Reduction of Threshold Voltage in Metal-Induced-Laterally-Crystallized Thin Film Transistors

Man Wong, Gururaj A. Bhat, and Hoi S. Kwok

Center for Display Research &
Department of Electrical and Electronic Engineering
The Hong Kong University of Science and Technology
Clear Water Bay, Kowloon, Hong Kong

Tel: +852 2358 7057, Fax: +852 2358 1485, email: eemwong@ee.ust.hk

Abstract In conventional metal-induced-laterally crystallized (MILC) thin film transistors (TFTs), the source and drain regions are crystallized by metal-induced crystallization (MIC) self-aligned to the edges of the gate electrodes. A distinct grain boundary exists at the border between the MILC and the MIC regions. It will be shown that the apparent threshold voltage (V_t) of the MILC TFTs is affected by the presence of these MILC/MIC grain boundaries (MMGBs) at the edges of the transistor channels. Furthermore, V_t can be reduced either by eliminating the MMGBs from both the source and drain junctions or by hydrogen passivation of the traps in the MMGBs.

key words Metal induced lateral crystallization, thin film transistor, MILC/MIC grain boundaries

Introduction

Recently, MILC has been extensively investigated [1,2] as an alternative to conventional solid-phase crystallization (SPC). While the resulting MILC TFTs have been shown to be better in a number of device performance measures compared to their SPC counterparts [3], they suffer from higher leakage current [4] and earlier drain breakdown [5] because of a distinct grain boundary (Fig. 1) existing at the border between the MILC and the MIC regions

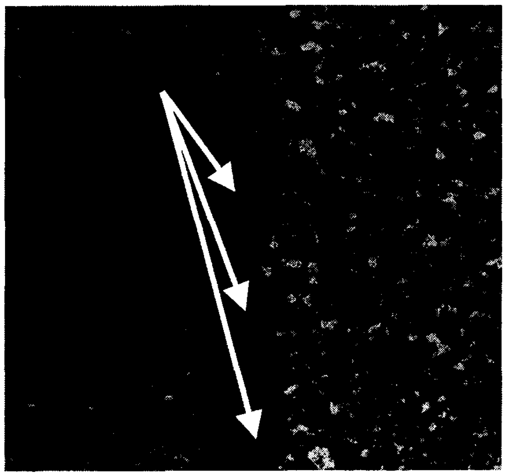

Figure 1. Transmission electron micro-graph showing a distinct grain boundary (MMGB) separating the MILC and the MIC regions.

The cause of these degradations has been attributed to the fact that the source and drain junctions of a conventional MILC TFT are formed by MIC that is self-aligned to the edges of the MILC channel region. Consequently, by separating the MMGB, with its high densities of traps and metal impurities (Fig. 2), from the drain metallurgical junction, with its high electric field, leakage current can be reduced and early drain breakdown can be eliminated [4,5].

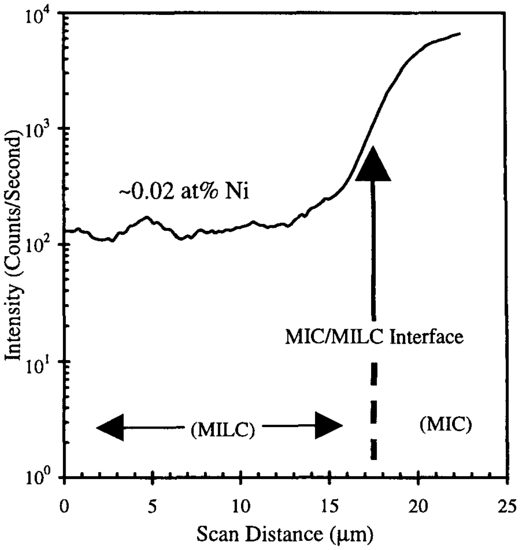

Figure 2. Secondary ion mass spectrometry showing higher Ni concentration within the MIC region and at the MIC/MILC boundary than within the MILC region.

It is further demonstrated in the present work that the presence of the MMGBs also affects the apparent V_t of the MILC TFTs, which is defined as the gate voltage (V_g) needed to achieve a drain current (I_d) = W/Lx10nA. Reduction of V_t can be realized either by eliminating the MMGBs from both the source and drain junctions or by hydrogen passivation of the MMGB traps.

