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Electrical Characteristics of a Uni-Directionally Crystallized MILC TFT

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MILC is known as an alternative for laser scanning for low temperature poly silicon. There have been, however, some problems to overcome before the industrialization of the MILC TFT, such as a high leakage current and relatively low electron mobility compared with those of other poly TFTs. Furthermore, the lateral crystal growth joint formed at the center of the TFT channel is thought to be responsible for these problems. The lateral crystal growth joint has been eliminated by the uni-directional MILC process proposed in this study and the electrical performance of the proposed TFTs has been investigated. It has been verified that the lateral growth joint is responsible for the high leakage current and low electron mobility. It was found that the electron mobility of the P-TFT is approximately 60 cm^2/Vsec and the leakage current was depressed to approximately 10 pA. These values are believed to be sufficient for the formation of not only the pixel but also the built-in driving circuits for AMLCDs and AMOLEDs. A new gate configuration for the elimination of the joint has been introduced and the electrical performance has been compared.

Keywords: MILC, LTPS, uni-directionally crystallization, TFT, AMOLED

1. INTRODUCTION

Since the electron mobility of poly silicon (poly-Si) is much higher than that of amorphous silicon (a-Si), display characteristics such as resolution, brightness, and image transport speed can be improved considerably if the current a-Si TFT can be replaced with a poly-Si TFT. Moreover, poly-Si TFTs have a large advantage in that it is possible to include built-in drivers[1]. Since advanced display products, such as Digital Multimedia Broadcasting (DMB) and portable TV, appeared in the market from late 2005, they are expected to create an explosive demand for poly-Si as well as AMOLEDs, in which high electron mobility is vital because it is a current driving device. Currently, high temperature poly TFTs are available in the market for devices such as projection LCDs, digital cameras, and so on.

Excimer Laser Scanning (ELS) can be used for the crystallization of a-Si into poly-Si on a common glass substrate[2]. The laser process, however, contains critical problems for industrialization, such as non-uniform crystallinity due to the inevitable scan overlap and surface roughness caused by the liquid-solid phase transformation, that are yet to be solved. Recently, much research has focused on non-laser LTPS processes such as Metal-Induced Lateral Crystallization (MILC)[3, 4]. In the case of MILC, the TFT channel is crystallized by lateral crystal growth at a temperature below 500 °C. The lateral crystal growth occurs through a catalytic phase transformation so that the channel area of the TFT is free from metal contamination[3-8]. The MILC TFT has many advantages over ELS TFT, but the relatively high leakage current and low electron mobility are regarded as problems for employing this technology[9]. Much research related to overcoming the problems in MILC TFTs has been undertaken and the general consensus is that the lateral crystal growth joint formed at the center of the channel is responsible for these problems. The lateral crystal joint contains many defects, such as twins, and metal silicide, which acts as trap sites for high leakage current. These defects seemingly work as a scattering source that considerably reduces electron mobility. One method for eliminating the joint is the application of an electrical field[8].

In this study, the metal catalyst, Ni, was deposited on only one side of the TFT (the source area) so that the lateral crystal growth could occur uni-directionally, which results in no crystal growth joint at the center of the TFT channel; furthermore, ion implantation on the joint was carried out in order to eliminate the trap sites. The electrical performance of the TFTs was compared and evaluated.

2. EXPERIMENTAL

Corning1737 glass was purchased and used as a substrate.

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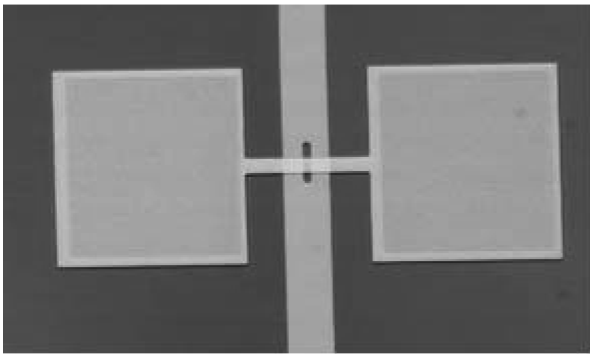

Fig. 1. Optical micrograph of the TFT with the holed gate. Ion mass doping was carried out after this masking step.

