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High Performance Bottom Gate TFTs by Excimer Laser Crystallization and Post Hydrogenation

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Pulsed laser crystallized poly-Si has defect density of the order of 10^{18} to $10^{19}/cm^3$. Plasma hydrogenation is generally used to terminate defects. Damage caused by UV emitted from the plasma glow discharge during plasma hydrogenation was identified as one of the causes limiting the quality of the bottom gate TFT devices which can be fabricated. By combining plasma hydrogenation and SiNx:H as a passivation source we obtained one of the best characteristics reported to date.

1. Introduction

Recently poly-Si thin film transistors(TFTs) have been studied extensively for their use in LCDs for integrated addressing and clocking circuitry fabricated on the base plate(1,2). Processes using laser annealed poly-Si are of considerable interest, because of their low thermal budget and the ability to form the poly-Si on low cost glass, plastic and ceramic substrates(3,4). Pulsed laser crystallization is very rapid, resulting in small grains and therefore a large number of defect density of the order of 10^{18} to $10^{19}/cm^3$ as shown by ESR measurements. Therefore proper termination of grain boundary defects is needed to make this poly-Si useful for devices. Plasma hydrogenation is generally used to passivate the grain boundaries. Here we show that it is necessary to screen the devices from UV light emitted from the plasma to obtained good TFT characteristics. The TFT characteristics obtained using our new device structure are presented, with defects terminated by RF plasma and further passivated by SiN.

2. Experiments

Figure 1 shows the TFT device structure. The structure had a 200nm thick MoTa gate electrode. On the gate electrode 200 nm of SiO_2 (gate dielectric) was deposited by PECVD. Subsequently 30 nm of a-Si:H was deposited by PECVD and the incorporated hydrogen was removed by annealing at

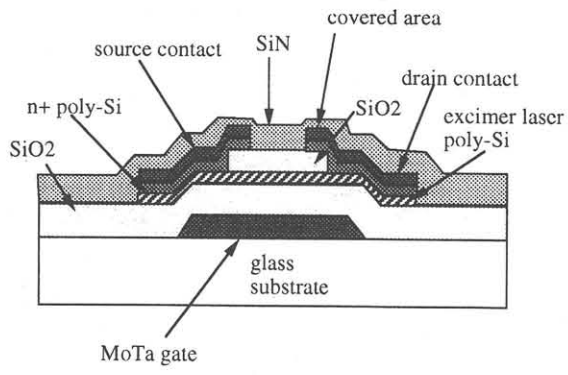

Figure 1. Cross-sectional view of our TFT structure.

400 °C. The heat treated a-Si:H film was crystallized by excimer laser ($\lambda = 308$ nm). On the laser crystallized film, SiO_2 was deposited and the channel region was defined. Next a doped a-Si

layer was deposited, annealed to remove the incorporated hydrogen and then crystallized by excimer laser. This layer was then patterned into source and drain regions. Next the devices were isolated by dry etching and Mo was sputtered and patterned to form source and drain contacts. Finally the devices were hydrogenated and passivated with SiN. To study the effect of UV emitted from the glow discharge on the devices independently of the effects associated with gas species, the devices were covered with a quartz substrate and were placed in the plasma.

3. Results and Discussions

Figure 2 shows the change in the characteristics of a typical TFT with hydrogenation (before nitride deposition). The characteristics after hydrogenation for 60 minutes (2b) are greatly improved compared to the unhydrogenated case (2a). The ON/OFF current ratio increases by nearly 6 orders of magnitude and the I_D-V_G slope increases(2b) due to the termination of grain boundary states by hydrogen.

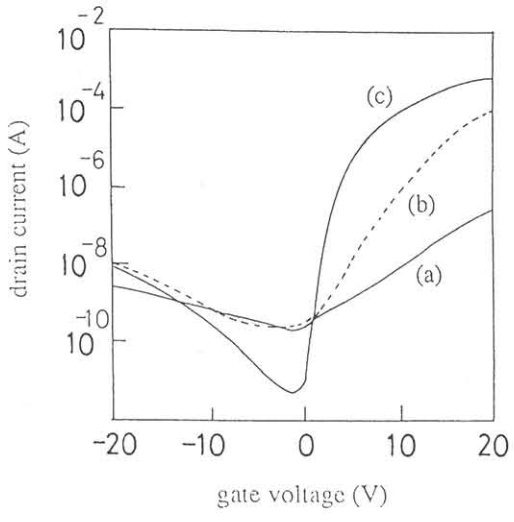

Figure 2. Transfer characteristics of a typical TFT (a) before hydrogenation, (b) 60 minute RF plasma hydrogenation, and (c) after SiNx:H passivation and thermal annealing.