Device Fabrication

Four-inch silicon wafers covered with 100nm thick thermal oxide were used as the starting substrates. A thin 100nm amorphous silicon (a-Si) layer was first deposited by low-pressure chemical vapor deposition (LPCVD) at respective pressure and temperature of 300mtorr and 550^{0}C. After patterning the a-Si layer to form the active islands, a 100nm thick layer of LPCVD low temperature oxide (LTO) gate insulator and 200nm thick a-Si gate electrode were deposited. The wafers were thoroughly cleaned after the gate electrode patterning and the exposure of selected areas in the source and drain regions. About 2nm of Ni was deposited in an ultra-high vacuum evaporation system. Subsequently, the source, drain, and gate regions were doped by self-aligned phosphorus implantation at a dose of $3x10^{15}/cm^2$ and an energy of 40keV. The wafers were then heat-treated at 500^{0}C, during which simultaneous Ni induced crystallization of the a-Si layers and dopant activation were accomplished. Finally, contact holes were opened through 500nm of LTO insulation layer, Al-1%Si was sputter deposited and the devices were sintered in Forming gas at 400^{0}C for 30 minutes. Hydrogen plasma passivation was performed in a 13.56MHz parallel plate reactor at 300^{0}C in a 300 mTorr gas mixture of 200sccm H_2 and 100sccm N_2. Schematic cross-sections of the devices with three different MMGB locations relative to the source and drain junctions are shown in Figure 3.

Results and Discussions

Shown in Figure 4 is the dependence of I_d on V_g of a) a conventional MILC TFT, b) an MILC TFT with the MMGB offset from the drain-junction and c) an MILC TFT with the MMGBs offset from both source and the drain junctions. Clearly, the I_d-V_g characteristics and the apparent V_t values of the first two devices are almost identical. On the other hand, the V_t value of the last device, with the double-sided offset, is clearly smaller.

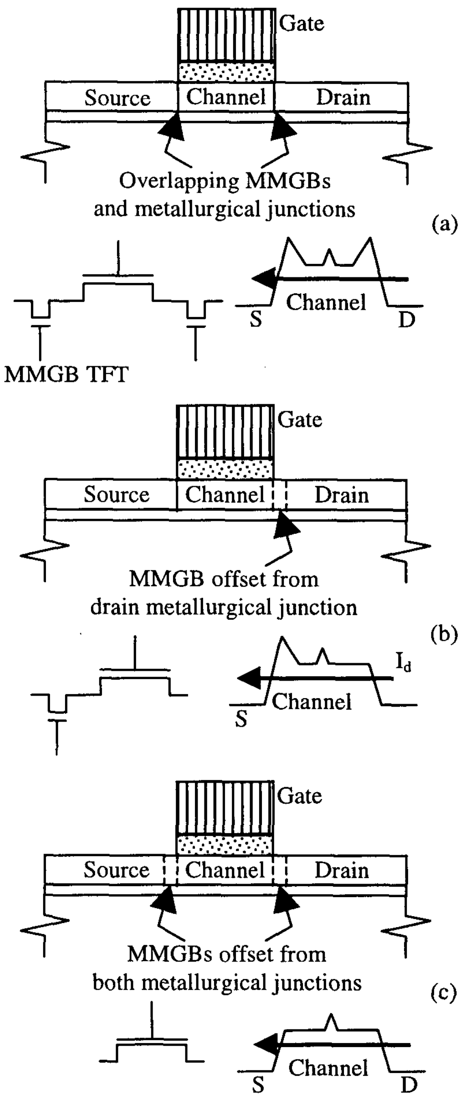

Figure 3. Schematic cross-sections, low V_t device models and the associated potential barriers across the channels of a) a conventional MILC TFT with the MMGBs self-aligned to both source and drain junctions, b) a one-sided offset MILC TFT and c) a double-sided offset MILC TFT.

When an MMGB coincides with any one of the metallurgical junctions, it becomes part of the channel. The high density of grain boundary trap states effectively raises the local, hence also the overall, V_t of the device. Only by removing the MMGBs from both junctions can one effectively reduce the V_t. However, it should be noted that the difference in this V_t is only apparent and does not lead to an increase in I_d at sufficiently high V_g. This is because an MMGB has a very small lateral extent, hence can be considered as a device with a very short channel length, albeit with a higher V_t. While conduction at low V_g is limited by the high V_t MMGB TFT (Figs. 3a), it is limited at high V_g by the resistance of the intrinsic MILC channel TFT (Fig. 3c), which is common to all three device structures.

