Transfer Characteristics of Poly-Si TFTs with Laser Energy Change

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Abstract

Transfer characteristics of poly-Si TFTs within process window of laser energy are investigated. In terms of surface morphology and transfer characteristics, process window of laser crystallization is evaluated. While maximum mobility exists in lower edge of process window in n-channel TFTs, maximum mobility exists in higher edge of process window in p-channel TFTs.

1. Introduction

In order to obtain high-quality low-temperature poly-Si (LTPS) films, several crystallization methods have been proposed. Among them, excimer laser crystallization (ELC) method has been widely used in mass production line. However this method has disadvantage of narrow process window. Using sequential lateral solidification (SLS) method, we can overcome this shortcoming of narrow process window. Compared with the ELC method, SLS method has wider process window (more than 200mJ/cm2) because it is performed in complete melting energy regime. The objective of our paper is to investigate transfer characteristics of poly-Si TFTs and surface morphology of crystallized Si for various crystallization energy within wide process window.

2. Experimental

Top-metal-gate structured poly-Si TFTs were fabricated on glass substrate with a $SiNx/SiO_2$(100nm/300nm) buffer layer, which serves to increase the grain size in the poly-Si film and to prevent impurity segregation from glass substrate. 55nm amorphous Si layer was deposited on the buffer layer by PECVD as the precursor to laser crystallization. With the use of XeCl excimer laser(λ =308nm) system, SLS process was performed, and then gate insulator of 100nm SiO_2 film was deposited. Before the crystallization, glass was dehydrogenated in furnace in order to remove excess hydrogen, which could lead to ablation upon crystallization. The 4 shot SLS process was performed with beam penetrating line width 2um and beam blocking line space 4um by 1.5um translation distance. In order to obtain transfer characteristics and surface morphology, laser crystallization was performed with different laser energy regime(224mJ/Pulse~600mJ/Pulse). After TFT fabrication, transfer characteristics of both n-channel and p-channel TFTs were measured at room temperature with Vds=0.1V and Vds=10V. Channel width(W)/channel length(L) was 8um/8um.

3. Results and discussion

Fig. 1 shows transfer characteristics of (a)n-channel TFTs(NTFTs) and (b)p-channel TFTs(PTFTs) for various laser energy. In both NTFT and PTFT, the positive Vth shift occurs as laser energy increases. Fig. 2 shows SEM photographs of secco-etched poly-Si surface showing grain morphology with different laser energy of Fig. 3. Each photograph shows 1 shot laser irradiation and 4 shot laser irradiation with different laser energy, respectively. At 224mJ/P laser energy, the grain morphology of both near complete melting regime and partial melting regime is shown, because laser energy is too low to induce lateral solidification. As laser energy increases to 276mJ/P, small super lateral grain (SLG) is formed. However, because the length of SLG also small, the grain growth by 2nd shot laser beam with 1.5um translation distance cannot occur in 1st shot SLG region, resulting in grain morphology showing partial SLG region. Around 326mJ/P laser energy, larger SLG is grown. However, because the length of SLS is not enough for grain by 2nd laser shot to grow with the seed of SLG by 1st laser shot, exclusive solidified region is shown in 4 shot SLS morphology. At 368mJ/P laser energy, grain morphology shows complete SLS morphology with SLG, because the grain by 2nd laser shot can grow with the seed of SLG by 1st laser shot. However, at 368mJ/P laser energy, transfer characteristics are not optimized due to the defect in grain(Fig. 3). In other words, the process window of TFT device is narrower than the process window of SLS surface morphology.

In NTFTs, maximum field-effect mobility exists in lower edge of process window. In general, it is reported that grain boundary trap density increases as grain boundary dangling bond density increases[1]. This increased grain boundary trap density also increases Vth[2], and Vgm[3], which means gate voltage at maximum field effect mobility. However, S factor, which is related with interface trap density between oxide and poly-Si[4], decreases slightly with laser energy.

On the other hand, in PTFTs, maximum field-effect mobility exists in higher edge of process window(Fig. 4). Because grain boundary trap density hardly influences on hole transport[5], the mobility in PTFTs increases as laser energy increases, mainly due to interface trap density between oxide and poly-Si.

