Field Enhanced Rapid Thermal Process for Low Temperature Poly-Si TFTs Fabrications

Hyoung-June Kim and Dong-Hoon Shin
Viatron Technologies Corp., R&D center, Geumcheon Gu, Seoul, Korea

Abstract

VIATRON TECHNOLOGIES has developed FE-RTP system that enables LTPS LCD and AMOLED manufacturers to produce poly-Si films at low cost, high throughput, and high yield. The system employs sequential heat treatment methods using temperature control and rapid thermal processor modules. The temperature control modules provide exceptionally uniform heating and cooling of the glass substrates to within $\pm 2^{a}$ *C. The rapid thermal process that combines heating with field induction accelerates the treatment rates. The new FE-RTP system can process 730×920 mm glass substrates as thin as 0.4 mm. The uniform nature of poly-Si films produced by FE-RTP resulted in AMOLED panels with no laser-Muras. Furthermore, FE-RTP system also showed superior performances in other heat treatment processes involved in poly-Si TFT fabrications, such as dopant activation, gate oxide densification, hydrogenation, and pre-compaction.*

1. Introduction

Low temperature poly-Si (LTPS) LCD and AMOLED are emerging as the newer generation of displays. However, technical difficulties and high production costs of current manufacturing methods of poly-Si backplane are preventing rapid progress and full growth potentials of LTPS LCD and AMOLED displays. Although various methods to produce poly-Si films on glass have been extensively researched in the last ten years, the only commercially available technology to date has been the excimer laser annealing (ELA). However, this method suffers from a number of adverse drawbacks when put into mass production operations, such as narrow process windows, rough film surfaces, hydrogen eruptions, and non-uniformity. In particular, the non-uniform quality of ELA-based poly-Si continues to impede the progress of AMOLED developments. Additionally, the ELA system has proven to be overly complicated and difficult to maintain to be effective as a mass production procedure.

In order to overcome many of the difficulties encountered in production of poly-Si, VIATRON TECHNOLOGIES has developed Field-Enhanced Rapid Thermal Processor (FE-RTP) that would enable the display manufacturer to produce uniform quality poly-Si films at low cost, high throughput, and high production yield.

Although the FE-RTP system is developed primarily for poly-Si film production (i.e., rapid crystallization of a-Si), its applications can be expanded to include other heat treatment processes, such as dopant activations, gate oxide densifications, hydrogenations, and pre-compaction of glasses.

2. Field Enhanced Rapid Thermal Process

The precept of FE-RTP system is uniform heating and cooling of glass substrates in a combination with RTA function to accelerate the crystallization process. Schematic description of FE-RTA system is shown in Fig. 1.

Figure 1. Schematic diagram of FE-RTP system

The system is of an in-line design consisting of multiple temperature control modules (TCM) and an FE-RTP process module. The modules sequentially heat and cool the glasses. Uniform heating and cooling of glass substrate is found to be essential in preventing glass damage and attaining poly-Si film that exhibit uniform TFT performances. The TCM with multi-zone temperature control system provided temperature uniformities of glasses within $\pm 2°$ C.

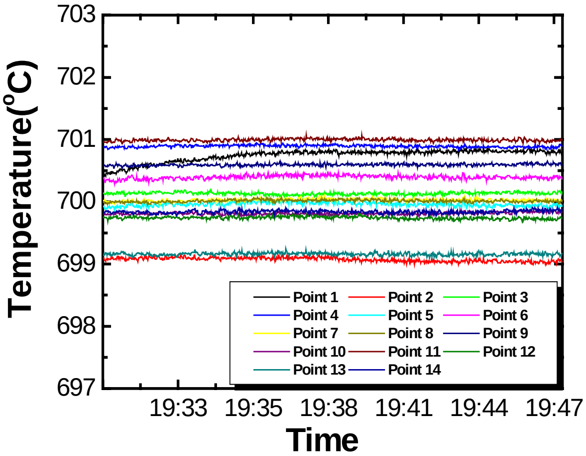

Figure 2. Temperature uniformity at 14 glass positions during TCM heat treatments, measured by thermocouple-attached glass

The FE-RTP process module located between heating and cooling modules enhances the crystallization kinetics thus accelerating the process. The FE-RTP heat treatment involves rapid thermal heating of glass in combination with alternating magnetic field induction that is observed to increase the heating efficiency. The alternating magnetic field induced alternating electric voltage of up to 2000V. It has been reported that the induction of electric field during the heat treatment increased the kinetics of MIC, MILC, and SPC processes [1~4].

3. Processes

3.1 Crystallization of amorphous Si

Crystallization of amorphous Si (a-Si) into poly-Si by solid phase crystallization (SPC) and metal-induced crystallizations (MIC) are well established in the industry and the academia. However, these processes required relatively high temperatures and/or long process times, often resulting in glass damages, such as warping, breakage, and thermal stress. The FE-RTP system has been able to process SPC and MIC on glasses without damages because of its ability to control temperature uniformities and significantly reduce crystallization times. Fig. 3 shows FE-RTP process times of complete-SPC compared to those of conventional furnace. Generally, SPC takes 10 hours or longer in conventional furnaces. The FE-RTA system reduced the crystallization time by orders of magnitudes. The current FE-RTP system can process 12 to 20 Gen-4 size glasses an hour. While the quality of poly-Si film and its TFT performance are dependant on crystallization process conditions and

