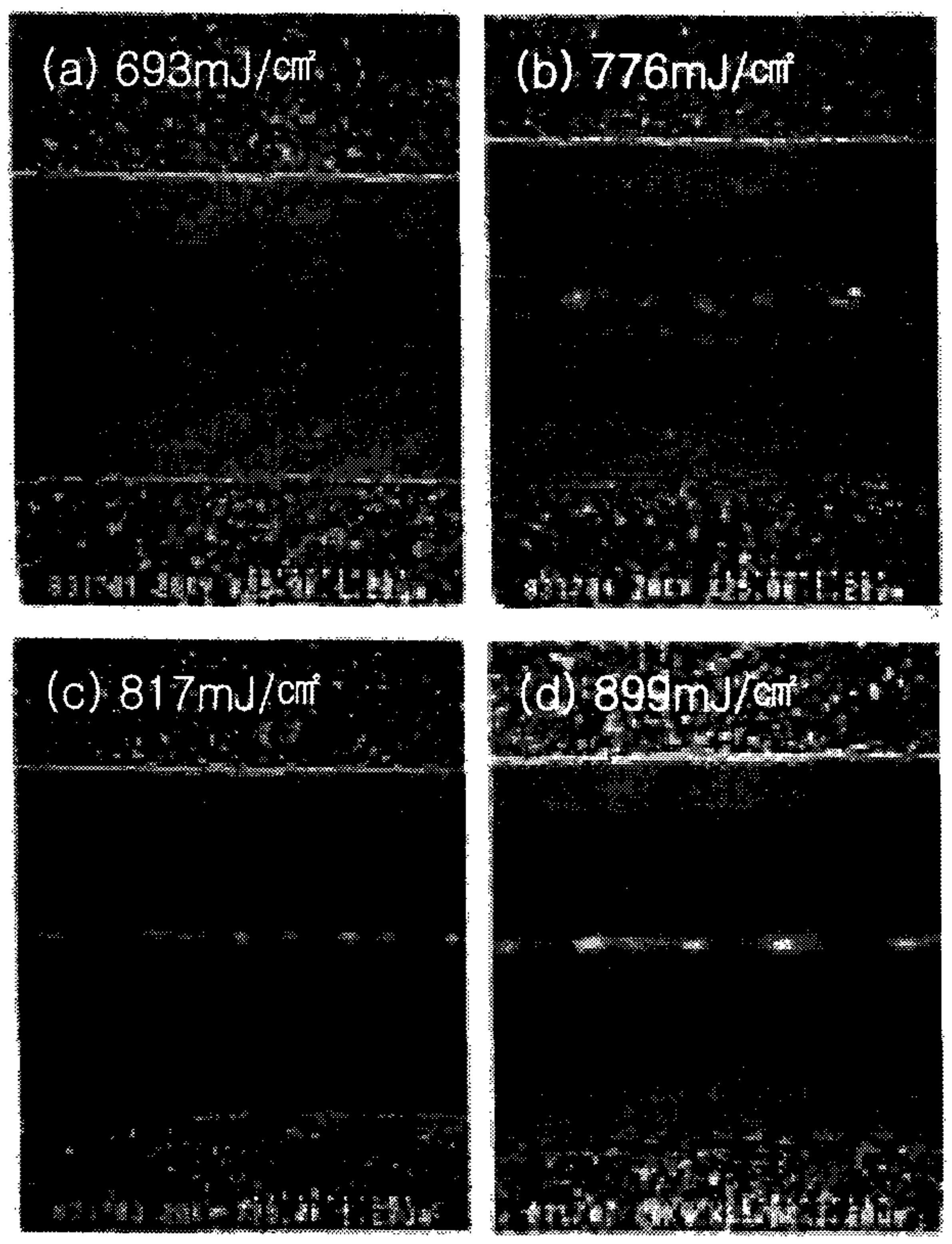


Figure 6. SEM images of microstructure resulting from single-pulse irradiation of 800Å-thick films irradiated at energy densities of (a) 693mJ/㎠, (b) 776mJ/㎠, (c) 817mJ/㎠, (d) 899mJ/㎠

In figure 6 from (a) 693mJ/㎠ to (b) 776mJ/㎠, shows the partial melting and solidification. The melting width of single-shot irradiation is shown to increase with increasing laser energy density until 776mJ/㎠.

In figure 6 (c) shows lateral grain growth initiated by a single pulse irradiation at 817mJ/cm^2. The ridge height of SLS poly-Si can be decreased in 817 mJ/cm^2 . In figure 6 (d), increases in fully melting width correspond with increases in surface ridge height.

4. Conclusion

We showed that the surface ridge height increases linearly with increasing silicon film thickness.

It is possible to decrease the surface ridge height by applying the single shot laser irradiation with optimum energy density (817mJ/cm^2) on the ridge area after SLS crystallizations.

The sequential lateral solidification crystallized poly silicon films that have more planar surface can be used to active materials of high-quality TFTs for P-Si TFT-LCD and AMOLED.

5. References

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