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Symmetric Ni-Induced Lateral Crystallization Poly-Si TFTs with Low Metal Contaminations

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Abstract

In this work, the low metal contaminations symmetric Ni induced lateral crystallization (LC-NILC) poly-Si TFTs were successfully fabricated. The amounts of Ni diffused into the poly-Si film could be successfully controlled, with preheating by a hot plate, before removal of Ni layer and crystallization in the furnace, without additional lithography or thin film deposition process. With the proper preheating temperature of 100°C, the Ni atoms can distribute uniformly to enhance the device uniformity, the transconductance (G_m) and on/off currents ratio can also be improved. This novel method of poly-Si crystallization is suitable for future trend of ultra-high definition (UHD) display, and micro-LED display, which requires the TFTs with high carrier transportation ability and high on/off current ratio.

1. Introduction

TFTs are key components in nowadays display technology. TFTs with the active layer of a-Si:H are widely used in display industries[1-3]. However, with the advancement of display technology, the degree of visual entertainment is required to be improved. Compared to the a-Si:H TFTs, poly-Si TFTs with higher aperture ratio, faster response rate, and lower power consumption will be more feasible for the future trends of ultra-high definition (UHD) and micro-LED display [4-6].

Low-temperature polycrystalline silicon (LTPS) is polycrystalline silicon that has been crystallized at relatively low temperatures (< 600 °C) compared to in traditional methods (above 900 °C). LTPS is important for display industries since the use of large glass panels prohibits exposure to high temperatures. There are many methods that can transfer a-Si into poly-Si, such as SPC, excimer laser crystallization (ELC) and metal-induced crystallization (MIC) / metal-induced lateral crystallization (MILC). MIC/MILC methods have the merits of lower processing temperature, larger poly-Si grain size, and lower defects densities compared to SPC method, and cheaper processing cost and lower surface roughness compared to ELC method. But still facing the issues of high leakage currents, due to the metal contaminations in the channel layer, and asymmetric S/D regions.

In this work, we developed and fabricated symmetric Ni-induced lateral crystallization poly-Si TFTs with low Ni contaminations (LC-NILC poly-Si TFTs) by using a novel preheating method. The main differences between our novel methods of low metal contaminations Ni induced lateral crystallization (LC-NILC) and traditional MILC are: the Ni was removed before crystallization in the furnace; the amounts of Ni diffused into the channel layer were controllable by different low preheating temperatures, then the Ni contaminations could be successfully controlled.

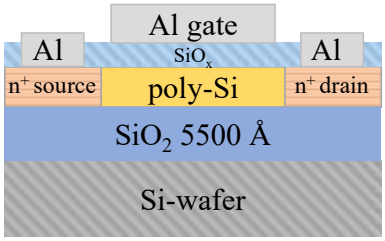

Fig. 1. Schematic of LC-NILC poly-Si TFTs cross-section.

2. Experimental Procedure

Fig. 1 shows the schematic of cross-sectional viewed LC-NILC poly-Si TFTs. The experimental process flows were shown in Fig. 2. First, a 4 inches p-type Si wafer was capped with a layer of 5500 Å thick SiO_2 wet oxide. Then a layer of 500 Å thick a-Si was deposited by low-pressure chemical vapor deposition (LPCVD) at 550°C. The a-Si layer was patterned and defined as the active layer, and Ni seeding windows were then subsequently patterned and defined by the photolithography process. An ultra-thin layer of 10-nm-thick Ni was deposited into seeding windows. The LC-NILC samples were preheated by the hot plate at 100°C for 10 minutes, and one control condition was unheated. The other one was annealed by RTA at 400°C for 30 seconds to form NiSi (R-NILC). After heating and RTA, Ni was removed by SPM solution. As a comparison, one control group was fabricated by traditional NILC (T-NILC) methods without removing of Ni layer. The NILC process was performed in the furnace at 500°C for 24 hours in N_2 ambient. Finally, recrystallization of NILC poly-Si films were done by RTA at 700°C for 30 seconds to eliminate defects in the poly-Si grain boundaries and obtain better crystallization quality. We have also fabricated a sample by conventional SPC methods. In SPC devices, a-Si was directly crystallized into poly-Si by the furnace at 600°C for 24 hours in N_2 ambient.

Afterward, source and drain areas were defined by the implantation of phosphorus with a dose of 5×10^{15} cm^{-2} and energy of 15keV. Dopants activation were done at 600°C for 2 hours to form n-channel devices. A 1000 Å thick plasma-enhanced chemical vapor deposition (PECVD) silicon oxide (SiO_x) were deposited as a gate insulator (GI). Then, the

source and drain contact windows were opened by wet etching. Finally, a 2500 Å thick Al was deposited and patterned as gate and S/D electrodes.

