

Joule-heating induced crystallization (JIC) for AMOLED TFT-Backplanes

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Abstract

The grain size of JIC poly-Si can be varied from few tens of nanometers to the one having the larger grain size exceeding that of excimer laser crystallized (ELC) poly-Si according to transmission electron microscopy. JIC poly-Si exhibits an excellent uniformity with regards to the grain size. We report here the blanket crystallization of the large area using the 2nd generation glass substrate.

1. Introduction

Active matrix organic light emitting diode (AMOLED) has recently come into the spotlight for its applicability to the next-generation flat panel displays. Since the device operates in a current-driven mode uniform source/drain current is critical to uniform picture quality. Low temperature polycrystalline silicon (poly-Si) is thus preferred to amorphous silicon (a-Si) for the thin-film-transistor backplanes. A crystallization technology should produce poly-Si having a uniform grain size over the whole panel especially for AMOLED application. The methods of forming poly-Si at a low temperature include solid phase crystallization (SPC) [1], metal induced crystallization (MIC) [2], metal induced lateral crystallization (MILC) [3], and excimer laser crystallization (ELC) [4]. We reported a crystallization technique named as Joule-heating induced crystallization (JIC) at SID '06 [6]. In this technique, Joule heat is generated by applying an electric field to a conductive layer and is used to raise the temperature of the silicon film to crystallization temperature. We used a conductive Mo-layer located beneath or above the amorphous silicon film for JIC crystallization as a Joule-heat source in this work. Crystallization was

accomplished within the range of a millisecond by solid state transformation. We report here the blanket crystallization of the large area using the 2nd generation glass substrate.

2. Experimental

Schematic diagrams illustrating the constitution of a JIC specimen were already reported elsewhere [5, 6]. Using the plasma enhanced chemical vapor deposition (PECVD) method, a SiO₂ layer (first dielectric layer) with a thickness of 300 nm was formed on a 0.7 mm-thick glass substrate. A Mo thin film (conductive layer) having a thickness of 100 nm was deposited on the first dielectric layer by sputtering, and then a SiO₂ layer (second dielectric layer) having a thickness of 300 nm was deposited thereon using the PECVD method. The PECVD method also resulted in an amorphous silicon thin film having a thickness of 50 nm being deposited on the second dielectric layer. Thus, an array, glass/SiO₂/Mo/SiO₂/a-Si, was prepared. Or, an array, glass/SiO₂/a-Si/SiO₂/Mo, was also used. The sheet resistance of the conductive layer was measured to be $\sim 2 \Omega/\square$. An electric field was applied to a Mo film within the range of a millisecond for crystallization.

3. Results and discussion

When we used an ITO film as a conductive layer for Joule-heating the produced JIC poly-Si only exhibited nano-crystalline phase with equiaxed morphology according to the results of transmission electron microscopy (TEM) [7]. In this study we used

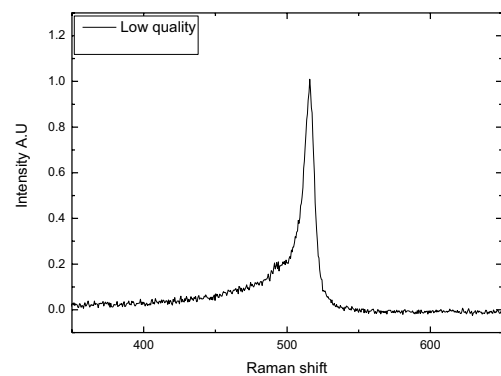
a conductive Mo-layer as a Joule-heat source, where we observed that crystallinity could be varied widely by changing processing parameters. Figure 1 shows the Raman spectra of JIC poly-Si produced under different processing conditions. In Fig. 1 the Raman spectrum of (a) corresponds to JIC poly-Si produced by applying an electric field of 600 V/cm for 15 μ s, while (b) and (c) show the spectrum of the ones produced by applying an electric field of 700 V/cm for 15 μ s and of 750 V/cm for 15 μ s, respectively. Crystalline quality was observed to approach to that of ELC poly-Si by increasing the strength of electric field.

Using the same 3 samples shown in Fig. 1 we conducted transmission electron microscopy. Figure 2 shows bright field TEM micrographs of the JIC poly-Si produced under different processing conditions. The a-Si film was observed to be fully crystallized according to TEM observation. As can be seen in Fig. 2 the grain size of JIC poly-Si can be varied from tens of nanometers to hundreds of nanometers. It is interesting to note that the JIC poly-Si produced by applying an electric field of 750 V/cm for 15 μ s has the grain size of \sim 500 nm as shown in Fig. 2(c), which is larger than that of the typical ELC poly-Si.