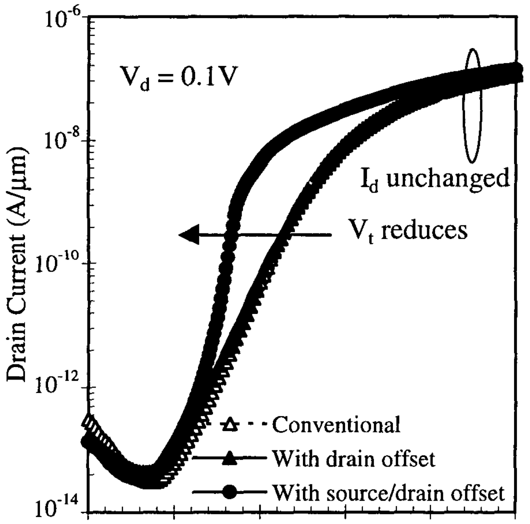

Figure 4. I_d-V_g characteristics of the three different kinds of MILC TFTs.

Clearly, since the high apparent V_t is caused by the high density of MMGB traps, it should be possible to reduce this V_t by passivating the traps, as shown in Figure 5.

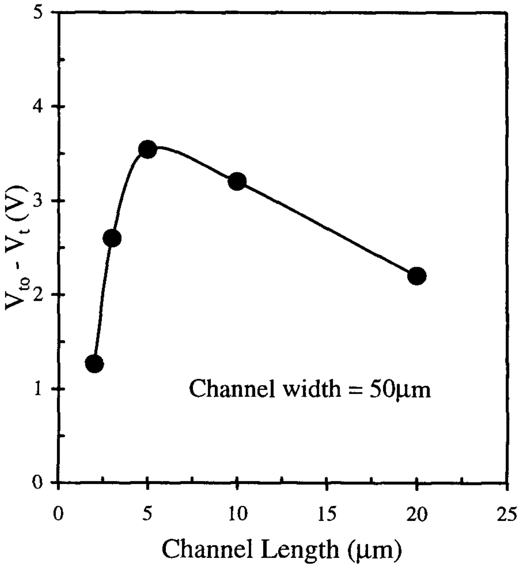

Figure 5. Changes in the apparent threshold voltage before (V_{to}) and after (V_t) a 30-minute plasma hydrogen passivation.

Unlike the data shown in Figure 4, those in Figure 6 show an increase in I_d at high V_g, probably because the MILC channel TFT is also partially passivated by the hydrogen plasma.

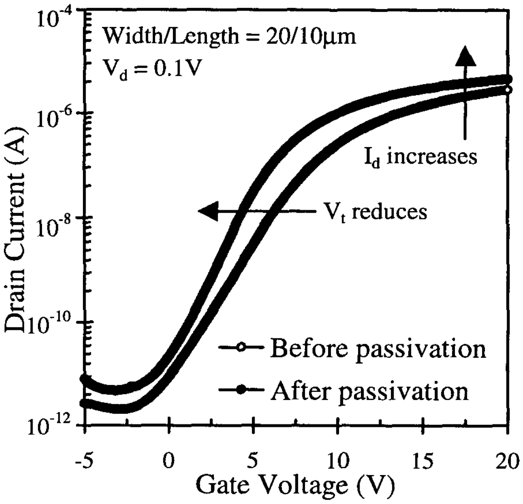

Figure 6. Effects of plasma hydrogenation on the I_d-V_g characteristics of MILC TFTs.

Conclusions

In this work, the effects of the MMGBs on the apparent V_t of MILC TFTs are reported. Complete removal of the MMGBs results in an apparent V_t reduction but not necessarily in an increase in I_d at high V_g. The MMGB traps can also be passivated in a hydrogen plasma, resulting in a reduction in the apparent V_t and a simultaneous increase in I_d.

Acknowledgment

This work was supported by grants from the Hong Kong Research Grants Council and the Hong Kong Industrial Department.

References

1. S. W. Lee and S. K. Joo, IEEE Electron Device Letters, Vol. 17, No. 4, 1996, p160-163.
2. Z. Jin, G. A. Bhat, M. Yeung, H. S. Kwok, M. Wong, J. Appl. Phys., vol 84, no 1, 1 July 1998, pp. 194-200.
3. G. A. Bhat, Z. Jin, H. S. Kwok and M. Wong, "Effects of Longitudinal Grain Boundaries on the Performance of MILC TFTs", IEEE Electron Device Letters, Vol. 20, No. 2, 1999, p97-99.
4. T. H. Ihn, B. I. Lee, T. K. Kim, K. H. Kim, J. W. Shin, P. S Ahn, W. C. Jeong, and S. K. Joo, Digest of Technical Papers, SID '97, p188-191.
5. G. A. Bhat, Z. Jin, H. S. Kwok and M. Wong, the 56th Annual Device Research Conference, June 22-24, 1998, p110-111.