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Uniform Performance TFT with Excimer Laser Annealing of Solid Phase Crystallized Poly-Si

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Solid phase crystallized poly-Si films were annealed by XeCl excimer laser, for improvement of crystallinity, and poly-Si TFTs were fabricated. The obtained TFTs had the superior characteristics with excellent uniformity. The mobilities were fairly constant in the wide energy density range from 230 to 310mJ/cm^2 for 80nm thick poly-Si TFTs. TEM observation reveals that crystallinity of the surface-near region of the poly-Si film was improved. This indicates that the surface-near region melted and then recrystallized from the underlaid poly-Si layer. The results show the process stability of this method.

1. Introduction

Polycrystalline silicon thin film transistors (Poly-Si TFTs) are attractive for the application of the switching element and the peripheral circuit of the active matrix liquid crystal display. In order to obtain high performance poly-Si TFTs, the various approach has been investigated in the past decade.[1,2,3] One of the promising technique is the excimer laser induced crystallization of amorphous-Si (a-Si). However, the crystallization technique has serious problem of uniformity of the performance, since uniformity is strongly influenced by stability of the energy density of the excimer laser, and by homogeneity of the energy density within the beam. Moreover, the poor quality poly-Si in the overlapped region between beams degrades the performance, when the beam is scanned.[4]

The other approach is to use large grain poly-Si films by solid phase crystallization technique.[5] Although uniformity is excellent, the defective part of poly-Si films formed by this method deteriorates the performance.

In this paper, we will show that we successfully obtain the high performance poly-Si TFTs with excellent uniformity, by means of excimer laser annealing (ELA) of the solid phase crystallized poly-Si films.

2. Device fabrication

80nm and 120nm thick a-Si films were deposited at 500 ℃ on the quartz substrates, and were annealed at 600℃ in N_2 for 20hrs. for the crystallization. Then XeCl excimer laser was irradiated to the poly-Si films. The energy density was varied from 190 to 450 mJ/cm^2 with the area-scanning on the wafers. The number of shots was varied up to 50 shots without scanning.

After the definition of the active areas, 100nm gate oxide was deposited by LPCVD, and the poly-Si TFTs were fabricated by the conventional MOSFET process with maximum process temperature of about 900℃. For the p-ch and n-ch S/D formation, B^+ ions and P^+ ions were implanted at a dose of 1E15cm^{-2} each. The offset gate structure was used for the reduction of the leakage current.

3. Results and discussion

3-1 TFT characteristics

Mobility was calculated from the gm,max in the linear region of the self aligned TFT, and leakage current was measured with n-ch offset gate TFT.

Figure 1 shows the typical Id-Vg characteristics of n-ch TFT with ELA at the different energy densities. The threshold voltage was lowered, and the leakage current was reduced with increasing energy density.

Figure 2 shows the dependence of the field effect mobility on the energy density. This figure shows that the mobility was unchanged below

190mJ/cm^2, however, the mobilities increased abruptly over 210mJ/cm^2. This is the indication of the melting of the poly-Si films.

In the energy density range from 230 to 307 mJ/cm^2 for the 80nm thick poly-Si and from 230 to 420mJ/cm^2 for the 120nm thick poly-Si, the mobilities were fairly constant for both p-ch and n-ch TFTs, and their deviation is as small as that of the TFTs without ELA. As will be discussed after, the wide process margin of the energy density originates in high latent heat of the poly-Si, which is equivalent to the excimer laser energy density of 80mJ/cm^2 for the 80nm poly-Si film, considering the reflectivity.

The mobilities became higher with larger deviation, at 335mJ/cm^2 for 80nm thick poly-Si TFTs, and they had rather strong dependence on the energy density, which may cause instability of the process.

In Fig.3, the mobility was found to have little dependence on the number of the shots, and the leakage current of TFTs was kept lower less than 20 shots, for the 80nm thick poly-Si TFTs.

The above results show that ELA of poly-Si film is effective for fabricating uniform performance TFTs, because of little dependence on the annealing condition in wide range of energy density.

3-2 TEM observation

TEM micrographs of the 80nm thick poly-Si films before and after ELA are shown in Fig.4. After ELA at 307mJ/cm^2, defect is reduced but the structure of the poly-Si film is the same as that without ELA, as is shown in Fig.4(a) and (b).

