In-Situ Fluorine Passivation by Excimer Laser Annealing

Sang Hoon Jung, Cheon Hong Kim, Jae Hong Jeon, Juhn Suk Yoo and Min Koo Han

Abstract

We propose a new *in-situ* fluorine passivation of poly-Si TFTs using excimer laser annealing to reduce the trap state density and improve reliability significantly. To investigate the effect of an *in-situ* fluorine passivation, we have fabricated fluorine-passivated p-channel poly-Si TFTs and examined their electrical characteristics and stability. A new *in-situ* fluorine passivation brought about an improvement in electrical characteristic. Such improvement is due to the formation of stronger Si-F bonds than Si-H bonds in poly-Si channel and SiO_2/poly-Si interface.

Keywords : Poly-Si, TFT, fluorine, passivation, excimer laser, ELA

1. Introduction

Poly-Si TFTs (polycrystalline silicon thin film transistors) has attracted considerable attention to 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 passivation is widely used for passivating 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 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 for reducing 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 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 in improving the electrical characteristics and stability of poly-Si TFTs.

2. Experiments

The *in-situ* fluorine passivation method proposed in this study is illustrated in 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. 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 =308nm) with the laser

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S. H. Jung, C. H. Kim, J. H. Jeon, J. S. Yoo and M. K. Han are with the School of Electrical Engineering, Seoul National University, Seoul 151-742, Korea. **E-mail** : jsh@emlab.snu.ac.kr **Tel** : +2 880-7992 **Fax** : +2 883-0827

energy density of 250mJ/cm^2 was irradiated on SiO_xF_y/a-Si and SiO_2/a-Si structure, respectively.

After removing the 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 of the samples.

Then, the 1000Å-thick gate TEOS-oxide and the 2000Å-thick Molybdenum layer for gate electrodes were deposited by PECVD and sputtering, respectively. After defining the 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 5000Å-thick oxide layer was deposited and contact holes were opened. After deposition and patterning of Al layer, the devices were sintered at 450°C for 30 minutes in N_2 ambient.

