In-situ Fluorine Passivation by Excimer Laser Annealing

Sang-Hoon Jung, Cheon-Hong Kim, Jae-Hong Jeon, Juhn-Suk Yoo and Min-Koo Han
School of Electrical Engineering, Seoul National University, Seoul, Korea

Abstract

We propose a new *in-situ* fluorine passivation of poly-Si TFTs by excimer laser annealing to reduce the trap density and improve the reliability significantly. This improvement is due to the formation of stronger Si-F bonds than Si-H bonds which passivate the trap states.

Introduction

Poly-Si TFTs (polycrystalline silicon thin film transistors) has attraced a considerable attention for AMLCDs (active matrix liquid crystal displays). However, It is well known that considerable defects in poly-Si active layer degrade the electrical property of poly-Si TFTs[1].

The hydrogen passivatoin is widely used to passivate the grain boundaries and the intra-grain defect. 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 [2,3].

Recently, it has been reported that the fluorine ion implantation on poly-Si layer as well as hydrogenation is an effective method to reduce the trap state density [4,5]. 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 [5]. 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 [4,5].

The purpose of this work is to report a new *in-situ* fluorine passivation method without ion implantation and an additional annealing step by low-temperature process with ELA (excimer laser annealing). 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.

Experiments

The *in-situ* fluorine passivation method proposed in this study is illustrated in the inserted figure of Fig. 1 When a-Si (amorphous silicon) film is irradiated with excimer laser, we use fluorine-doped silicon oxide (SiO_xF_y) as a capping 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. After defining 800Å-thick a-Si 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 [6]. 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 250*mJ/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.

