Extended Abstracts of the 1994 International Conference on Solid State Devices and Materials, Yokohama, 1994, pp. 673-675

# Different Hydrogen Passivation Effects on Low-Temperature and High-Temperature Processed Poly-Si TFT's

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We have investigated the different hydrogen passivation effects on low-temperature (LT) processed and high-temperature (HT) processed poly-Si TFT's. The hydrogen passivation on LT poly-Si TFT's results in the increase of the field-effect mobility and the decrease of the threshold voltage while the hydrogenation increases the field-effect mobility and decreases the leakage current in HT poly-Si TFT's. The hydrogenation of LT poly-Si TFT's passivates the intragranular defects as well as grain boundary defects while that of HT devices compensates grain boundary defects. The effective trap-state densities of LT poly-Si TFT before and after 5 hrs hydrogenation are estimated about  $4 \times 10^{12}$  /cm<sup>2</sup> and  $1.5 \times 10^{12}$  /cm<sup>2</sup>, while those of HT poly-Si TFT are about  $1.5 \times 10^{12}$  /cm<sup>2</sup> and  $1.2 \times 10^{12}$  /cm<sup>2</sup>, respectively.

## **1. INTRODUCTION**

Polycrystalline silicon (poly-Si) thin film transistors (TFT's) can be fabricated by either high-temperature (HT) process (~1000 °C) on quartz substrate or low-temperature (LT) process ( $\leq 600$  °C) on glass substrate. Hydrogen passivation of grain boundaries may be an important process to improve the performance of poly-Si TFT's. However, most of previous hydrogenation works in poly-Si TFT's have been concerned with either low-temperature process<sup>1,2)</sup> or high-temperature process<sup>3)</sup>. The purpose of our work is to identify the effects of hydrogen passivation on LT processed and HT processed poly-Si TFT's.

#### 2. EXPERIMENTAL

We have fabricated solid phase crystallized (SPC) TFT's of which active layers have been thermally annealed at 600 °C (LT) and 950 °C (HT), respectively. The 1000-Å-thick amorphous silicon (a-Si) for active layer is deposited by LPCVD on oxidized silicon wafers at 550 °C. These a-Si films have been crystallized by thermal annealing at either 600 °C for 36 hrs or 950 °C for 1 hr in N<sub>2</sub> ambient. After definition of silicon islands, 1000-Å-thick silicon dioxide film is deposited by APCVD as a gate dielectric layer for LT processed poly-Si TFT's, while a composite gate dielectric is formed consisting of 100-Å of SiO<sub>2</sub> thermally grown in dry O<sub>2</sub> and 900-Å of SiO<sub>2</sub> deposited by atmospheric-pressure chemical vapor deposition (APCVD) for HT processed poly-Si

TFT's. The gate poly-Si is deposited in the amorphous phase by LPCVD at 550 °C and crystallized by thermal annealing at 600 °C. The polysilicon for gate and source/drain electrodes are heavily doped by self-aligned  $P^+$  implantation at an energy of 30 keV and dose of  $5 \times 10^{15}$  cm<sup>-2</sup>.

Plasma hydrogenation is performed in a plasma reactor up to 5 hrs. The hydrogen plasma treatment conditions are 300 °C and 0.5 Torr. The r.f. power density is 0.25 W/cm<sup>2</sup> at 13.56 MHz. The device characteristics, such as field effect mobility ( $\mu_{fet}$ ) and threshold voltage (V<sub>th</sub>), have been measured as a function of hydrogenation time. The trap state density (N<sub>t</sub>) of poly-Si layer has been extracted by the linearity of ln(I<sub>ds</sub>/V<sub>g</sub>) vs. 1/V<sub>g</sub> curve<sup>4</sup>).