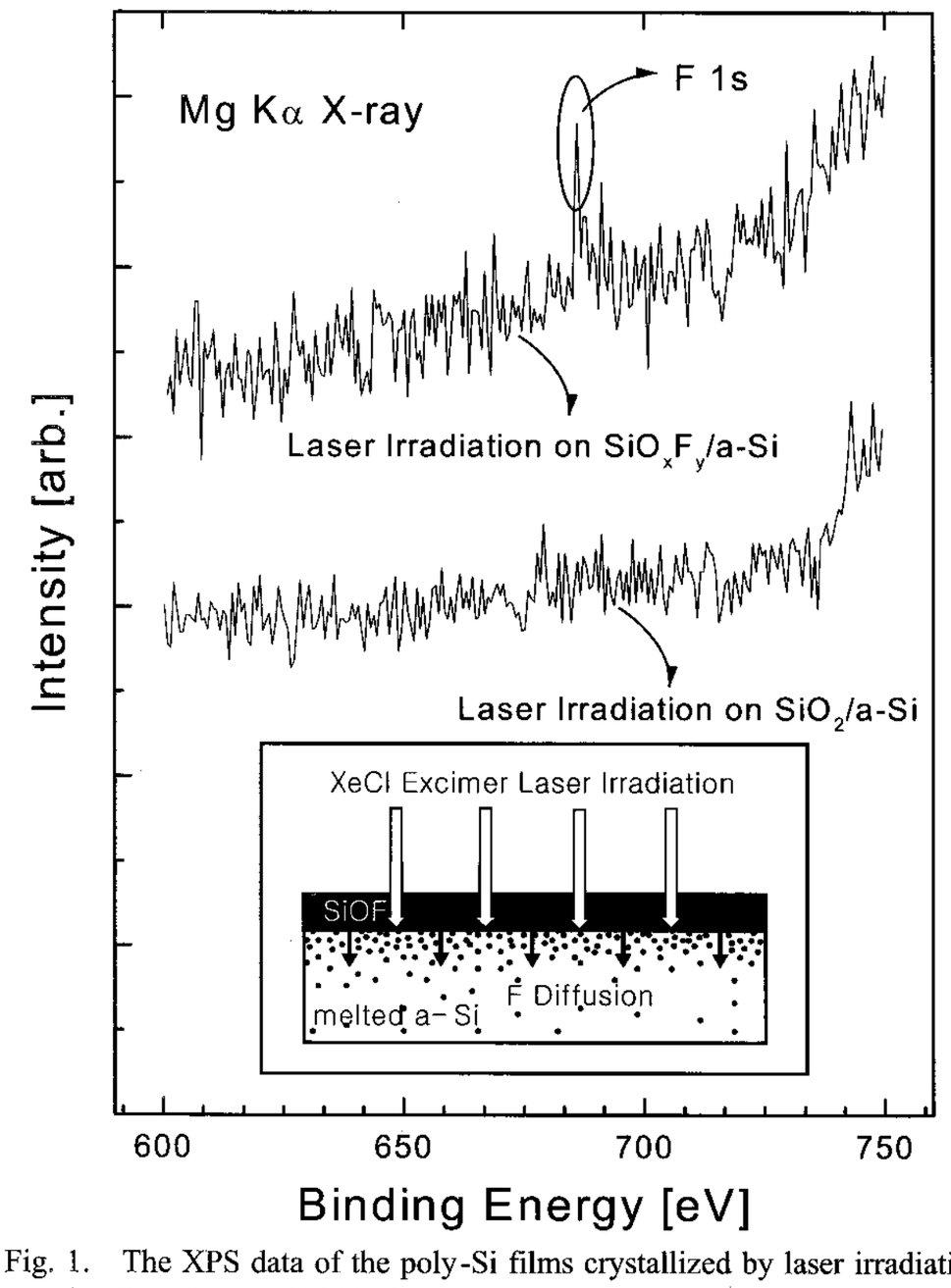

Fig. 1. The XPS data of the poly-Si films crystallized by laser irradiation on SiOxFy/a-Si and SiO2/a-Si structure, respectively. The inserted figure depicts the schematic cross section of the proposed fluorine passivation method.

3. Results and Discussion

Fig. 1 shows the XPS data of two samples. The peak in the binding energy of 686eV of the poly-Si film crystallized by laser irradiation on SiO_xF_y/a-Si structure indicates that fluorine atoms are incorporated in poly-Si film. While a-Si melt crystallized, fluorine atoms may diffuse and passivate trap states. As a result, a-Si film was transformed to fluorine-passivated poly-Si film'

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.