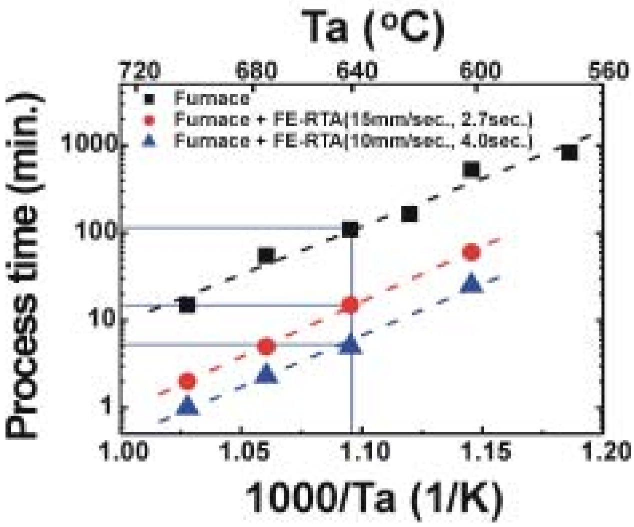

Figure 3. Crystallization time as a function of temperature with and without FE-RTA treatments.

TFT process recipes, n- or p- TFT mobilities of 20 to 50 cm^2/Vsec had been achieved using FE-RTP. The most important characteristic of FE-RTP poly-Si emerged to be TFT uniformity. The uniformity of poly-Si TFTs within 1% V_t variation was achieved.

We believe that high uniformity of poly-Si panels will be a key factor in the successful developments of AMOLED display manufacturing. Several display makers have already demonstrated uniform AMOLED panels (free of laser-Mura) using FE-RTP technology.

Figure 4. Poly-Si glass panel of Gen. 4 size (730×920 mm) by FE-RTP

3.2 Dopant activation

Another useful application of FE-RTP is found to be dopant activation annealing. As the poly-Si TFTs advance toward system-on-panel (SOP) designs, dopant activation techniques without junction damage, especially in n-type doping, are becoming increasingly important. ELA or conventional furnaces were traditionally used for dopant activations. However, high operating cost and complexity of ELA and incomplete and insufficient dopant activations of furnace annealing have limited the wide acceptance of such methods in the industry. Not only is the low sheet resistance value important, but complete defect recovery is also critical for achieving high performance poly-Si TFTs. Fig. 3 shows the measured R_s value and defect recovery for various FE-RTP process conditions. Source/drain n-type doping through gate oxide was carried out for laser-crystallized poly-Si layer.

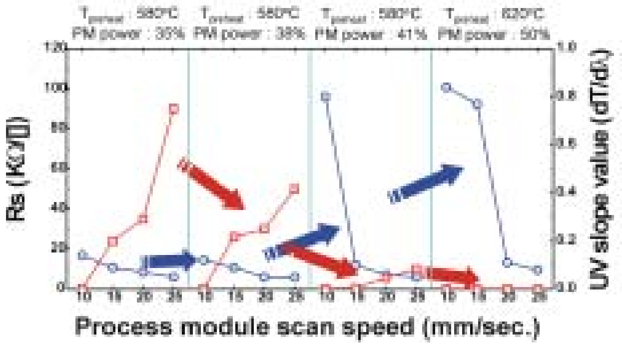

Figure 5. R_s and UV slope value for various FE-RTP conditions.

Here, the defect recovery was monitored by transmittance of UV-Visible spectrometry. UV-slope value was determined at 431 nm from transmittance spectrum. The slope shows low value of about 0.1 after amorphization of Si lattice by doping. As the amorphized Si was recovered to crystalline Si through recrystallization, the UV slope value was increased up to 0.8. As seen in Fig. 5, R_s and UV slope values strongly depend on the scan speed in the process module. By decreasing the scan speed from 25 mm/sec to 10 mm/sec, the Rs was lowered to ~300 ohm/□. It is interesting to note that even though R_s was lowered to minimum value, amorphized Si was not fully recovered when the scan speed was high. The presence of residual amorphous Si at the source/drain junctions leads to the degradation of TFT characteristics. The combination of TCM and FE-RTP modules resulted in fast dopant activation with complete defect recovery at relatively low temperatures (~620 ^oC).

4. Conclusion

FE-RTP system provides the unique heat treatment methodology of sequential furnace and field-enhanced rapid thermal processes. The FE-RTP system produces uniform poly-Si glass panels at low cost and high productivity. We believe that high uniformity of poly-Si panels as large as Gen.4 will provide the solution to the successful developments of AMOLED and LTPS LCD display manufacturing. FE-RTP system also shows superior performances in other heat treatment processes in poly-Si TFT fabrications, such as dopant activation, gate oxide densification, hydrogenation, and pre-compaction of glass.

5. References

[1] Jun, S. I., Yang, Y. H., Lee, J.B., and Choi, D.K. Appl. Phys. Lett. 75, 15 (1999)

[2] Ahn, J.H., Lee, J.N., Kim, Y.C., and Ahn, B.T., Curr. Appl. Phys. 2, 135 (2002).

[3] Yoon, S.Y., Park, S.J., Kim, K.H., and Jang, J., Thin Solid Films 383, 34 (2001).

[4] Park, S.H., Kim, H.J., Kang, K.H., Lee, J.S., Choi, Y.K., and Kwon, O.M., J. Appl. Phys. 38, 1511 (2005)