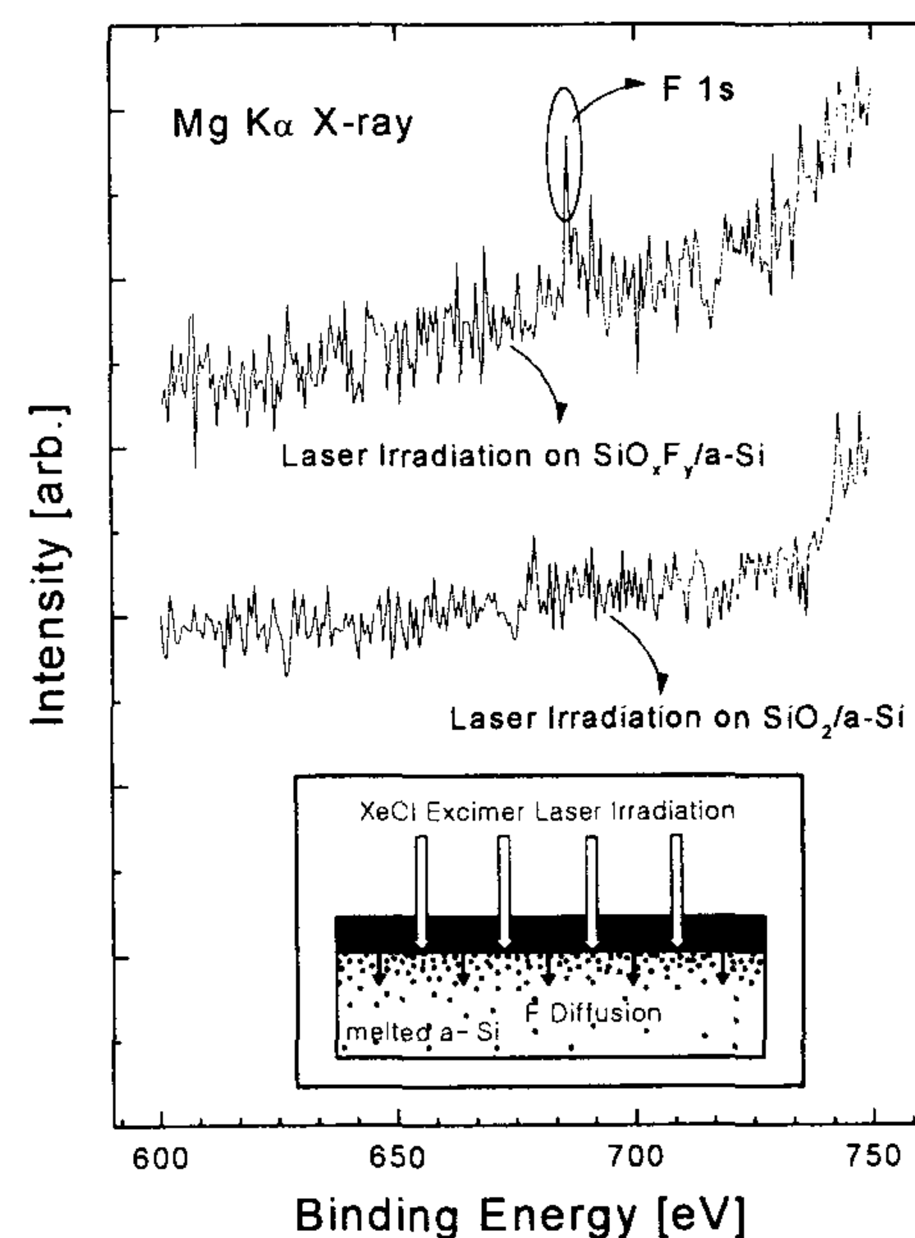

Fig. 1 The XPS data of the poly-Si films crystallized by laser irradiation on SiOxFy/a-Si and SiO2/a-Si structure, respectively. The inserted figure depicts the schematic cross section of the proposed fluorine passivation method.

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.

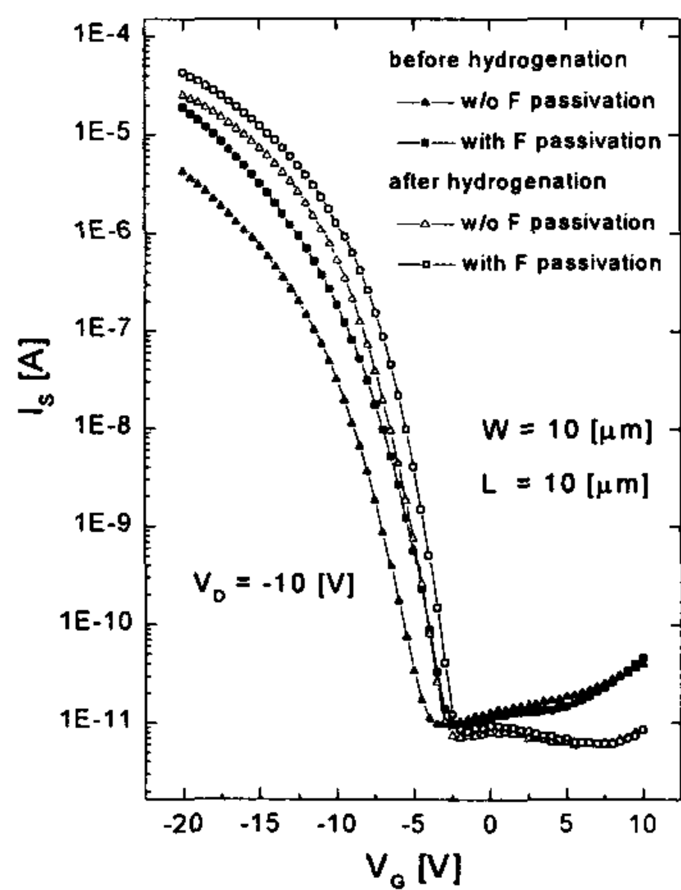

Fig. 2 The typical transfer characteristics of devices with and without *in-situ* fluorine passivation before and after hydrogenation.

Table 1 The device parameters of devices without and with various passivations

Parameters		V_T (V)	S (V/dec)	μ_p ($cm^2/V{\cdot}s$)	N_t (10^{11} cm^{-2})
before hydrogenation	w/o F passivation	-11.4	1.41	8.5	1.42
	With F passivation	-9.5	1.19	17.5	1.30
after hydrogenation	w/o F passivation	-8.3	1.01	15.3	1.26
	With F passivation	-7.2	0.92	29.0	1.13

Fig. 2 shows the typical transfer characteristics of devices with and without *in-situ* fluorine passivation at V_D=-10*V* before and after hydrogenation. The subthreshold and the on-state characteristics of device with *in-situ* fluorine passivation were improved significantly. The threshold voltage(V_T) and the subthreshold swing (S) for devices with *in-situ* fluorine passivation were improved from –11.4*V* and 1.41 *V/dec* to –9.5*V* and 1.19*V/dec*, respectively. However, the off-state leakage current was almost unchanged. These results are consistent with the fluorine implantation cases[4,5].

Finally, the electrical reliability of device with and without *in-situ* fluorine passivation after hydrogen passivation was investigated. Fig. 3(a) shows the threshold voltage shift (-ΔV_T) and the trap state densitiy (ΔN_t) for typical devices as a function of stress time after devices were stressed at V_D=-25*V* and V_G=-25*V*. The subthreshold swing shift(ΔS) and the driving current degradation (-$\Delta I_s/I_s$) are also shown in Fig. 3(b). The driving current(I_s) was evaluated at V_D=-20*V*. It is observed that the degradation rate of all device parameters was remarkably decreased for the *in-situ* fluorine passivation device.