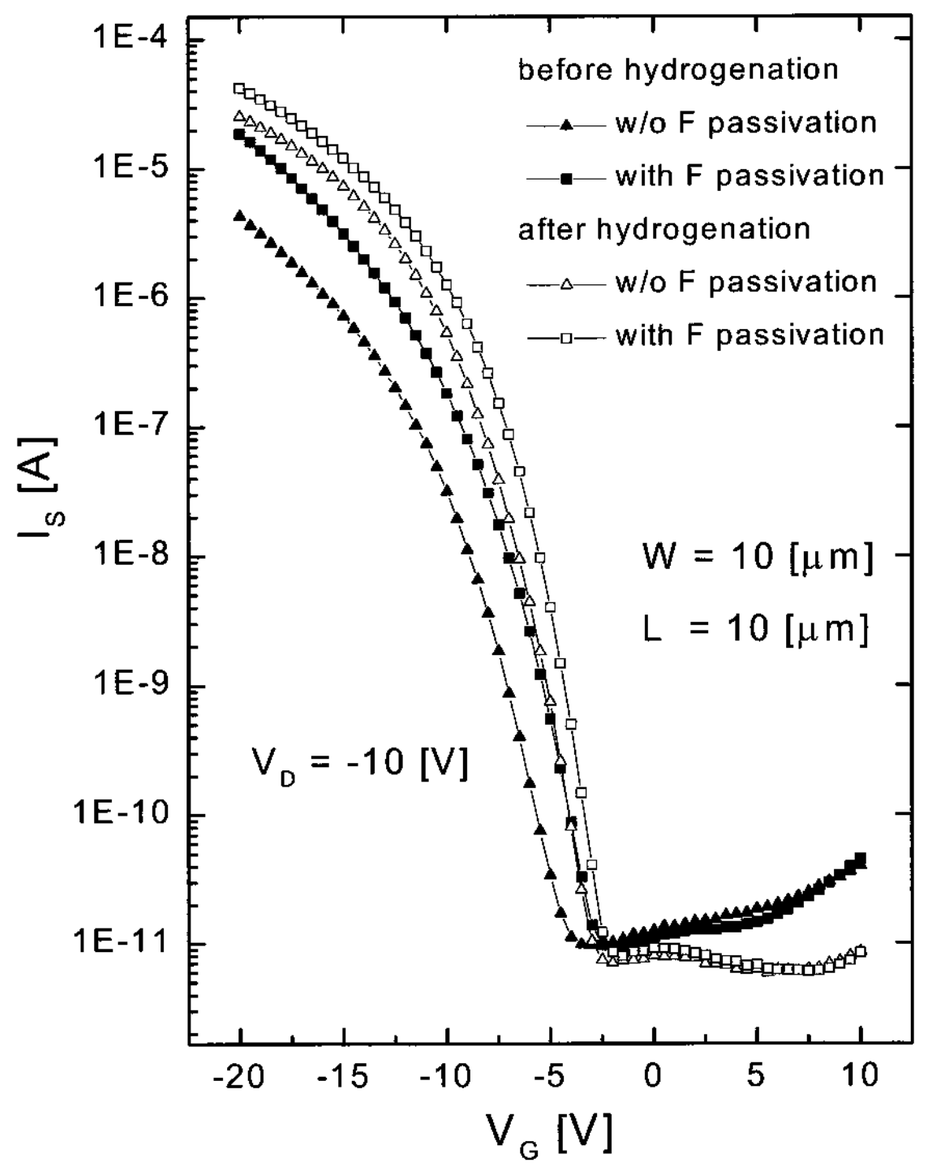

Fig. 2. The typical transfer characteristics of devices with and without *in-situ* fluorine passivation before and after hydrogenation.

Fig. 2 shows the typical transfer characteristics of devices with and without *in-situ* fluorine passivation at V_D=-10V 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 –11.4V and 1.41V/dec to –9.5V and 1.19V/dec, respectively. However, the off-state leakage current was almost unchanged. Because fluorine breaks the weak Si-H bond or the weak Si-OH bond and form a strong Si-F bond in its place at the Si/SiO_2 interface, the improvement of TFT characteristics can be seen to be the passivation effect of fluorine atoms

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

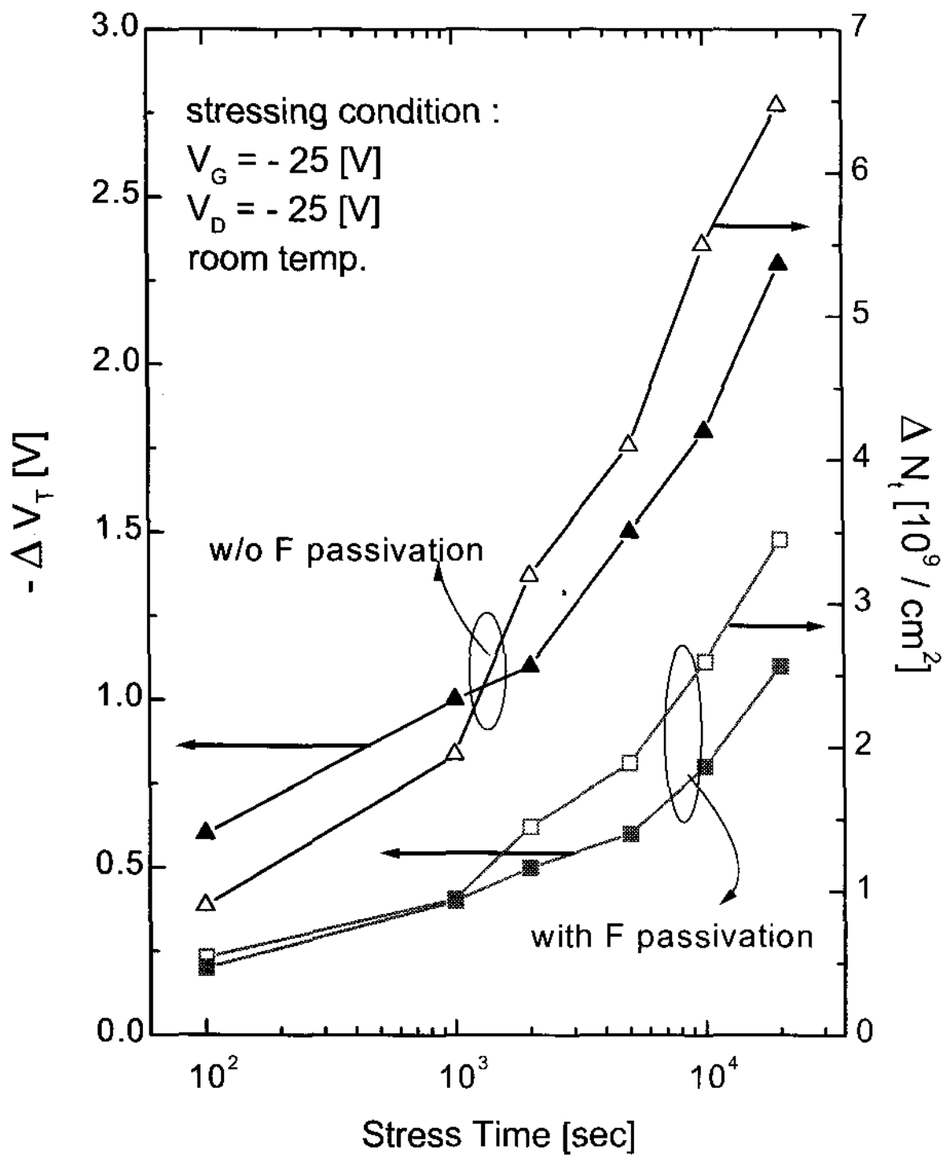

Fig. 3. The threshold voltage (V_T) and the increase of the trap state density (ΔN_t). of devices as a function of stress time after devices were stressed at V_D=-25V and V_G=-25 V .

mainly at the Si/SiO_2 interface. 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 shows the threshold voltage shift ($-\Delta V_T$) and the trap state density (ΔN_t) for typical devices as a function of stress time after devices were stressed at V_D=-25V 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.4. The driving current(I_s) was evaluated at V_D=-20V. It was 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, 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 the breakage of the weak Si-H bonds by mobile carriers, which results in the increase in the trap state density [2]. Our experimental data indicates 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.

