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Improvement of Poly-Si TFT Characteristics by Hydrogenation at SiO_2/Poly-Si Interfaces, Characterized by TDS Measurement of Deuterium Terminated Poly-Si

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The influence of hydrogen passivation at SiO_2/poly-Si interface traps and at grain boundary traps within poly-Si was investigated by thermal desorption spectroscopy(TDS) and electrical characteristics of TFTs. These results suggest that TFT characteristics can be improved by hydrogen passivation of the SiO_2/Poly-Si interface traps, although TFT characteristics degraded at longer hydrogenation times. It is also found that it is difficult to improve the characteristics of p-ch TFTs, since the states of the valence band tail can't be reduced sufficiently by hydrogenation.

1. Introduction

Hydrogenation has been widely used in the improvement of poly-Si TFT characteristics[1,2] for the application of high density-LCDs and mega-bit SRAMs. Further improvement is required for the fabrication of high density and high resolution poly-Si TFT light valves with CMOS driver integration. However, hydrogenation mechanism is not clear and limitation of hydrogenation is also uncertain. In this paper, we report that poly-Si TFTs characteristics can be improved by hydrogenation at SiO_2/poly-Si interfaces, which was confirmed by TDS measurement of deuterium-terminated poly-Si. We also point out the difficulty to improve the leakage current in p-ch TFTs, due to poor passivation of valence band tail-states.

2. Experimental

Co-planar type top gate poly-Si TFTs were fabricated, as shown in Fig.1. TFT poly-Si films were fabricated by solid-phase crystallization of 100nm-thick amorphous-Si at 600℃. Gate oxide films and gate poly-Si films were deposited by LPCVD. Source and Drain regions were made by Phosphorous/Boron ion implantation. After an Al-metallization process, hydrogenation was carried out at 350℃ in H_2-plasma. The channel length of the TFTs was $2\sim6\mu m$.

3. Results and Discussion

Id-Vg characteristics of n-ch TFTs are improved with the increase of hydrogenation time, as shown in Fig.2. The dependence of threshold voltage(Vth) and interface fixed charge(Qf) on the hydrogenation time is shown in Fig.3. These results indicate that the electrical characteristics are drastically improved at hydrogenation times within 30 minutes. In order to clarify this phenomenon, TDS measurement was carried out, and the hydrogen concentration at the SiO_2/poly-Si interface and in the channel poly-Si was evaluated. For TDS measurement, two samples were fabricated; structures-A and B. Structure-A was 100nm-thick CVD-SiO_2/100nm-thick poly-Si /Si-substrate, as shown in Fig.4. Hydrogenation was carried out, and the total hydrogen content both at the SiO_2/poly-Si interface and in the poly-Si film can be measured by using the sample of structure-A. On the other hand, the sample of structure-B, shown in Fig.4, was fabricated for the measurement of the hydrogen content within the poly-Si film. After hydrogenation of the sample of structure-A, the CVD-SiO_2 film was removed using D_2O diluted HF and the surface of a poly-Si film was terminated by deuterium. Hydrogen content in the poly-Si film could be observed by using the sample of structure-B. Therefore, the hydrogen content at the SiO_2/poly-Si interface can be

obtained from the difference of hydrogen concentration between the structure-A and the structure-B. Figure 5 shows the hydrogen content against the hydrogenation times for the structures-A and B. The total hydrogen content in structure-A(solid-line) increased drastically just after hydrogenation-started and saturated above 60 minutes. On the other hand, hydrogen content in poly-Si film in structure-B(broken-line) increased after 30 minutes and saturated above 60 minutes, as shown in Fig.5. It is suggested that hydrogen terminates the dangling-bonds at the interface within 30 minutes and then in the poly-Si itself afterwards. Therefore, hydrogenation of SiO_2/poly-Si interface trap states is effective for the improvement of electrical characteristics. However, poly-Si TFT characteristics degrade above 60 minutes, as shown in Fig.6. The drain voltage decreased as hydrogenation time increased, when the channel-potential was fixed at 0.6V. The channel-potential is determined by the recombination of holes and traps within channel poly-Si. By the reduction of traps in the poly-Si film by hydrogenation, holes accumulated in the channel region above 30 minutes. Thus, increase of the channel-potential occurred. These results indicate that the key for the TFT characteristics improvement is the reduction of interface traps.

