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Excimer-Laser-Induced Fluorine Passivation Effects on Electrical Characteristics and Stability of Poly-Si TFTs

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1. Introduction

Polycrystalline silicon (poly-Si) thin film transistors (TFTs) employing excimer laser annealing (ELA) is a promising device for active matrix liquid crystal displays (AMLCDs). It is well known that considerable defects in poly-Si active layer degrade the performance of poly-Si TFTs. Various techniques have been employed to improve the device performance by reducing the trap state density or increasing the grain size of poly-Si active layer. The hydrogenation is widely used to passivate trap states [1], but the long-term stability of hydrogenated poly-Si TFTs should be improved because the weak Si-H bonds may not be stable under the electrical stress [2].

Recently, it has been reported that the fluorine ion implantation on poly-Si films as well as hydrogenation is an effective method to reduce the trap state density [3, 4]. Furthermore, it was reported that the fluorine implantation also improves the electrical stability of poly-Si TFTs due to the rather strong Si-F bond formation in poly-Si channel and SiO_2/poly-Si interface [3]. However, ion implantation has troublesome problems in large-area electronics and high-temperature annealing is also required to activate implanted fluorine atoms and cure implant damages [3, 4].

The purpose of this work is to report a new excimer-laser-induced fluorine passivation method without ion implantation and an additional annealing step by low-temperature process. We have fabricated fluorine-passivated p-channel poly-Si TFTs and examined their electrical characteristics and stability. Our experiments show that the proposed method is effective to improve the electrical characteristics and the stability of poly-Si TFTs.

2. Experimental

The excimer-laser-induced fluorine passivation method proposed in this study is illustrated in the inserted figure of Fig. 1. When amorphous silicon (a-Si) film is irradiated with excimer laser, we use fluorine-doped silicon oxide (SiO_xF_y) as a pad oxide. During the laser irradiation, the SiO_xF_y film may be a diffusion source of fluorine atoms. While a-Si melt crystallized, fluorine atoms may diffuse and passivate trap states. As a result, a-Si film may be transformed to fluorine-passivated poly-Si film.

To investigate the proposed fluorine passivation effects on poly-Si TFTs, we have fabricated p-channel poly-Si TFTs. The 800Å-thick a-Si film was deposited by LPCVD at 550°C on thermally oxidized Si wafers. After defining active islands, the 200Å-thick SiO_xF_y film was deposited on a-Si film by PECVD at 390°C using TEOS (tetraethoxysilane), O_2 and C_2F_6 gas [5]. For comparison, the SiO_2 film of the same thickness was also deposited by the same method without only C_2F_6 gas. XeCl excimer laser (λ =308*nm*) with the laser energy density of 250mJ/cm^2 was irradiated on SiO_xF_y/a-Si and SiO_2/a-Si structure, respectively.

After removing oxides, Mg Kα X-ray photoelectron spectroscopy (XPS) analysis was performed to investigate the surface composition of poly-Si films. Poly-Si resistors (W/L=500μm/90μm) were also fabricated on some samples.

Then, the 1000Å-thick gate TEOS-oxide and the 2000Å-thick Molybdenum layer for gate electrodes were deposited by PECVD and by sputtering, respectively. After defining gate patterns, B_2H_6 ion shower doping was performed to form source and drain electrodes. The dopants were activated at 400°C for 2 hours in N_2 ambient. The devices were covered with 5000Å-thick oxide and contact holes were opened. After deposition and patterning of Al layer, the devices are sintered at 450°C for 30 minutes in N_2 ambient.

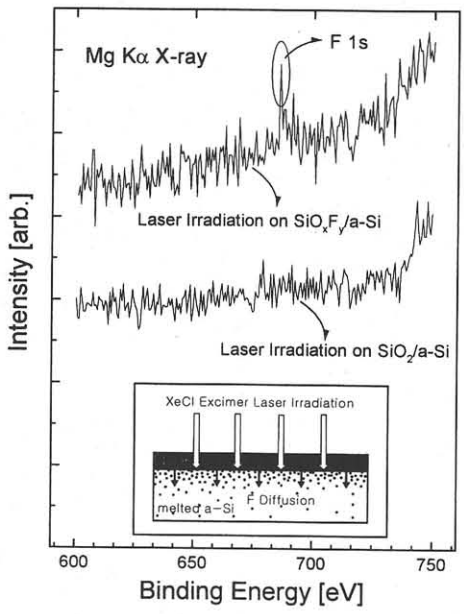

Fig. 1 The XPS data of the poly-Si films crystallized by laser irradiation on SiO_xF_y/a-Si and SiO_2/a-Si structure, respectively. The inseted figure depicts the schematic cross section of the proposed fluorine passivation method.

3. Results and Discussion

Fig. 1 shows the XPS data of two samples. The peak in the binding energy of 686*eV* of the poly-Si film crystallized by laser irradiation on SiO_xF_y/a-Si structure indicates that fluorine atoms are incorporated in it.

The conductivity of the poly-Si film was improved from $2.07\times10^{-6}\Omega^{-1}cm^{-1}$ to $1.16\times10^{-5}\Omega^{-1}cm^{-1}$ due to fluorine

incorporation. This result and XPS data indicate that trap states in poly-Si film have been successfully passivated by fluorine atoms.