Based on the Levinson's thermionic field conduction model[6, 7], grain boundary trap density is calculated from the slope of the ln(Id/Vg) vs. 1/Vg relation. Fig. 5 shows ln(Id/Vg) vs. 1/Vg relation with different laser energy. Within process window, grain boundary trap density increases as laser energy increases. So, in NTFTs, laser crystallization should be performed in lower edge of process window. Fig. 6 shows one-way analysis of variance(ANOVA) results of grain boundary trap density, which is calculated from the slope of the ln(Id/Vg) vs. 1/Vg relation. As laser energy increases, trap density significantly increases.

4. Conclusion

Compared with the ELC method, SLS method has the wider process window. In this work, we investigate transfer characteristics of poly-Si TFTs within wide process window. While maximum mobility exists in lower edge of process window in n-channel TFTs, maximum mobility exists in higher edge of process window in p-channel TFTs.

5. References

[1] H.-S. Kong, and C. Lee, J. Appl. Phys. 78(10)15(1995)6122-6131.

[2] S. Seki, O. Kogure, and B. Tsujiyama, IEEE Trans. Electron Devices, 35(5)(1998)669-674.

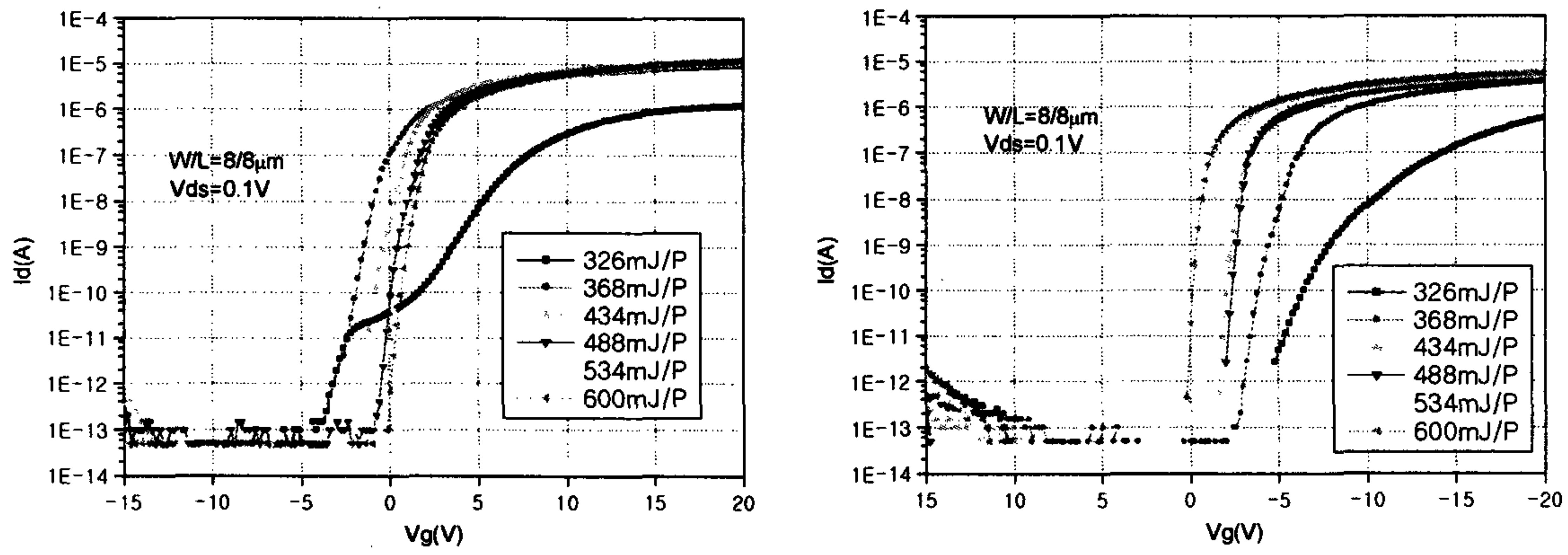
[3] K. Yamaguchi, J. Appl. Phys. 89(1)(2001)590-595.

[4] A. M. Marmorstein, A. T. Voutsas, and R. Solanki, Solid-State Electron. 43(1999)305-313.

[5] D.-H. Choi, S. Imai, and M. Matsumura, Jpn. J. Appl. Phys. 34(1995)459-463.

[6] J. Levinson, F. R. Shepherd, P. J. Scanlon, W. D. Westwood, G. Este, and M. Rider, J. Appl. Phys. 53(2)(1982)1193-1202.