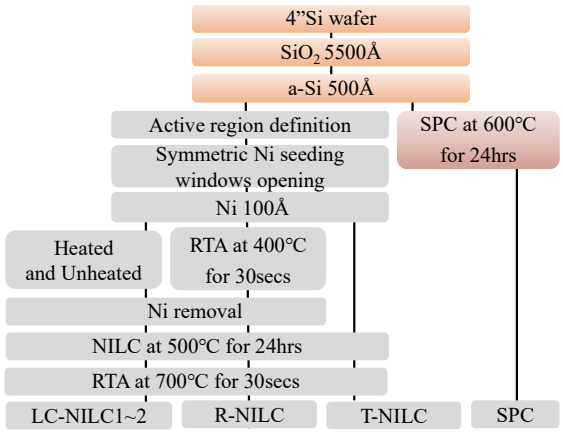

Fig. 2. Process flows for symmetric NILC and SPC ploy-Si TFTs

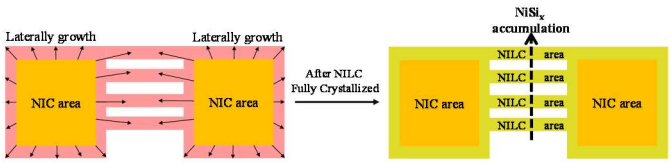

Fig. 3. Schematic of $NiSi_x$ accumulation in the channel region.

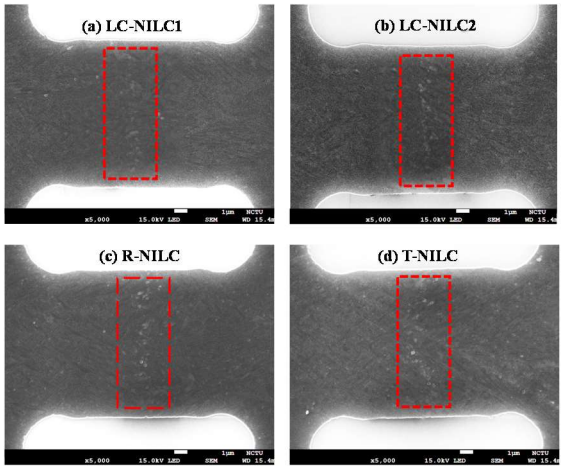

Fig. 4. SEM images of the channel region for (a)-(c) NILC poly-Si thin film with different preheating temperatures and (d) T-NILC.

3. Results and Discussion

Since the NILC device was crystallized from both side, the $NiSi_x$ will be accumulated in the middle of the channel after NILC, as illustrated in Fig. 3. The SEM images (Fig. 4) of the channel region with the magnification of 5k indicate that with the higher preheating temperature, the accumulation of Ni in the channel region is getting more serious. This is also the main reason that affects the leakage currents and subthreshold swing (S.S.). The middle of the channel, where the Ni accumulation occurred is marked out with the red dash line, the area of the rectangle is 4 μm × 10 μm. As we can see from both the SEM images, amounts of $NiSi_x$ residues in the channel are getting higher as the heating temperature increased, the highest amount of $NiSi_x$ residues existed in the T-NILC poly-Si TFTs.

Fig. 5 shows the comparison of I_D-V_G transfer curves in LC-NILC1~2, R-NILC, T-NILC, and SPC poly-Si TFTs. R-NILC and T-NILC poly-Si TFTs exhibit higher leakage currents, poorer subthreshold swing (S.S.), and lower on/off current ratio (I_{on}/I_{off}) compared to LC-NILC1~2 poly-Si TFTs. Those parameters are strongly correlated to the defects in the channel region, due to the contaminations of Ni.

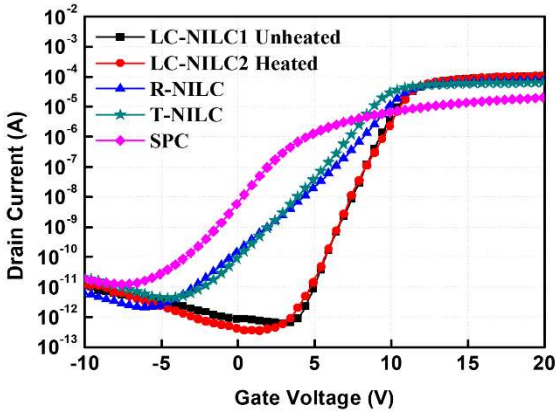

Fig. 5. Comparison of I_D-V_G transfer curves in LC-NILC1~2 to R-NILC, T-NILC, and SPC poly-Si TFTs.

4. Conclusions

We have demonstrated a novel method of NILC called LC-NILC. Differ from the traditional NILC method, Ni catalyst was removed before crystallization in the furnace. The amounts of Ni diffused into the poly-Si film could be successfully controlled with preheating by hot plate before removal of Ni layer. With reducing preheating temperature, the fewer amounts of Ni introduced into a-Si film, lower Ni contaminations can be obtained. The crystallization can also be done without preheating. The novel symmetric LC-NILC poly-Si TFTs with low metal contaminations appear great potentials for ultra-high definition (UHD) and micro-LED display applications in the future.

Acknowledgements

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