Taking the effective diffusion coefficient of hydrogenation in SiO_2 as 10^{-10} cm^2s^{-1}, and in poly-Si as10^{-12} cm^2s^{-1}(1/10 of the value for crystalline Si(5)), in principle it should take 10 sec. to hydrogenate a 30 nm film. As can be seen from Fig. 2, device hydrogenation took much longer than this calculated value. This is because hydrogen has to diffuse laterally to hydrogenate remote covered areas. The calculated time for this is $2.5x10^3$ sec., in agreement with our experiments. However, if we exposed the devices to the plasma for a period longer than 60 minutes, we observed degradation of the characteristics. This is because during plasma exposure layers under the opening are continuously bombarded by energetic particles and ultra violet light which creates damage in the device.

Hydrogen plasmas exhibit strong UV emission in the range 110-180 nm . A poly-Si device exposed to such a high energy can easily be damaged. Figure 3 (a) shows the characteristics of a plasma hydrogenated TFT device. The characteristics are much better than non-hydrogenated device but not very good. This is because of damage caused by glow discharge UV light and energetic

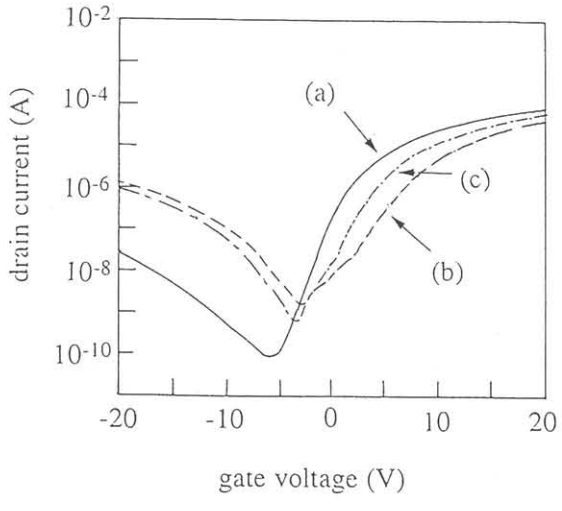

Figure 3. Transfer characteristics of a plasma hydrogenated device(a), after subsequent glow discharge UV light exposure(b), and thermal annealing (c).

particles. This device was exposed subsequently to plasma UV at 285 °C with the sample covered by a piece of quartz to block the hydrogen flux. The characteristics after UV irradiation are shown in Fig. 3 (b).

As can be seen from the Fig. 3(b) the characteristics degraded significantly. This confirms that UV exposure produces damage in the TFT device. The device was annealed at 285 °C for one hour to see if it was possible to heal the damage caused by UV by thermal treatment. The characteristics are shown in Fig. 3c. The characteristics improved to some extent but still UV damage remained.

The use of plasma hydrogenation alone limits the quality of devices which can be fabricated due to the defect creating mechanisms associated with the plasma. To address these problems, we deposited a hydrogen-rich a-SiNx:H passivation layer on the devices and annealed the samples to promote diffusion of hydrogen from the nitride into the poly-Si. This hydrogenation method should be non-defect creating and therefore permit further reduction of the defect density.

The large quantity of hydrogen required to passivate laser poly-Si film means that it may be difficult to introduce all the hydrogen from a diffusion source.

The effectiveness of the nitride as a hydrogen source is demonstrated in the characteristics shown in Fig. 2c. The calculated field effect mobility, from TFT device characteristics, is 80 $cm^2/V.s$, the measured sub threshold slope is 0.6 V/dec., and the ON/OFF current ratio is 10^8(OFF current less than 10^{-11}A with W/L = 180 μm/30 μm). To our knowledge these are among the best bottom gate TFT characteristics reported to date, fabricated by low thermal budget (excimer laser) processes on glass substrates.

4. Conclusion

We have shown that defects created by UV light emitted from the glow discharge during plasma hydrogenation limits the quality of devices which can be fabricated. It is likely that superior device performance can be obtained if a plasma hydrogenation method is used which screens the devices from UV while allowing hydrogen through.

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