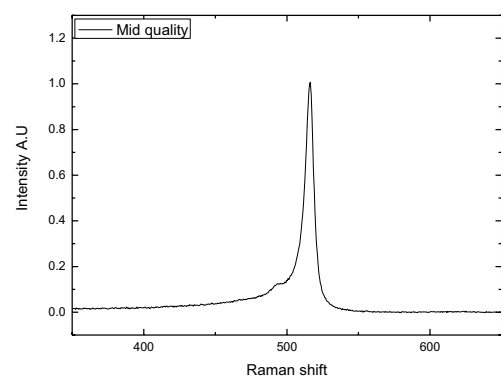
We checked the macroscopic uniformity of the crystallinity for the three kinds of poly-Si samples produced by the methods of JIC, ELC, and MIC, respectively using Raman Spectroscopy. Raman measurements were conducted on the 9 points using the poly-Si samples having dimensions of 20 mm x 20 mm. It was observed that non-uniformity of JIC poly-Si, ELC poly-Si and MIC poly-Si shows 1.1 %, 2.3 %, and 7.2 %, respectively. Among the three different samples JIC poly-Si reveals the best crystalline uniformity. Since the Joule heat is generated uniformly throughout the conductive layer, temperature of the film can be more uniform compared with any other conventional heating methods. From these measurements it was found that ELC poly-Si also shows a good uniformity since the microstructure of ELC poly-Si has a pseudo-hexagonal grain structure due to the nature of transformation from liquid to solid. ELC poly-Si, however, may have a localized non-uniform zone due to variation of laser intensity or due to inaccuracy of overlap. These factors may lead to mura-problem especially in the case of large-sized AMOLED panel. In the case of MIC method the spatial distribution of Ni particles on the a-Si film directly determines the variation of the grain size of the transformed poly-Si.

Therefore a special care should be taken in order to overcome this problem. Moreover, an optimum gettering process should be well developed in order to minimize metallic contamination leading to the problem of leakage current.

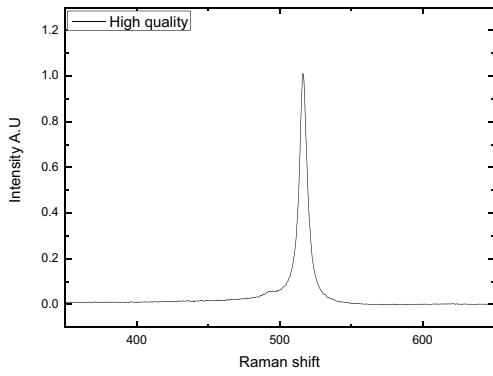
We have investigated processing conditions related to JIC crystallization such as the magnitude of electric field, the pulsing time, and the sample structures using the small-sized samples as indicated in Fig. 3. In this work we conducted blanket crystallization using the 2nd generation glass substrate using a high pulsed power-supply. Figure 4 illustrates the two photographs showing (a) the a-Si sample before applying an electric field, and (b) the crystallized poly-Si sample produced by the JIC process. Complete crystallization was successfully accomplished on the whole 2nd generation glass substrate.



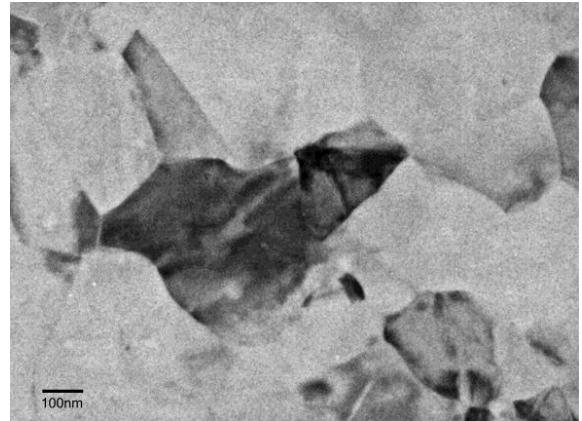
(a)



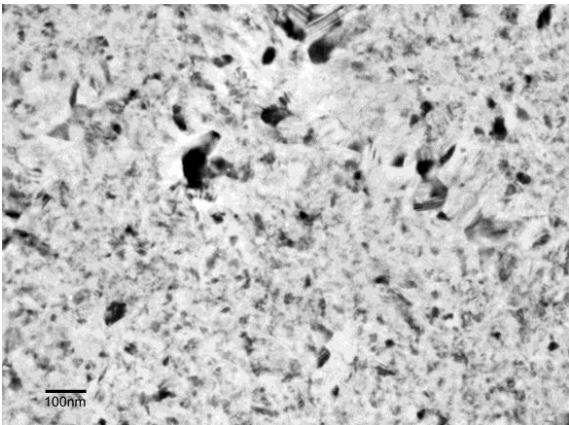
(b)



