Possibility of Si TFT Technology

Takashi Noguchi
Institut d'Electronique Fondamentale, UMR 8622 Universite Paris-Sud,
Bat. 220, 91405 ORSAY Cedex, France
Phone: +33-1-69157842, E-mail: noguchi@ief.u-psud.fr

Abstract

Si TFTs are applied not only to stacked SRAM but also to FPD. Improvement of device characteristic such as an enhancement of carrier mobility or a reduction of leakage current is studied intensively. The TFT technology is developing based on conventional Si LSI technology. By establishing a stable fabrication process on flexible substrate and high performance characteristic uniformly and reliably, TFT technology has a possibility to develop to SOP or other highly functional applications similar to or beyond the conventional Si LSI in the era of information and telecommunication.

1. Introduction

Si TFTs have been developed remarkably in the last 20 years and play an important role as a semiconductor device, today. a-Si TFT with uniform characteristic is an effective device to drive a pixel in large panel LCD (Liquid Crystal Display). The poly-Si TFT is applied to mono-functional devices such as a static memory or a FPD (Flat Panel Display) with peripheral circuit of CMOS driving, and has a further possibility for multi-functional system i.e. SOP (System on Panel). For the FPD, O-LED (Organic Light Emitting Diode) of direct emission is also actively reported. The TFT performance can be improved by optimizing the device structure as well as the process by adopting the effective fabrication process such as SPC (Solid Phase Crystallization), ELA (Excimer Laser Annealing) or MILC (Metal Induced Lateral Crystallization) etc.. High performance TFT can be realized not only on glass or on Si substrate but also on flexible metal or on plastic. On the other hand, following a trend of lowering voltage and shrinkage of device size similar to the Si LSI, the improvement of characteristic including reliability is studied intensively. [1, 2]

2. Enhancement of drain current for high performance characteristics

Many efforts are done to realize a higher performance TFT with high on current. Results on high field effect mobility in TFT as high as the bulk mobility in conventional Si MOS transistors have been reported by increasing the grain size using laser crystallization or metal induced crystallization etc.. In order to improve both of the TFTs as CMOS application, detailed study on carrier conduction should be done not only for electron but also for hole. [3] Also, reliability of device performance is important. [4]

In order to produce the maximum performance of TFT characteristics, optimum process and materials are required for the thin source and drain electrodes. To realize a lower resistivity and good ohmic contact, efficient activation, new doping process and/or silicidation process in low temperature process have been studied. [5]

3. The requirement for a reduction of driving voltage and a shrinkage of device size

Si TFTs are practically applied for a high density SRAM (Static Random Access Memory) in LSI and for LCD and for O-LED or ELD (Electro-Luminescence Display) as an active matrix panel. Today and from now on, not only an improvement but also reliable and uniform device characteristics are required for poly-Si TFTs following a trend of a reduction of driving voltage and a shrinkage of device size. As smaller the size is, the device characteristics depend more sensitively on the film structure. In principle, the larger the grain size, the higher the TFT performance, the more degraded the uniformity. [6, 7]

In pixels, the mobility value of TFTs is not required so high as in peripheral circuits for active-

matrix FPD. a-Si TFTs of low mobility still has a higher advantage in terms of uniformity for the large panel LCD. TFTs and their process having optimum grain size should be developed in order to suit the circuits in each application.

In order to realize uniform and high performance TFTs, fabricating one TFT in each single-crystal grain, i.e. location controlled crystallization method, has been proposed. [8] Excellent SOI-like characteristics have been reported by fabricating a TFT in a single-crystal-like grain. [9, 6, 10, 11] In order to ensure the highly uniform and high performance TFT characteristics, basic research on the device and process must be further studied.

In order to develop the TFT technology universally as in Si LSI, the conventional MOS process or the system should be reviewed. Conversely, the TFT process or the system will affect the Si LSI technology, before long.

