

Hydrogen Passivation on the Grain Boundary and Intragranular Defects in Various Polysilicon Thin Film Transistors

Kwon-Young Choi, Juhn-Suk Yoo, Hong-seok Choi, Min-Koo Han, Yong-Sang Kim*, and In-Gon Lim**

Department of Electrical Engineering, Seoul National University, Seoul 151-742, Korea

*Department of Electrical Engineering, Myongji University, Kyonggi-do 449-728, Korea

**LG Electronics Research Center, 16, Woomyeon-Dong, Seocho-ku Seoul 137-140, Korea

We have investigated the hydrogenation effects on two types of defect states in poly-Si TFT's, of which the gate oxide thickness is varied from 1000 Å to 4000 Å and active poly-Si layers are altered by the different annealing methods. Hydrogenation experiments show that the degree of decreases in threshold voltage, which is related to the density of deep trap-states, is almost identical in all devices. In the poly-Si TFT's with thick gate oxide or with post annealed active layers, the increase of the field effect mobility and the decrease of leakage current, which are influenced by the tail states, are remarkable. The density of hydrogen atoms and tail trap state are the key factors to control the hydrogen passivation rate.

1. INTRODUCTION

In polycrystalline silicon (poly-Si), the grain boundary and in-grain defects result in the continuous distribution of trap-states in the forbidden bandgap¹⁾. It is well known that the hydrogen passivation cures these defects and improves the performance of poly-Si thin film transistors (TFT's)¹⁾. The deep trap-states originated from the dangling bond in the grain boundaries influence on the threshold voltages while the tail trap-states originated from in-grain defects on the field-effect mobility and leakage current. Since the density of in-grain defects is much higher than the hydrogen quantity diffused into the active layer, it takes hydrogen a longer time to diffuse to the grain interior than to the grain boundary, which results in the retardation of the enhancement of field-effect mobility¹⁾. Recently, it has been reported that the in-grain defects is eliminated effectively by post-annealing process³⁾.

In this paper, we have investigated that the hydrogen diffusivity to the grain interior was increased due to the reduction of the tail trap-states by employing the various annealing techniques. Also, we have reported that the hydrogen quantity diffused through the gate oxide, which is the dominant hydrogen diffusion pathway²⁾, had a much effects on the passivation rate of tail trap-states.

2. EXPERIMENTAL

The 500 Å amorphous silicons (a-Si) for active layer are deposited by LPCVD on oxidized silicon wafers at 550 °C. One groups of them are crystallized in the furnace at 600 °C for 24 hours (LT-SPC), then followed by thermal annealing at 950 °C for 1 hour (HT-SPC). The other groups are crystallized by LT-SPC and post-annealed by excimer laser (ELA). During the post-annealing process, the grain size does not change because the rearrangement of the grain boundaries occurs above 1150 °C³⁾. However, inside the grains, the poly-Si quality is improved significantly by elimination of in-grain defects, which are mainly microtwins of first and higher order³⁾. We have varied the thickness of gate oxide in order to control the quantity of hydrogen

atoms. The silicon dioxide as a gate dielectric is deposited by APCVD from 1000 Å to 4000 Å on the LT-SPC poly-Si active layers. The other fabrication procedures of poly-Si TFT's are almost identical to those of the widely used poly-Si TFT's³⁾.

3. RESULTS AND DISCUSSION

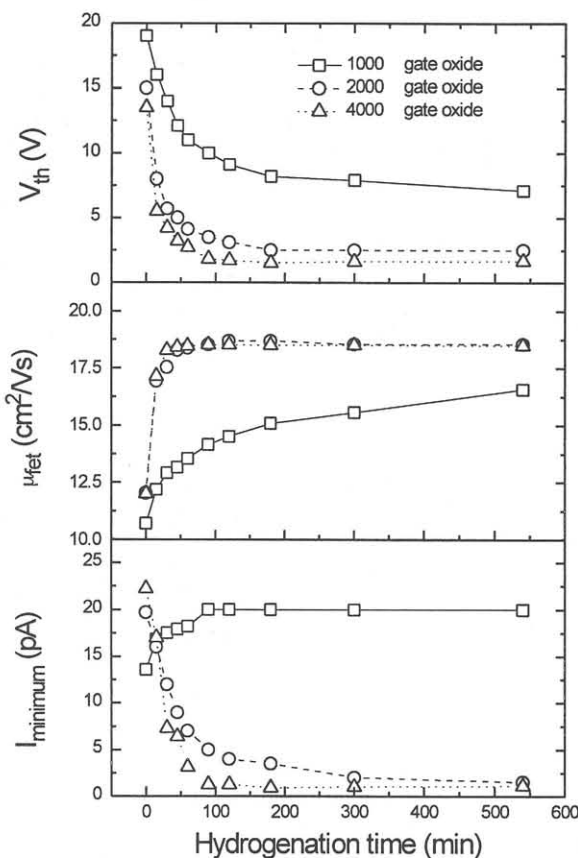


Fig. 1 Device parameters as a function of hydrogen passivation time for LT-SPC poly-Si TFT's with various gate oxide thickness (1000, 2000, 4000 Å)

The threshold voltage is decreased significantly regardless of gate oxide thickness with hydrogenation. As the gate oxide thickness is increased, the field-effect mobility and leakage current are improved significantly. It should be noted that in the LT-SPC poly-Si TFT's, of which gate oxide thickness is 1000 Å, the in-grain defects cannot be cured effectively due to the smaller hydrogen quantity than the tail trap-states.