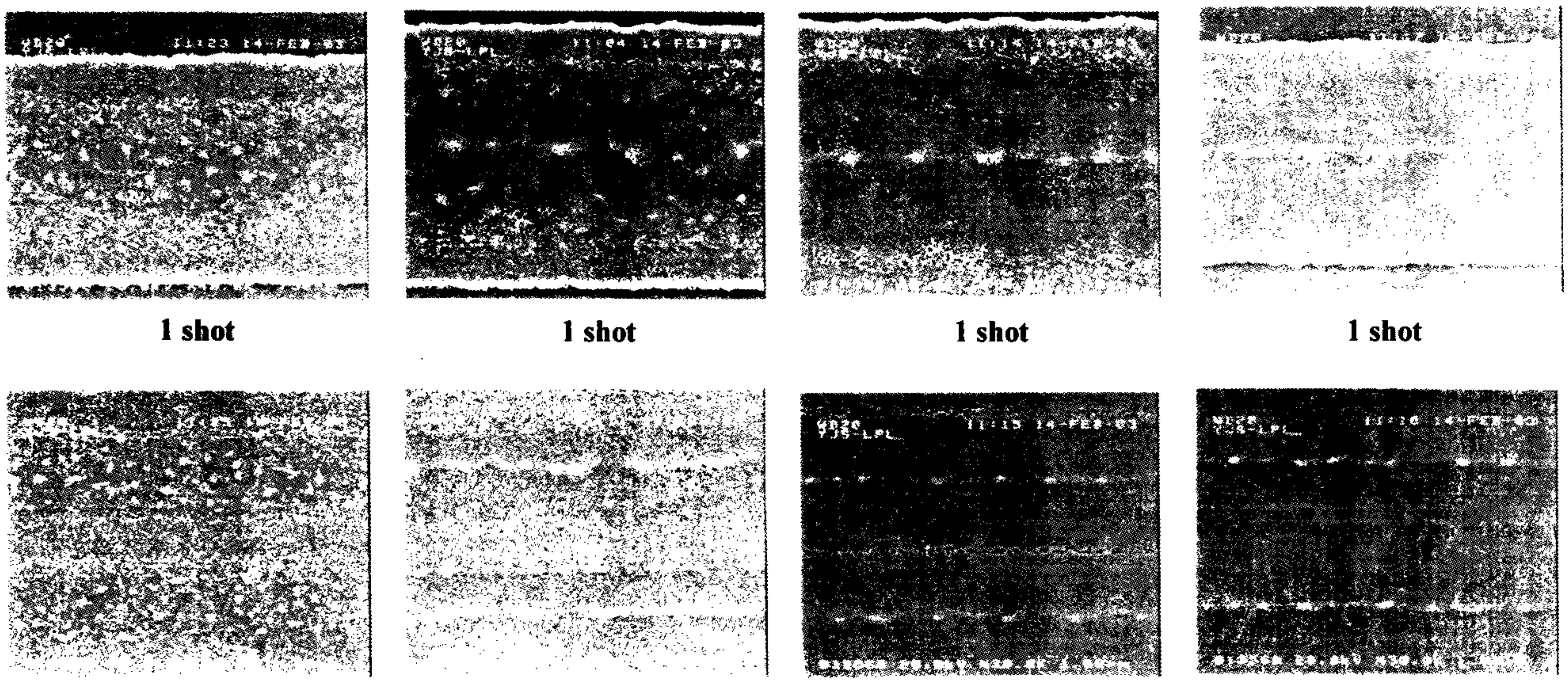
[7] K.-C. Moon, S. Yim, P. Choi, H.-K. Min, H.-G. Kim, AM-LCD 2000, 157-160.



(a) NTFTs

(b) PTFTs

Figure 1 Transfer characteristics of (a) NTFTs and (b) PTFTs with laser energy.



1 shot 1 shot 1 shot 1 shot

4 shot 4 shot 4 shot 4 shot

(a) 224mJ/P (b) 276mJ/P (c) 326mJ/P (d) 368mJ/P

Figure 2 SEM photographs of secco-etched poly-Si surface showing grain morphology.