At 600 °C, compaction was carried out prior to any TFT fabrication processes. A 4000 Å buffer oxide was deposited with PECVD, followed by 600 Å a-Si deposition with LPCVD. The thickness of the gate oxide was 700 Å and a 2000 Å MoW was deposited as the gate. Ion mass doping was used to form the source and drain; boron diluted with H_2 was poured into the chamber at 13 SCCM, where 150 W RF was applied inside the chamber and 20 KeV DC was applied between the grids located above the samples. 100 Å Ni was sputtered either on the source or drain area, and MILC was carried out at 570 °C for 5 hours in a tube furnace with H_2 ambience.

A separate gate mask with a hole in the center of the gate was used in order to fabricate a TFT with a holed gate, as shown in Fig. 1. The MILC can be identified with an optical microscope, and the electrical characteristics of the prepared TFTs have been analyzed with HP4140B.

3. RESULTS AND DISCUSSION

In Fig. 2, the electrical properties of the TFT with and without the lateral crystal growth joint are compared; the differences in the leakage current and electron mobility are shown. The leakage current is defined as the minimum current along the gate voltage. The leakage current measured at 20 V was found to be reduced from 3.7 E-11 to 1.8 E-11. The hole mobility in the P-TFT was measured at 31 with the joint in the channel and 40 without the joint.

In Fig. 3, the electrical properties of the TFT with a normal gate and holed gate are compared. The difference is not as large as expected, even though the TFT with the holed gate shows better leakage current and mobility than the normal gate. In this case, both samples contained the lateral crystal growth joint after the MILC because the MILC is performed from both the source and drain at the same time. However, since the ion implantation is performed after the hole is made in the gate, the boron is implanted into the lateral crystal growth joint so that the defects and Ni silicides are mixed with the boron. Furthermore, the channel is not formed with

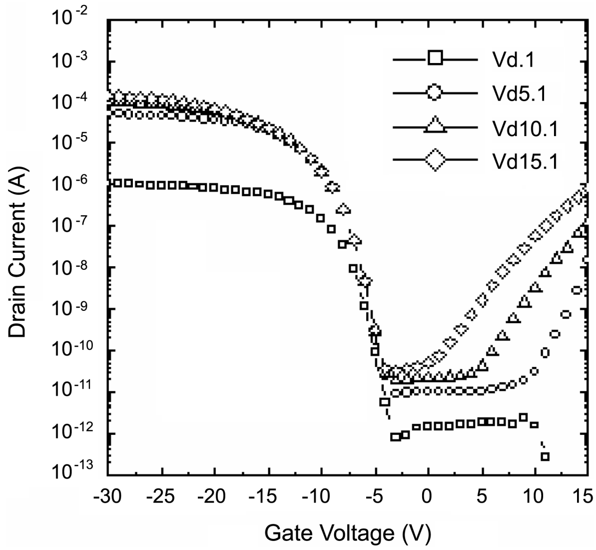

Fig. 2. I-V curves of the uni-directional MILC TFT (P-type TFT).

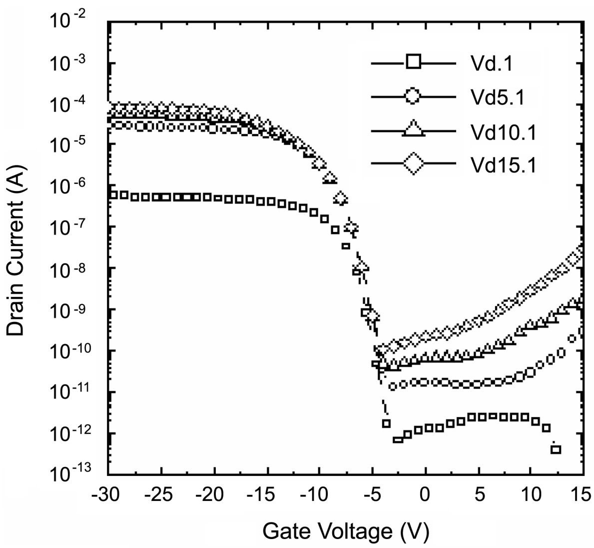

Fig. 3. I-V curves of the normal MILC TFT (P-type TFT).