In order to verify the effects of post annealing and hydrogen passivation on the trap-state density, we extract the trap-states density (N_T) from the measured I-V curves in poly-Si TFT's. The N_T is determined by iterating the on-state current calculation until the calculated current (I_c) converges on the given measured values (I_M)⁴. The post annealing effects on the calculated I-V curves (a) and the trap-states densities (b) are shown in Fig. 2.

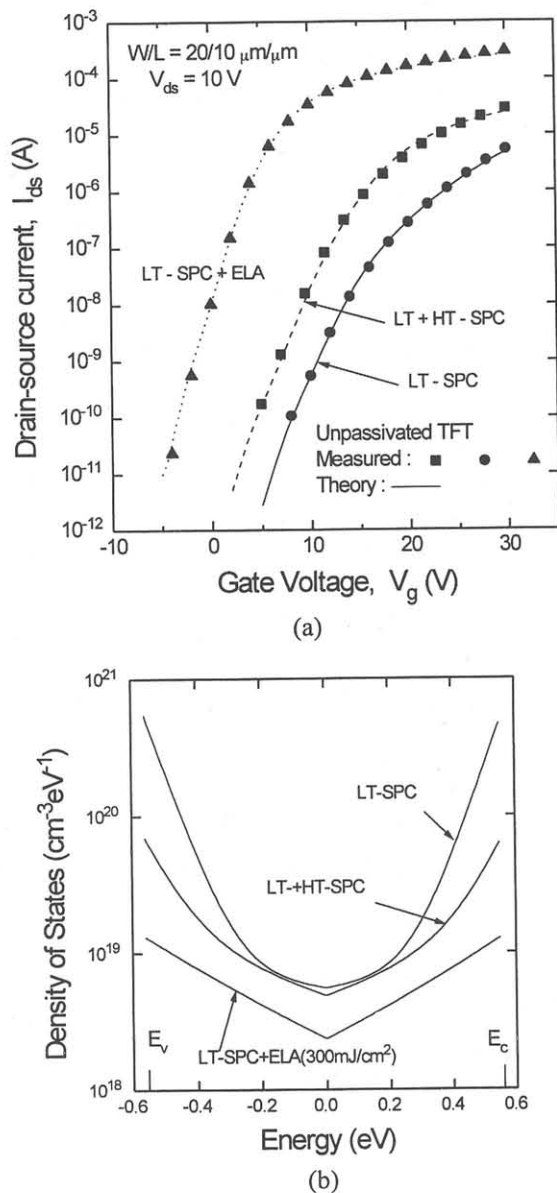


Fig. 2 The post annealing effect on calculated I-V curves (a) and trap-states distribution (b)

The relationship between N_T and different annealing methods has verified that the tail trap-states originated from the in-grain defects was removed significantly by the post annealing.

The hydrogen passivation effects on the poly-Si TFT's by the various annealing techniques including low-temperature annealing, high temperature annealing and excimer laser annealing are summarized in Fig. 3. In post-annealed poly-Si TFT's, the field-effect mobility is increased and the leakage current is decreased significantly similarly to that of thick gate oxide devices. In the LT-SPC+ELA poly-Si TFT's, the density of tail trap-states, which is reduced by the post annealing, comes to be comparable with the density of the hydrogen atoms. Therefore, even though the thin gate oxide restricts the diffusion of hydrogen atoms, the field-effect mobility is increased and the leakage current is decreased remarkably. In the LT+HT-SPC poly-Si TFT's, the device parameters has a relatively slower response to hydrogenation than that of the LT-SPC+ELA devices. As can be seen in Fig. 2 and Fig. 3, the HT-annealing is much less effective to the improvement of passivation rate than the ELA post annealing.