#### **3. RESULTS AND DISCUSSION**

The typical transfer characteristics of HT and LT poly-Si TFT's with hydrogen passivation are shown in Fig. 1. The threshold voltage of 3.18 V, field-effect mobility of 68.8 cm<sup>2</sup>/V·sec, and subthreshold slope of 0.95 V/dec have been measured in the as-fabricated HT poly-Si TFT. Whereas, threshold voltage of 15.8 V, field-effect mobility of 20.8 cm<sup>2</sup>/V·sec, and subthreshold slope of 2.23 V/dec have been obtained in LT poly-Si TFT. The effects of hydrogen passivation on HT poly-Si TFT are dominant to improve the subthreshold characteristics while those on HT poly-Si TFT are the decrease of leakage current.



Fig. 1 Improvement of device characteristics with hydrogen passivation ; (a) low-temperature processed poly-Si TFT, (b) high-temperature processed poly-Si TFT.

The activation energies of the LT and HT poly-Si TFT's before and after 1 hr r.f. plasma hydrogen passivation, have been measured as a function of gate voltage. The activation energy of HT poly-Si TFT's has been increased significantly in the off-state while that of LT device has been decreased remarkably in the on-state as shown in Fig. 2. It may indicate that the hydrogen passivation of LT poly-Si TFT reduce the tail-state density as well as the deep-state density while deep-state density is significantly decreased in HT device.



Fig. 2 Variation of activation energy with gate voltage before and after 1 hr hydrogenation ; (a) lowtemperature processed poly-Si TFT, (b) hightemperature processed poly-Si TFT.

In LT poly-Si TFT's, the threshold voltage decrease significantly, which is different from HT poly-Si TFT's, while the increase of field-effect mobility shows almost same trend with HT devices as can be seen in Fig. 3. The threshold voltage and the subthreshold slope of poly-Si TFT's are related with the deep trap-states originated from dangling bond in grain boundaries while the field-effect mobility and off-current with tail trap-states from intragranular defects<sup>1)</sup>. Therefore, our experimental results show that the hydrogenation of LT poly-Si TFT's passivates the intragranular defects as well as grain boundary defects while that of HT devices compensates mainly grain boundary defects.



Fig. 3 Decrease of the threshold voltage ( $\Delta V_{th} = V_{th}(t) - V_{th}(0)$ ) and normalized increment of field-effect mobility ( $\mu_{fet}(t)/\mu_{fet}(0)$ ) as a function of hydrogenation time for LT and HT poly-Si TFT's. The symbol *t* refers to hydrogenation time.

The effective trap-state density (Nt) of poly-Si layer has been extracted from the linearity of ln(Ids/Vg) vs  $1/V_g$  curve. Figure 4 shows the reduction of trap state density with hydrogenation time for HT and LT poly-Si TFT's. The trap-state densities of LT poly-Si TFT before and after 5 hrs hydrogenation are about  $4 \times 10^{12}$  /cm<sup>2</sup> and  $1.5 \times 10^{12}$  /cm<sup>2</sup>, while those of HT poly-Si TFT are about  $1.5 \times 10^{12}$  /cm<sup>2</sup> and  $1.2 \times 10^{12}$  /cm<sup>2</sup>, respectively. It can be seen that the reduction of trapstate density in LT poly-Si TFT is much larger than that in HT device. The trap-state density originated from grain boundaries in LT poly-Si is much larger than HT poly-Si before hydrogenation. After 5 hrs hydrogenation, however, it can be seen that the trapstate densities of LT and HT poly-Si TFT's are almost identical.



Fig. 4 Variation of effective trap-state density with hydrogenation time for HT and LT processed poly-Si TFT's.

### 4. CONCLUSION

The hydrogen passivation process is essential for LT poly-Si TFT's in order to increase the field-effect mobility and decrease the threshold voltage. The hydrogenation is also effective for HT poly-Si TFT's in order to increase the field-effect mobility and decrease the leakage current. The hydrogenation of LT poly-Si TFT's passivates the intragranular defects as well as grain boundary defects while that in HT devices compensates grain boundary defects. The trap-state densities of LT poly-Si TFT are remarkably reduced with hydrogen passivation, while those of HT poly-Si TFT are decreased a little.

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