Effective ELA for Advanced Si TFT System on Insulator

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Abstract

Effectiveness and its possibility of ELA (Excimer Laser Annealing) for advanced Si TFT system on insulator are described. Currently, extensive study is carried out to realize an advanced SoG (System on Glass) based on LTPS (Low Temperature Poly-Si) technique. By reducing further the process temperature and by improving the fabrication process of LTPS, addressing TFT circuits for FPD (Flat Panel Display) can be mounted onto a flexible plastic as well as onto a glass substrate. Functional devices on the insulating panels are developed to be formed by using ELA. Although technical issues are remained for the fabrication process, Si transistors including 3D TFT structure formed by ELA is expected as a functional Si system on insulator in the ubiquitous IT era.

1. Introduction

The poly-Si TFT (Thin Film Transistor) has been developed for high-resolution LCD (Liquid Crystal Display) panel with peripheral circuit on glass using LTPS (Low Temperature Poly-Si) process, and has a further possibility for highly functional SoG (System on Glass)[1). For the AM FPD (Active Matrix Flat Panel Display), currently, O-LED (Organic Light Emitting Diode) display has been actively reported as well as conventional LCD of indirect emission type. As the LTPS-TFT performance is improved by optimizing the effective crystallization process of ELC (Excimer Laser Crystallization), Si TFTs can be realized not only on glass but also on flexible metal or on plastic. In order to realize an advanced functional FPD, many efforts are carried out on the improvement of the device structure by modifying the fabrication process. On the other hand, following a tend of lowing the voltage related to the decrease in device size and the requirement of a display with a high resolution, a uniformity issue including reliability for the TFT becomes important[2). Advanced functional devices are also required in the realization of a new application. A TFT structure and its fabrication process should be considered from a viewpoint of a low-temperature process using ELA technique for advanced system on insulator.

2. High quality a-Si film required for U-LTPS

The conduction current in a poly-Si TFT depends not only on the device geometry but also strongly on the carrier mobility related to the crystallinity in the Si channel. An excimer laser having UV (Ultra-Violet) pulsed beam can heat up only Si surface or thin Si layer without inducing a thermal damage on the substrate. Notable random grain growth by optimizing the energy condition with multi-shots ELC or ELA has been reported[3-6). A lateral crystallization effect at intentional thermal slope in the Si film is drastic[7-9). As the sufficient energy density of excimer laser exposure melts the Si film, the grain boundary improves and the electrical barrier height becomes lower similar to the case after SPC (Solid Phase Crystallization). The cystallinity of the film after ELC is higher than that of the film after SPC[10), although the surface smoothness is inferior. For a much lower temperature process of poly-Si TFT below 200°C, deposition by sputtering[11-13) or by Catarytic CVD[14) is a candidate technique in place of PE (Plasma Enhanced) CVD which is used conventionally in LTPS. By adopting r.f. sputtering technique using He[12) or Xe[13) gas, optimized amorphous-Si film with low impurity has been obtained. As a result of ELC, quite large grains of 0.5-1 μm or larger are obtained at room temperature.

For the source and drain in the thin Si film, effective activation process is required. Effective doping results of low resistance have been reported using ELA[15, 16]. The activation by using ELA is higher advantage than by using thermal annealing because of the lower resistance without giving thermal damage against the substrate.

3. Si TFTs on panel as a functional system using low-temperature-compatible ELA process

A Poly-Si TFT is studied for the application of driving circuit for an LCD or O-LED display. Currently, for FPD, a more functional and/or unique application is desired by mounting high performance TFTs on a panel. By using short channel TFTs with uniform and high performance characteristic, functional logic circuits shall be mounted on glass. If the process is optimized, a more ideal TFT structure such as double (both-sided) gates TFT or FIN type TFT[17] is a candidate for the future AM FPD as well as in Si micro-electronics. By adopting a uniform lumped beam ELA to realize the two dimensional thermal slope during the grain growth[7-9, 17], superior poly-crystalline grain structure can be obtained, and a FIN typed TFT of high mobility can be obtained without adding the photo-lithography mask number. By improving and by optimizing the fabrication process, much higher performance with low leakage is expected for the future fine patterned TFT structure.

Mounting the N-V (Non Volatile) memory using Fe (Ferro-electric) material such as PZT (PbZrTiO) is also expected as a smart panel application[18]. By combining LTPS, the integration of TFT Fe-RAM (Random Access Memory) on panel such as a structure of 1T/1C stacked array is expected. In the case of floating dot TFT structure, some of the unique dot formation by adopting ELA technique has been reported, and primitive device characteristic as a NV memory cell has been analyzed[19].

In the case of stack-typed SRAM (Static RAM) in Si LSI, x-Si (single-crystalline-Si) TFTs with uniform characteristic are required in place of poly-Si TFTs. A x-Si layer of 3D (Three Dimensional) structure has been realized on SOI (Silicon on Insulator) substrate using UHV (Ultra-High Vacuum) CVD and subsequent seeded lateral ELC[20]. As a result of fabricating a TFT for the obtained x-Si liked layer, excellent transfer curve showing high mobility of 558 $cm^2/V.s.$ was obtained[21]. 3D TFT system will be realized in the future system on insulator application.

On the other hand, currently, a plastic AM FPD panel, which is light and thin, and has a strong robustness, is desired in portable use.. A typical plastic substrate such as PES (Poly-Ether-Sulphone) or PEN (Poly-Ethylene-Naphtahalate) has a small thermal hardness and large thermal expansion property; thus, a lower temperature process below 200°C is required for the TFT fabrication. Furthermore, in general, a direct acid treatment for cleaning must be neglected. A sputtered amorphous Si film[11-13] or micro-polycrystalline Si film formed by ICP (Inductive Coupled Plasma) CVD at high plasma density[22] is a candidate for the ultra-low temperature pre-deposition of a Si film for a channel, as the amount of hydrogen contained in the film is fairly low. Promising results for a TFT on plastic have been reported[12, 23-26]. In this method, not only the TFT design but also the buffer layer on the plastic must also be considered to optimize the U-LTPS process[24, 25]. As a flexible substrate, poly-Si TFT can be fabricated even on metal for a reflective LCD or an O-LED display. On the other hand, transfer process techniques from one temporal substrate to another plastic are proposed as a panel fabrication[27]. A stable, and optimal flexible material with small thermal expansion for a substrate having a modified buffer structure, which endures thermal and chemical damage and is compatible with LTPS, is required.

For a portable cellular phone, flexible substrate using U-LTPS TFT process having a highly robust, thin and light-weight is more advantageous than conventional glass substrate. By improving LTPS using ELA technique, mounting the functional circuits, such as a peripheral circuit, the fabrication of DAC (D/A Converter), ADC, sensor[28], a memory and even CPU (Central Processor Unit) is expected. Functional and high-performed Si TFTs formed by adopting the ELA process may serve as a smart display system as a future information terminal[29].

4. Summary

An improvement in the silicon thin film and relating high performance functional TFTs on insulator were briefly described based on the lower temperature process using ELA. Some of the new

TFT result realized by using ELA was introduced and reviewed. Currently, for an AM FPD, high functionality is expected by mounting additional circuits on insulating panels. Also, a higher image quality with lower voltage driving is expected using O-LED display, although the requirement of uniformity and stability for the TFT characteristic becomes severe. By overcoming the technical issues for a desired smart Si TFT system, coming SoP era should be possible.

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