Electrical characteristics of p-ch TFTs can be also improved by passivation at the interfaces. However, it is difficult to improve the leakage current in p-ch TFTs, as shown in Fig.7. The trap state level of generated leakage current was measured by the temperature dependence of leakage current and was found to be Ev+0.45eV. The interface trap density was measured by a quasi-static C-V method under the bottom-surface-accumulated conditions[3] as shown in Fig.8. Interface trap density reduced at 30 minutes, so that the leakage current decreased, as shown in Fig.7. However, the poor improvement of leakage current in p-ch TFTs above 30 minutes is due to insufficient reduction of interface trap density at valence band tail-states, as shown in Fig.8. Therefore, it is quite difficult to improve the p-ch TFTs characteristics by hydrogenation.

4. Conclusions

Poly-Si TFT characteristics can be improved by hydrogenation at SiO_2/poly-Si interfaces. Hydrogen content at the interfaces was measured by TDS in the deuterium terminated poly-Si. However, hydrogenation is not enough to passivate the trap states in p-ch TFTs.

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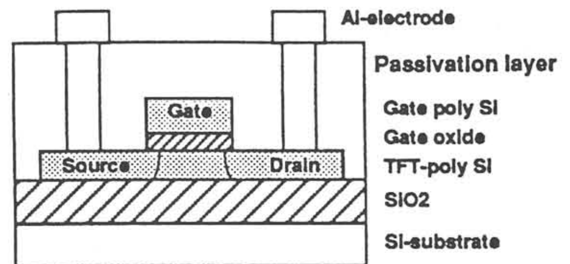

Fig.1 Schematic cross-sectional structure of co-planar top-gate poly-Si TFT.

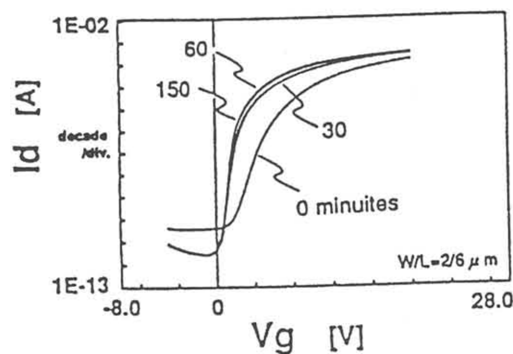

Fig.2 Typical Id-Vg characteristics for n-channel TFTs with various hydrogenation times.

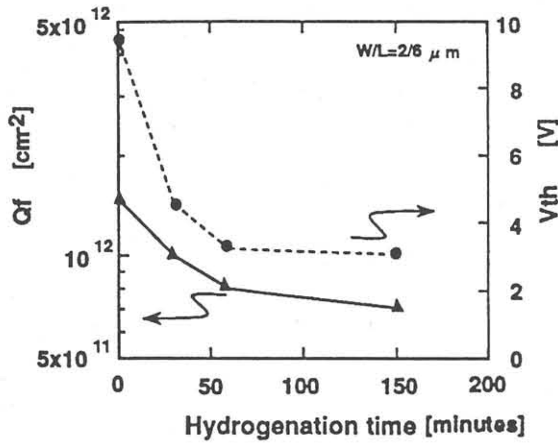

Fig.3 Interface fixed charge(Qf) and threshold voltage (Vth) as a function of hydrogenation times.

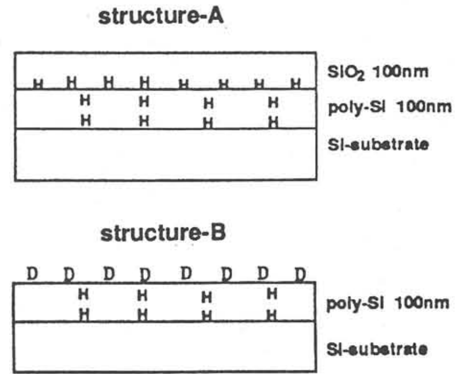

Fig.4 Schematic sample structures for TDS measurements.