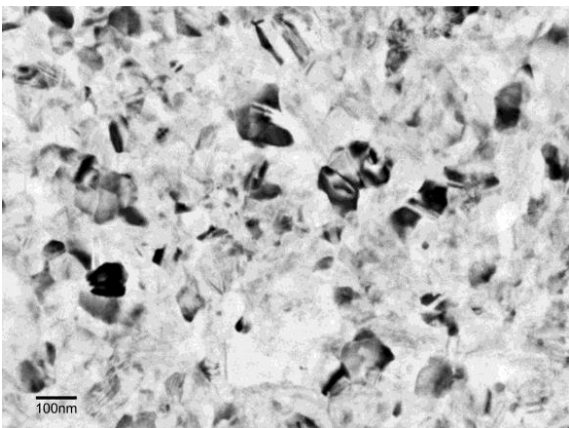
(c)
Fig. 1 Raman spectra of JIC poly-Si produced under different processing conditions



(c)
Fig. 2 Bright-field TEM micrograph of the JIC poly-Si produced under different processing conditions



(a)



(b)

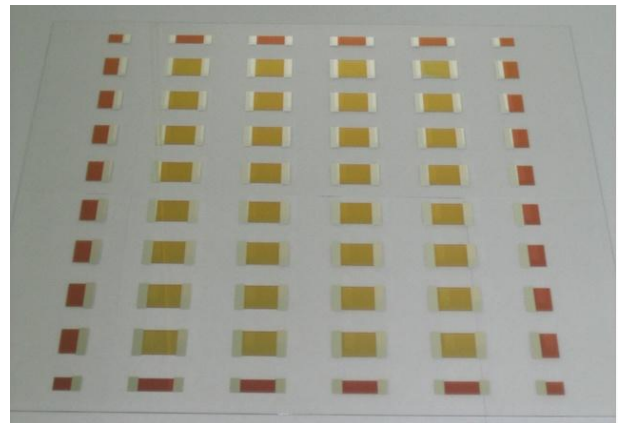
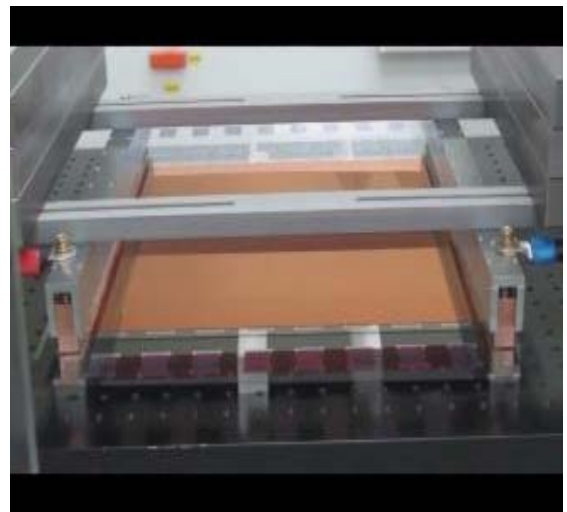
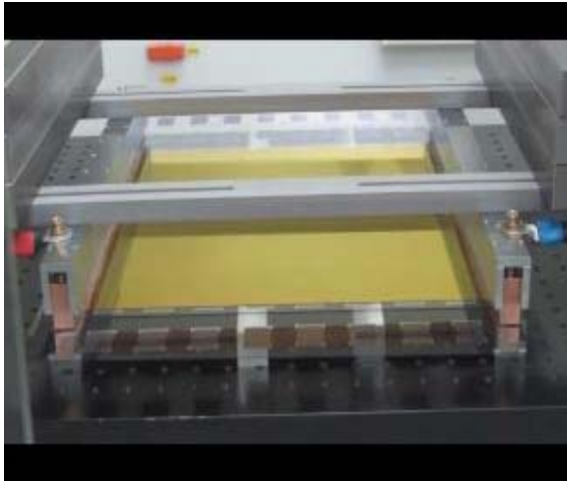


Fig. 3 Small-sized (20 mm x 20 mm) JIC crystallized samples on the 2nd generation glass substrate



(a)



(b)

Fig. 4 JIC sample (a) before applying an electric field, and (b) after applying an electric field using the 2nd generation glass substrate. After applying an electric field the complete crystallization on the whole substrate area was successfully accomplished.

4. Summary

We conducted Joule-heating induced crystallization (JIC) of amorphous silicon using a conductive Mo-layer as a Joule-heat source. JIC poly-Si shows a wide range of crystallinity by changing processing parameters. Under some conditions the grain size of JIC poly-Si was observed to be larger than that of ELC poly-Si. We demonstrated the blanket JIC crystallization using the 2nd generation glass substrate. Such a process does not make use of any metallic element for preferential nucleation, and is completed within a millisecond at room temperature. As the macroscopic/microscopic uniformity of the grains of the JIC poly-Si film is excellent, this process is expected to find its applications, especially with regards to AMOLED.

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