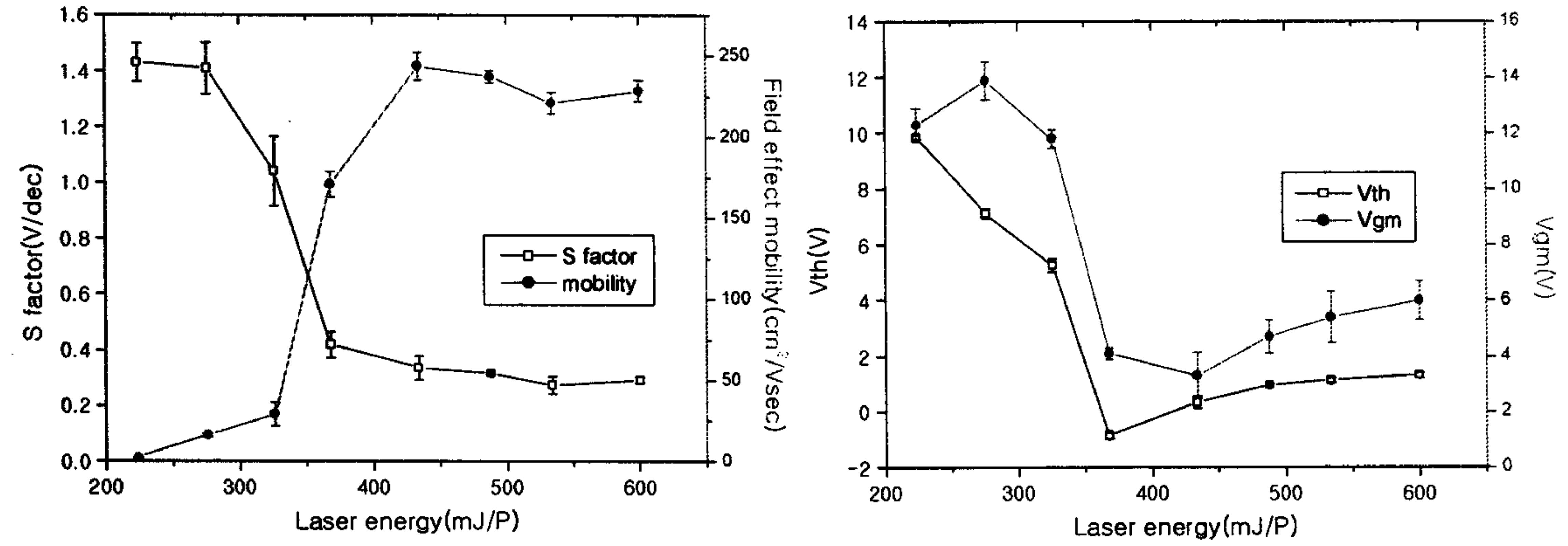


Figure 3 NTFT characteristics within process window with laser energy change.