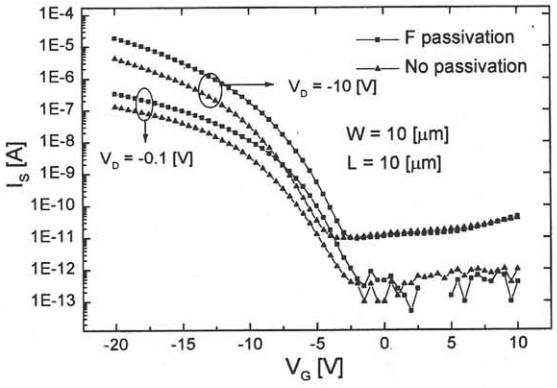

Fig. 2 The transfer characteristics of devices with and without fluorine passivation.

Fig. 2 shows the typical transfer characteristics of devices (W/L=10μm/10μm) without and with fluorine passivation at V_D=-0.1V and –10V. The subthreshold and the on-state characteristics of fluorine-passivated devices were significantly improved but the off-state leakage current was not nearly changed. These results are consistent with the previous report [3, 4]. This improvement is due to the fluorine passivation of dangling bonds and strained bonds in poly-Si channel and SiO_2/poly-Si interface [3].

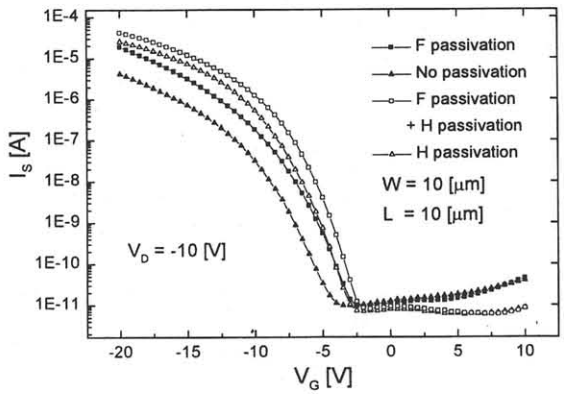

Fig. 3 The transfer characteristics of devices before and after hydrogenation.

Table I The device parameters of devices without and with various passivations.

Parameters	V_T(V)	S(V/dec)	μ_p($cm^2/V{\cdot}s$)	I_{max}/I_{min}
no passivation	-11.4	1.41	8.5	4.4×10^5
F passivation	-9.5	1.19	17.5	2.0×10^6
H passivation	-8.3	1.01	15.3	4.3×10^6
F+H passivation	-7.2	0.92	29.0	7.1×10^6

Hydrogenation was performed in a parallel-plate plasma reactor at 300^oC for 2 hours to compare with hydrogen passivation. The typical transfer characteristics and the device parameters, such as threshold voltage (V_T), field-effect mobility (μ_p), subthreshold swing (S) and on/off current ratio (I_{max}/I_{min}), before and after hydrogenation are shown in Fig. 3 and Table I, respectively. It is seen that hydrogenation improves the device characteristics in samples both without and with fluorine passivation. While hydrogen passivation decreases the off-state leakage current, fluorine passivation is more effective to improve field-effect mobility, as previously reported [3].

Finally, the electrical stability of device with hydrogen passivation and that with both fluorine and hydrogen passivation was investigated. Fig. 4 shows the threshold voltage shift ($-\Delta V_T$) and the subthreshold swing shift (ΔS) of those devices as a function of stress time after devices were stressed at V_D=-25V and V_G=-25V. It is found that the stability of device characteristics was significantly improved for device with fluorine and hydrogen passivation. This result is due to the stronger Si-F bond (5.8eV) formation than Si-H bond (4.2eV) in poly-Si channel and SiO_2/poly-Si interface [3].

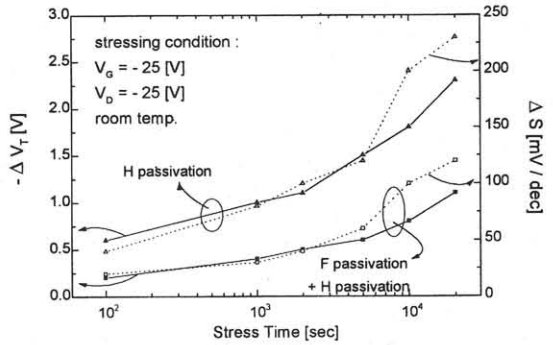

Fig. 4 The threshold voltage shift and the subthreshold swing shift of devices as a function of stress time.

4. CONCLUSION

We report a new excimer-laser-induced fluorine passivation method without ion implantation and an additional annealing step by low-temperature process and its effects on poly-Si TFTs. It has been shown that the proposed method is effective to improve the electrical characteristics, specially field-effect mobility, and the stability of p-channel poly-Si TFTs. The improvement is due to fluorine passivation, which reduces the trap state density and forms the strong Si-F bonds in poly-Si channel and SiO_2/poly-Si interface. From these results, we conclude that the high performance poly-Si TFTs can be obtained by employing the excimer-laser-induced fluorine passivation method.

Reference

1) I. W. Wu, T. Y. Huang, W. B. Jackson, A. G. Lewis and A. Ciang: IEEE Electron Device Lett. **EDL-12** (1991) 181.
2) S. Banerjee, R.Sundaresan, H. Shichijo and S. Malhi: IEEE Trans. Electron Devices **ED-35** (1988) 152.
3) H. N. Chern, C. L. Lee and T. F. Lei: IEEE Trans. Electron Devices **ED-41** (1994) 698.
4) J. W. Park, B. T. Ahn and K.Lee: Jpn. J. Appl. Phys. **34** (1995) 1436.
5) T. Usami, K. Shimokawa and M. Yosimaru: Jpn. J. Appl. Phys. **33** (1994) 408.