4. State of art of Si TFT on panel and a possibility

Currently, poly Si TFT is studied for the application of driving circuit for LCD or O-LED. [1, 2] Today, the FPD device requires more functional and flexible SOP. In general, glass is popular as an under substrate. On the other hand, a plastic display panel, which is light and has a strong robustness, is wanted. As this material, such as PES (Polyethersulphone) PET (Polyethyleneterephthalate) or PI (Polyimide) has a large thermal expansion in general, and lower process temperature is required for the TFT fabrication. Relating studies have been reported. [12] Recently, unique transferred process technique from glass to plastic named SUFLA (Surface Free Technology by Laser Annealing) has been proposed and demonstrated in circuit level. [13] On the other hand, poly Si TFT can also be fabricated on metal substrate as for a reflective type LCD or O-LED. TFT characteristic on stainless steel has been reported. [14] Suitable and stable material for the substrate in place of glass, appropriate film structure and optimum process are required and are under development.

As for a small panel size, a LCD viewfinder for video camera or for digital-still camera and a LCD projector have been fabricated in practical application. Today, small size cellular phone using not only LCD but O-LED is expected. In this case, flexible substrate with high robustness has a higher advantage. High functional mounting method of FSA (Fluid Self Assembly), which embeds LSI chips on the plastic substrate, has also been developed as a rival technique for TFT technology. [15]

As for medium panel using Si TFTs, mounting the functional circuits such as a peripheral circuit, DAC (Digital/Analog Converter), memory and even PU (Processor Unit) is expected. [1] Furthermore, as a static display application, paper-like display is expected and is being developed. [16] The TFT will contribute as an informational terminal between display and telecommunication system not only through TV or PC but also through portable cellular-phone or smart card.

For the display, high resolution with high contrast is required. For the application, sometimes, we should look back at the past techniques. In a window of a western styled church, a black stripe was adopted in a "stained glass" already a few centuries ago to enhance the contrast. Also, we can see a painting using three-dimensional or cubic technique in a museum in Asia or in Europe.

5. Summary

A possibility of TFT technology is briefly described from viewpoints of the technical trend and the application on panel. The high performance TFT having uniform and reliable characteristic is expected. Si TFTs have been developed in the last 20 years and have established an important status in Semiconductor device. Currently, for an active matrix FPD, high functionality is expected by mounting additional circuits such as a memory, a DAC including PU. In order to develop the technology for innovative applications on flexible substrates, a few technical subjects being lying ahead should be overcome, and coming SOP era using TFT should be possible.

6. References

[1] "AM-LCD'01" (2001).

[2] Proc. of "IMID" (2001).

[3] K. Kanzaki, AM-LCD'01, 71 (2001).

[4] T. Ohno, Y. Uraoka, T. Hatayama, T. Fuyuki, Y. Morita, Tech. Report of IEICE, ED2000-7, SDM 2000-7, 43 (2000-04).

[5] J. Jang and K.W. Kim, AM-LCD'99, 235 (1999).

[6] T. Noguchi, Jpn. J. Appl. Phys. 32, L1587 (1993).

[7] R. Ishihara, AM-LCD'01, 259 (2001).

[8] H. Kumomi, T. Yonehara and T. Noma, Appl. Phys. Lett. 59, 3565 (1991).

[9] N. Yamauchi, J.-J.J. Hajar and R. Reif, IEEE Trans. Electron Devices 38, 55 (1991).

[10] M.A. Crowder, P.G. Caray, P.M. Smith, R.S. Sposili, H.S. Cho and J.S. Im, IEEE Trans. Ele. Dev. Lett., 19, 306 (1998).

[11] K. Makihira and T. Asano, AM-LCD'00, 33 (2000).

[12] N. D. Young, D. J. Mcculoch and R. M. Bunn, AM-LCD, 47 (1997).

[13] T. Shimoda and S. Inoue, IEDM, 289 (1999).

[14] F. Omata and T. Serikawa, AM-LCD'99, 243 (1999).

[15] A. Chiang, AM-LCD'01, 81 (2001).

[16] "Nikkei Science" (February), 42 (2002).