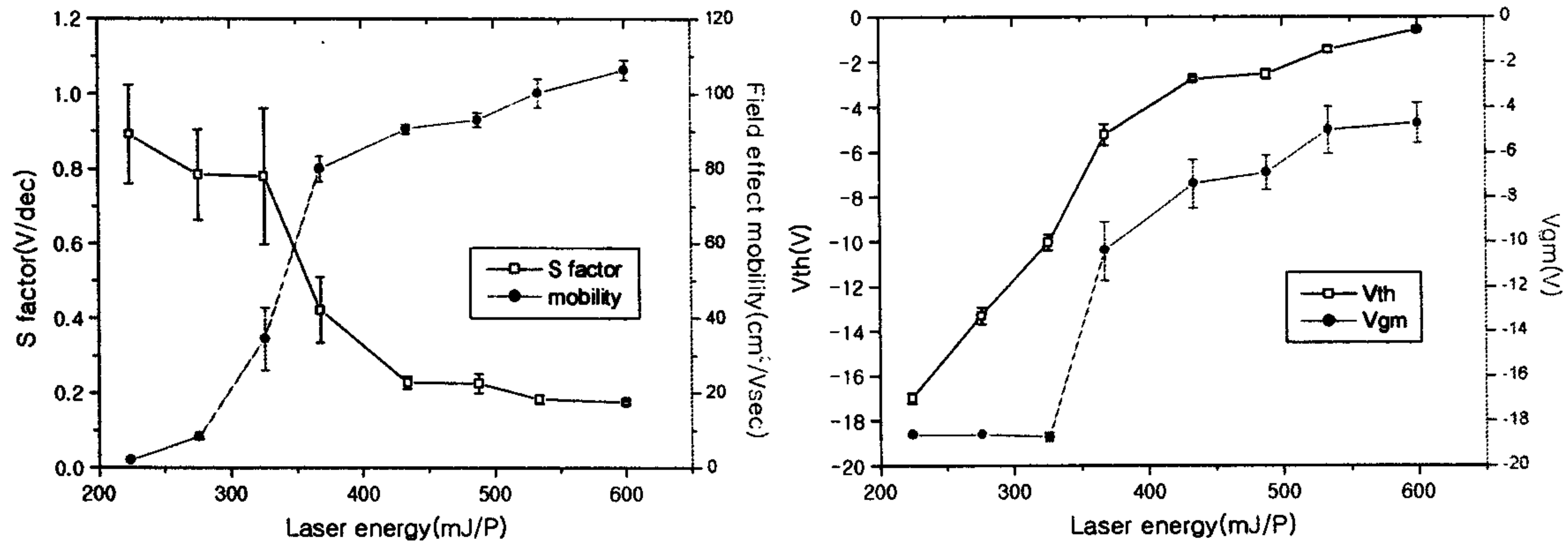


Figure 4 PTFT characteristics within process window with laser energy change.

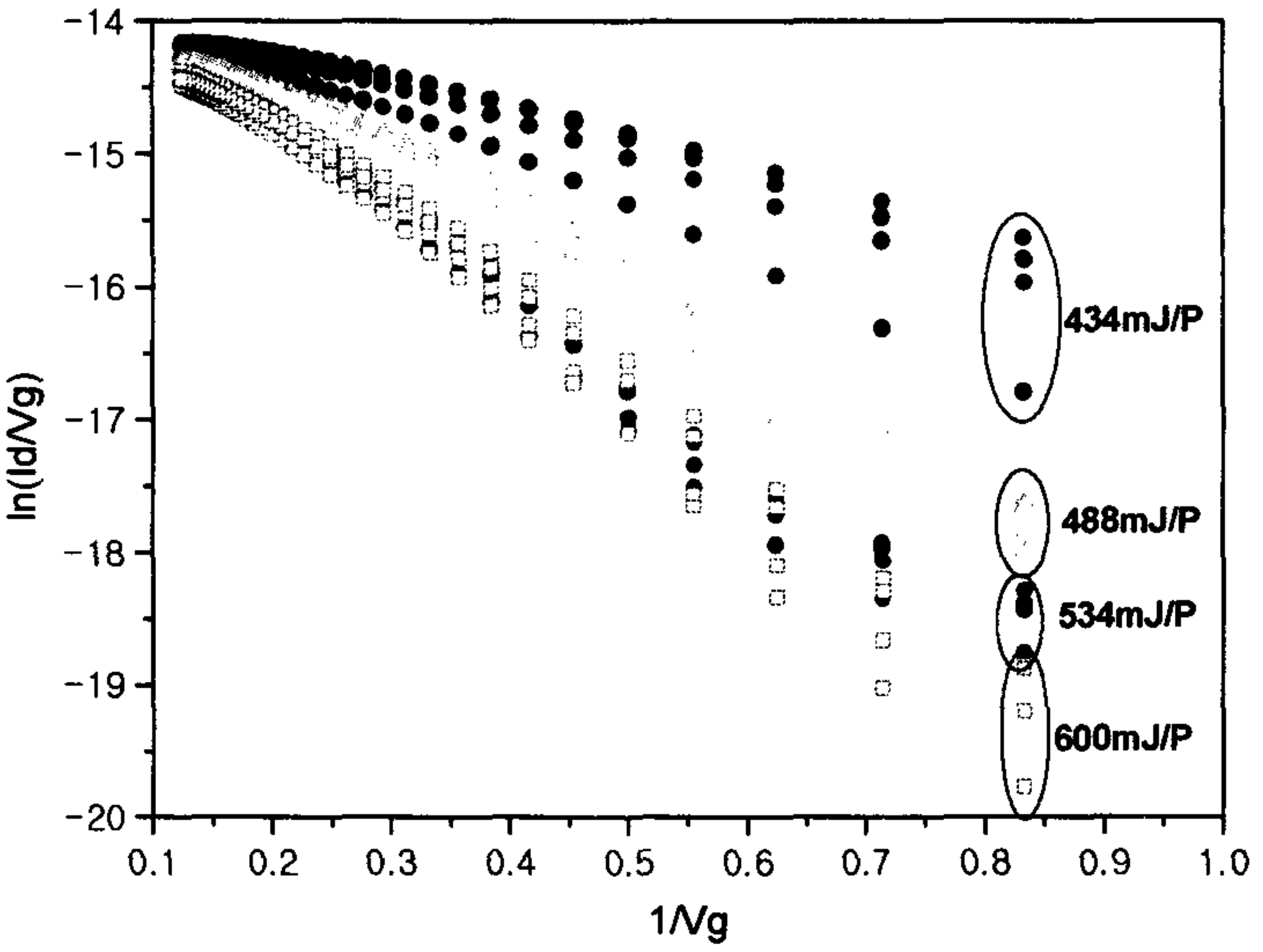


Figure 5 Plot of ln(Id/Vg) vs 1/Vg for NTFTs with different laser energy.