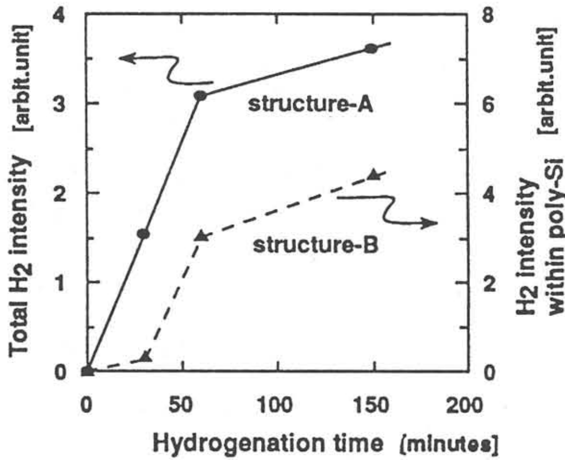

Fig.5 Hydrogenation time dependence of H2 concentration ; total H2 concentration(solid-line) and H2 concentration within poly-Si film (broken-line).

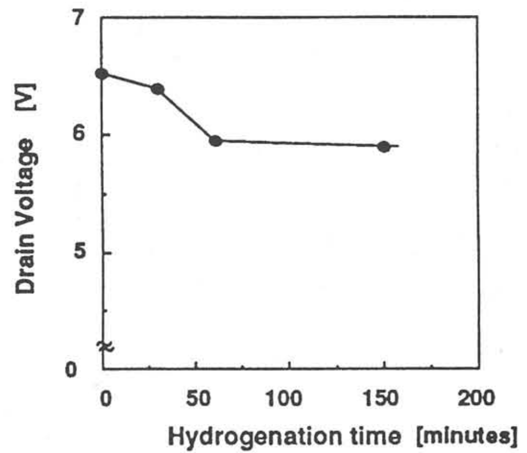

Fig.6 Hydrogenation time dependence of drain voltage at a channel potential of 0.6V .

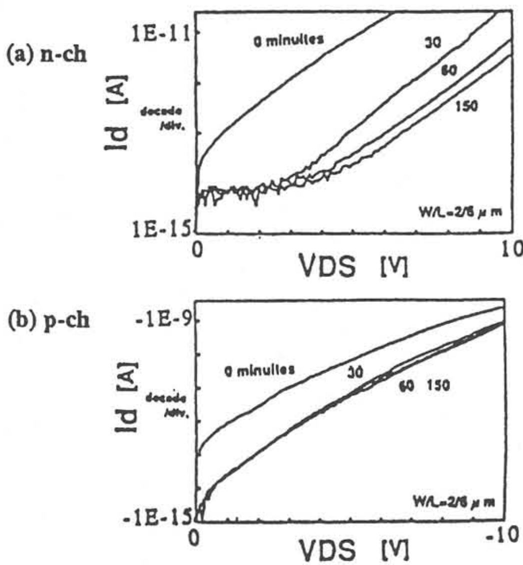

Fig.7 Leakage current for n-ch/p-ch TFTs.

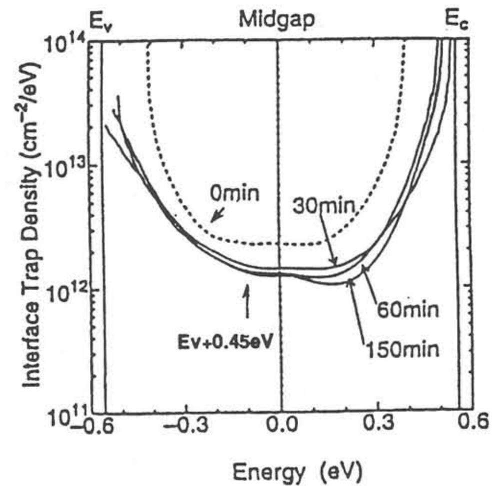

Fig.8 Energy distribution of interface trap density with different hydrogenation times.