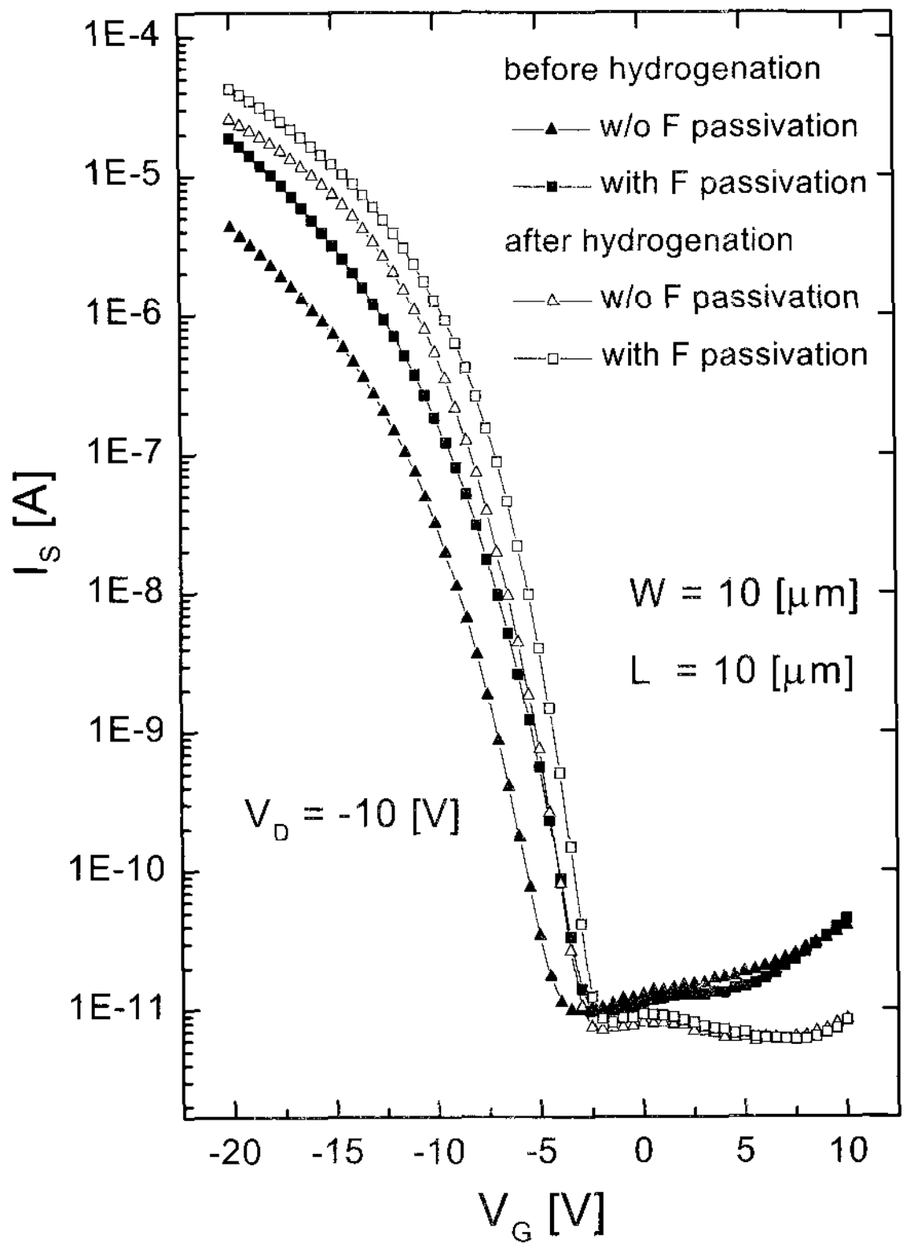

Fig. 4. The subthreshold swing shift (ΔS) and the driving current degradation ($-\Delta I_s/I_s$) of devices as a function of stress time after devices were stressed at V_D=-25 V and V_G=-25 V .

4. 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 for improving the electrical characteristics, specially field-effect mobility, and the reliability 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 better performance poly-Si TFTs can be obtained by employing the *in-situ* fluorine passivation method with ELA.

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