The degradation trend of threshold voltage(V_T) and trap state density (N_t) are similar as shown in Fig. 3(a) because the threshold voltage shift is closely related to the increase of the trap state density. The degradation of poly-Si TFTs under the electrical stress is probably due to breaking of the weak Si-H bonds by mobile carriers, which results in the increase of the trap state density[2]. Our experimental data indicate that the improvement of reliability is due to the rather strong Si-F bond formation in place of the weak Si-H bond in poly-Si channel and SiO_2/poly-Si interface.

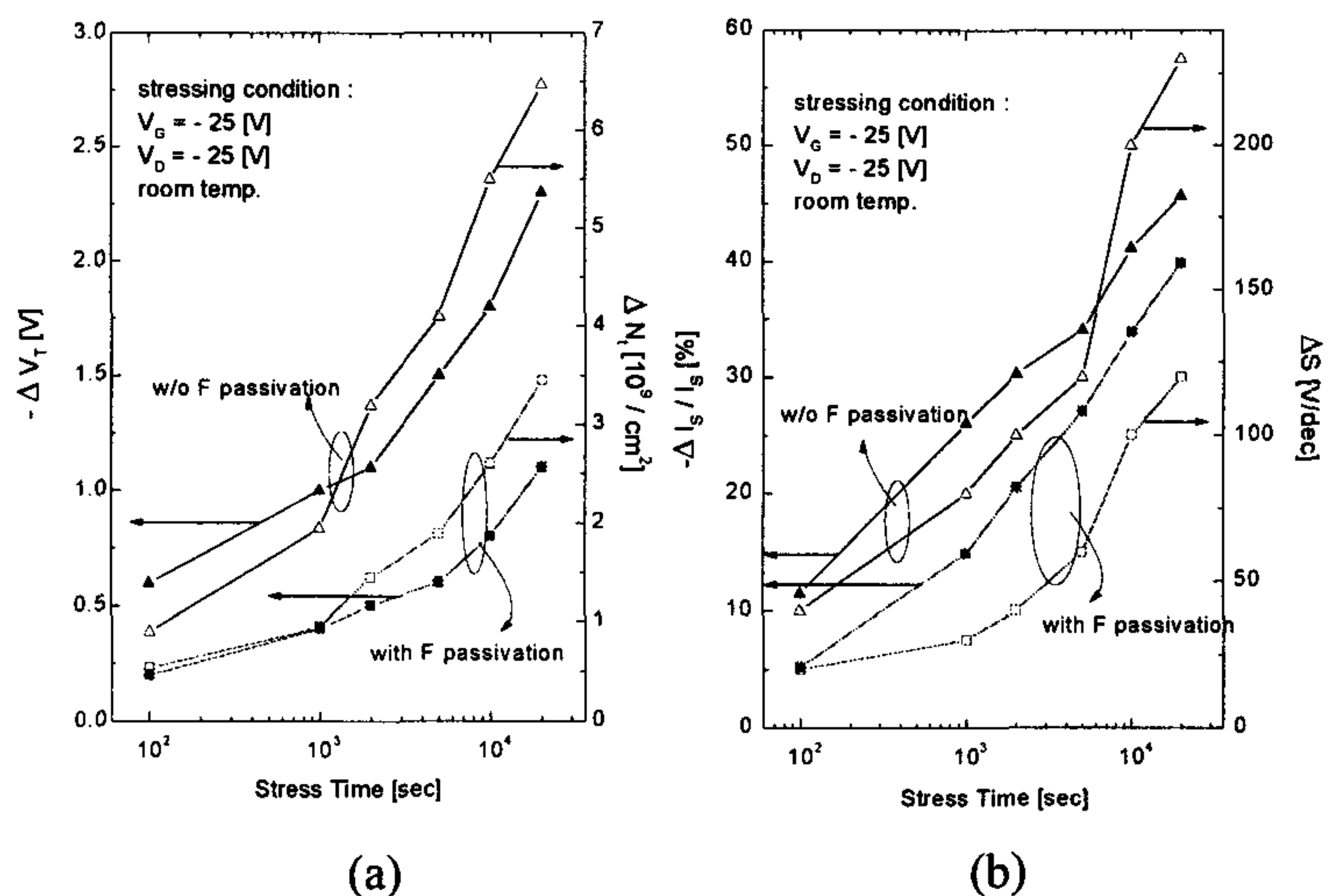

Fig. 3 (a) The threshold voltage(V_T) and theincrese of the trap state denstity(ΔN_t). (b) The subthreshold swing shift (ΔS) and the driving current degradation (-$\Delta I_s/I_s$) of devices as a function of stress time after devices were stressed at V_D=-25*V* and V_G=-25*V*.

Conclusion

We report a new *in-situ* fluorine passivation method without ion implantation and an additional annealing step by low-temperature process with ELA 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 relibility 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 *in-situ* fluorine passivation method with ELA.

Reference

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