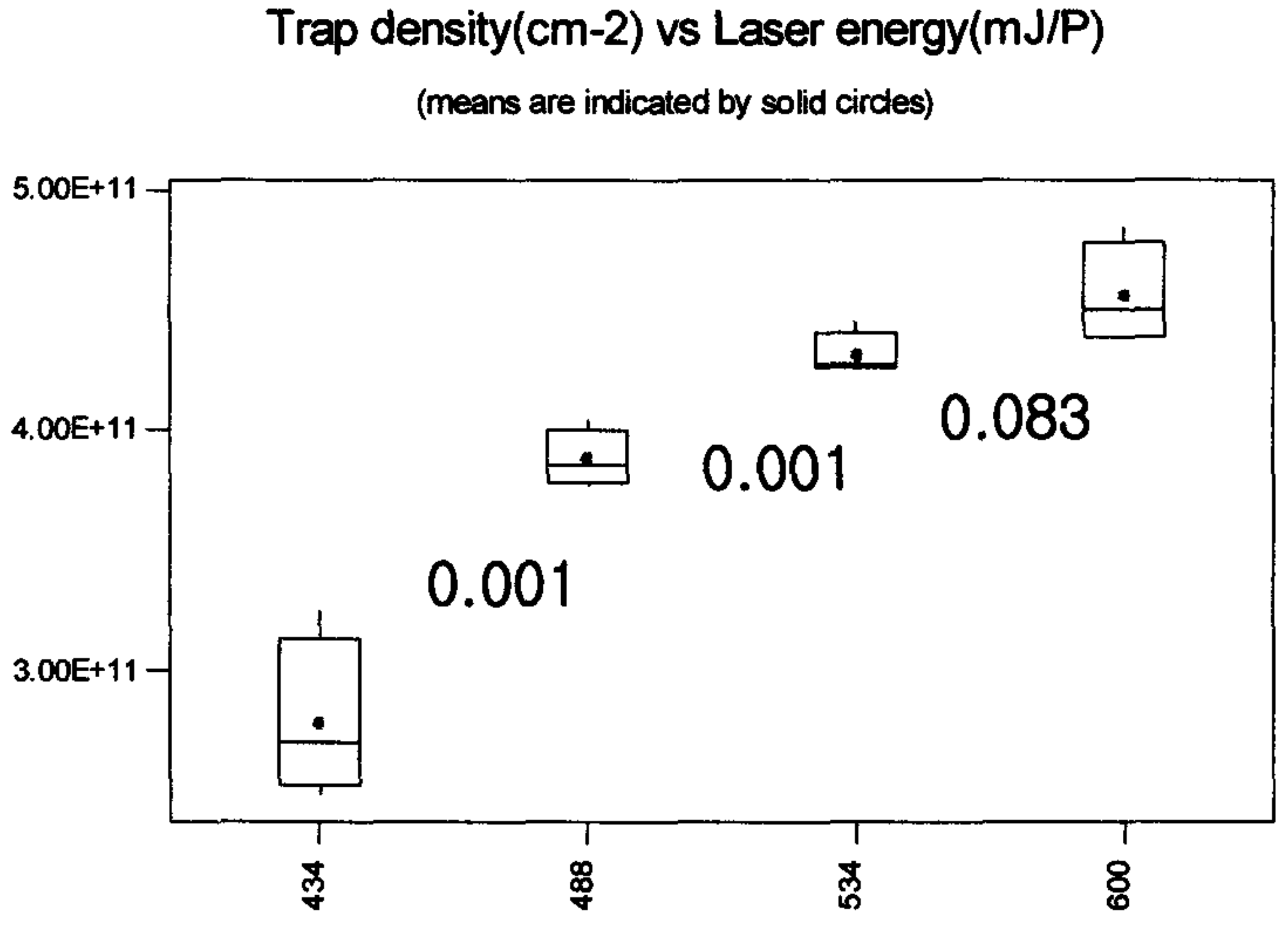


Figure 6 One-way analysis of variance of grain boundary trap density with different las