Alternating Magnetic Field Crystallization of Amorphous Si for LTPS-OLED

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1. Introduction

Formation of device-quality poly-Si films is one of key technology for achieving poly-Si Thin Films Transistors (TFTs) for various display applications including poly-Si TFT LCDs and OLEDs [1]. Since the poly-Si TFTs are fabricated on the glass substrates, the formation process of poly-Si should be carried out at low temperatures (<500 °C) to avoid the damage of glass substrates. Excimer Laser Crystallization (ELC) method is a common method for low temperature process of forming poly-Si film[1]. However, ELC method has numerous problems such as non-uniform crystalline quality, extremely narrow process window, rough film surface, and hydrogen eruptions. We propose a new method for obtaining high quality poly-Si films at low temperatures without causing the glass damage. This process features the induction of alternating magnetic field during the course of heat treatment for crystallizing the amorphously-deposited Si into a poly-Si form.

2. Experiments and Results

Amorphous Si films are deposited onto glass substrate (Corning 1737) using low pressure chemical vapor deposition (LPCVD) or plasma enhanced chemical vapor deposition (PECVD). When the sample is annealed in a conventional furnace, the crystallization takes approximately 7 hrs at 600 °C. As mentioned, this high thermal budget damages the glass substrate and is not acceptable for practical application.

As a means of lowering the crystallization temperature, we inducted high frequency magnetic field during the crytstallization annealing. Here, the strength of magnetic field is 100 Gauss and the frequency is 14 KHz. The induction of alternating magnetic field is found to enhance the crystallization kinetics remarkably. The crystallization is completed in less than 1 hr even at the temperatures as low as 430 °C. We also found that the increase of magnetic field strength linearly increase the kinetics of crystallization.

The reason for this enhancement is not clearly understood yet. It is well known that alternating magnetic field generates the electromotive force (EMF) to the amorphous Si films according to the Faraday's Law. One of possible explanation, therefore, is a activation of electron movement by EMF, causing the Joule heating as a case of induction heating for conductive metal objects. This explanation can be seemingly justified considering that the number of free electrons rapidly increases with temperature. However, the experimental measurement of film temperature shows the film temperature is negligibly increased by magnetic field. Also, theoretical thermal flow analysis indicates the absence of induction heating.

Another explanation is a field-enhanced atomic movement of Si atom. We carried out a molecular dynamic simulation for estimating the change of crystallization kinetics based on the assumption that fixed number of charged atoms can be reacted with external EMF field. The result suggests that the atomic movement and consequent crystallization can be greatly enhanced by the presence of EMF field.

3. Conclusions

We found that the induction of alternating magnetic field remarkably enhances the kinetics of crystallization of amorphous Si film. The reduction of crystallization temperature along with process time provides a strong potential of this method as the means of achieving poly-Si film on glass substrate. Furthermore, crystal quality of formed poly-Si is high enough for TFT performance for display operation. A mass- production system based on this technology for the use of manufacturing poly-Si TFT LCDs and OLEDs is now under development by Viatron Technologies Co..

4. References

[1] J.S. Im and R.S. Sposili, "Crystalline Si Films for Integrated Active-Matrix Liquid-Crystal-Displays", *MRS Bulletin*, MRS, March 1996, pp. 39-48.
[2] T. Sameshima, M. Hara, and S. Usui, "XeCl Excimer Laser Annealing Used to Fabricate Poly-Si TFTs", *Jpn. J. of Applied Physics*, 1989, pp. 1789-1793.