the application of the gate voltage in this region, as in the case of the dual gate TFT, so the leakage current related to the lateral crystal growth joint is expected to be small. The hole mobility may not change because the lateral crystal growth joint is in the channel in both samples. Since the hole gap is approximately 1-2 microns, doping at the hole may not appreciably affect the hole mobility.

In Fig. 4, the electrical properties of the uni-directional MILC TFT are compared with those of the TFT with a holed gate. Considerable improvements in the leakage current and hole mobility can be noticed. The process for the TFT with the holed gate may be preferred in production because the uni-directional MILC TFT requires a twice longer MILC annealing time than the TFT with a holed gate. Also, note

Table 1. Comparison of the electrical properties among the three different MILC TFTs.

MILC TFT	Vth	Swing	Mobility	On current	Off current	On/Off
Uni-directional	8.5	0.8	40	9.9 E-5	1.8 E-11	5.4 E6
Normal	8	0.7	31	5 E-5	3.7 E-11	1.5 E6
Holed gate	8.5	0.8	34	7 E-5	3 E-11	2.3 E6

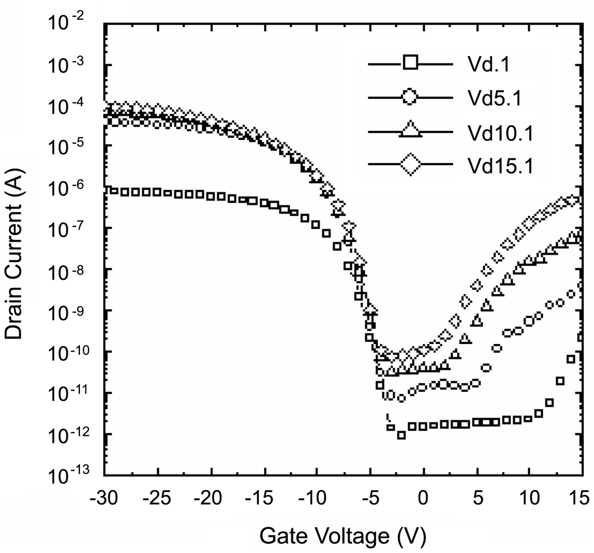

Fig. 4. I-V curves of the MILC TFT with a holed gate.

that the boron implantation into the lateral crystal growth joint formed by the MILC does not fully recover its electrical characteristics.

In Table 1, the electrical characteristics of the three TFT samples are compared. At this point, the effects of the lateral crystal growth joint on the electrical properties are not yet clear. However, the appreciable increase in the hole mobility and the reduction in the leakage current in the uni-directional MILC TFT strongly indicate that the lateral crystal growth joint is responsible for the poor electrical performance of the normal MILC TFT. Also, the slight but consistent improvements of the electrical properties of the TFT with the holed gate may lead to the development of the industrial technology that could put the MILC TFT into production in a near future.

4. CONCLUSIONS

It has been verified that the lateral growth joint is responsible to a certain degree for the high leakage current and low hole mobility. It was found that the electron mobility of the P-TFT is approximately 60 cm2/Vsec and the leakage current was depressed to approximately 10 pA. The lateral growth joint can be eliminated by allowing the MILC to occur from only one side, the source or the drain, but it will make the throughput lower in industrial terms due to an elongated processing time. A new gate configuration to eliminate the joint, the holed gate, has been introduced to produce an electrical performance as good as that of the uni-directional MILC TFT.

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