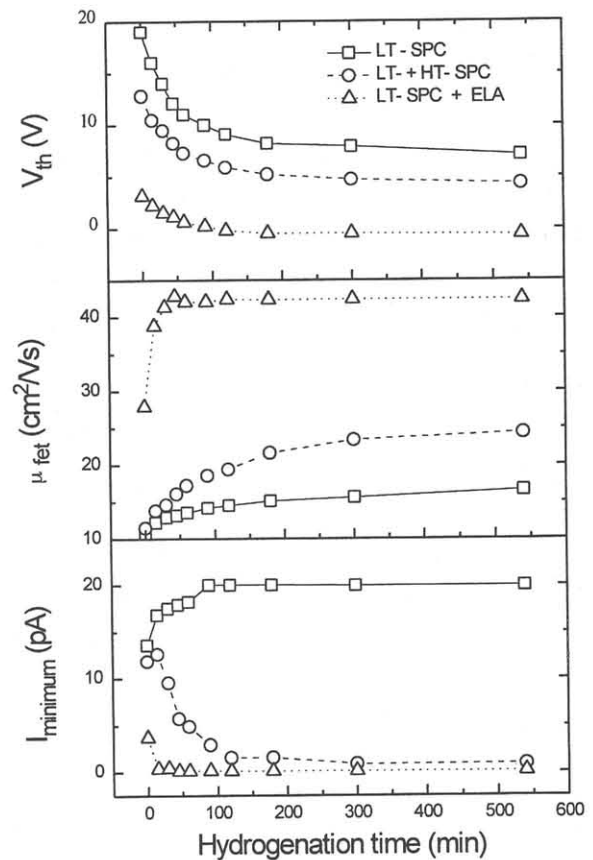


Fig. 3 Device parameters as function of hydrogen passivation time for LT-SPC, LT+HT-SPC, and LT-SPC+ELA poly-Si TFT's

The trap-states densities of LT-SPC and LT-SPC+ELA poly-Si TFT's are shown as a function of hydrogenation time in Fig. 4. In the LT-SPC poly-Si TFT's, the reduction of deep trap-state density is reduced fast by hydrogenation while the change of tail-state density is negligible. In the LT-SPC poly-Si TFT's, the tail-trap states as well as the deep trap-states are removed significantly by hydrogenation. Since the in-grain defects are eliminated by the post annealing, the post annealed poly-Si TFT's does not show the retardation of the mobility improvement that is caused by the high density of tail trap-states. The reduction of the tail trap-states improves the hydrogen diffusivity in the grain interior in the post annealed poly-Si TFT's.

4. CONCLUSION

We have investigated the hydrogenation effects on two types of defects in poly-Si TFT's with various gate oxide thickness and different active layers. In the LT-SPC poly-Si TFT's, the retardation of passivation rate was caused by the low diffusivity in the grain interior. As the gate oxide thickness is increased, the passivation rates on tail trap-states are significantly improved. In the post annealed poly-Si TFT's, the passivation rates on both the tail trap-states and deep trap-states are increased considerably.

It may be concluded that the hydrogen diffusivity, which is the most important in hydrogenation, could be improved significantly by the post annealing due to the elimination of the in-grain defects in the poly-Si films. Also, the hydrogen diffusion to the grain interior is most effective when the diffused hydrogen atoms is increased and the in-grain defects is decreased.

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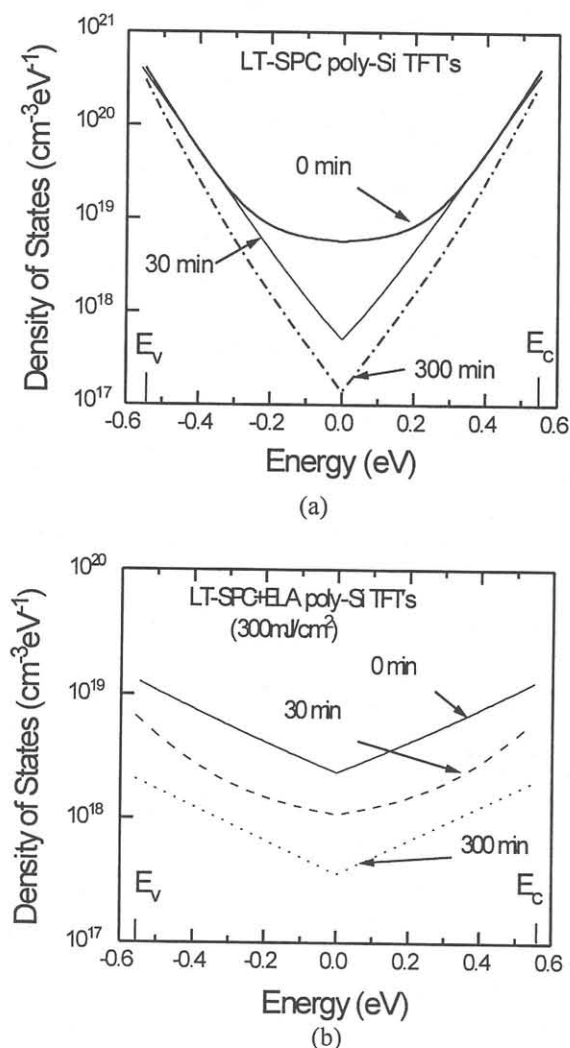


Fig. 5 Variation of trap-states distribution of poly-Si TFT's at different stages of hydrogenation ; (a) LT-SPC poly-Si TFT's and (b) LT-SPC+ELA poly-Si TFT's