Figure 5 shows the cross-sectional TEM micrograph of the poly-Si film after ELA at 245mJ/cm^2. This micrograph shows that the surface-near region changes to a columnar structure with some ridges at the grain boundaries from the defective poly-Si region and the crystallinity is better than the underlaid poly-Si layer. These indicate that melting at the surface-near region occurred. Thus, crystallinity of the surface-near region was improved by the recrystallization of the melting surface-near region, seeded from the underlaid poly-Si layer. This process is schematically shown in Fig.6.

In Figure 2, the melting threshold energy density is the same value, for the different thickness of poly-Si films. This is because the excimer laser is absorbed in the surface-near region, and then temperature of this region locally rises. As the energy density increases, the melting front proceeds toward the bottom of the poly-Si films, and when the melting front reaches the bottom, the structure of the poly-Si film changes drastically, as is shown in Fig.4(c).

The mobilities are not dependent on the energy density, since they are affected by quality of the surface-near region which corresponds to inversion layer. On the contrary, the leakage current and the threshold voltage, which reflect quality of whole poly-Si films, may be improved as the melting front proceeds.

4. summary

Using ELA of solid phase crystallized poly-Si, high performance TFTs can be obtained with excellent uniformity, in the wide range of the energy density of 210 to 307mJ/cm^2 for the 80nm thick poly-Si TFTs. TEM observation shows that crystallinity of the surface-near region is improved. Improvement of crystallinity is caused by the melting and the recrystallization of the surface-near region.

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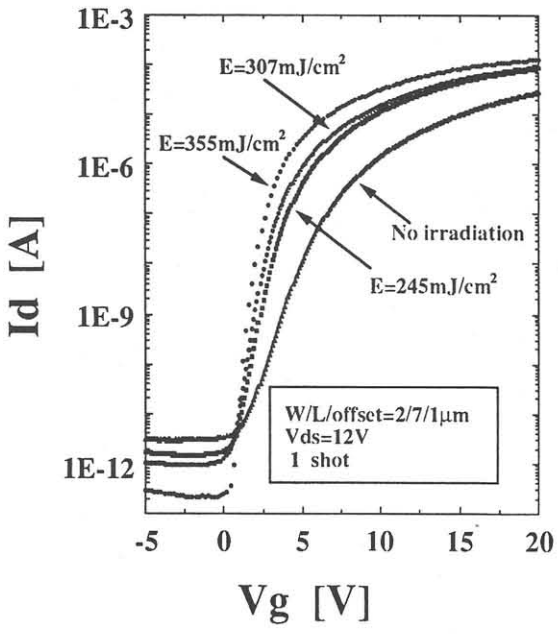

Fig.1. Id-Vg characteristics of the TFTs irradiated at the different energy densities.

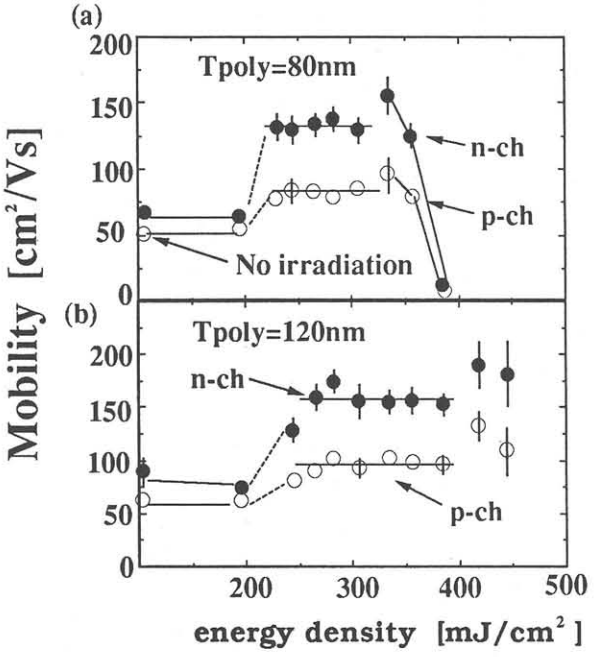

Fig.2. The mobilities as a function of the energy density of the XeCl excimer laser. The thickness of the poly-Si film (Tpoly) is (a) 80nm and (b) 120nm.

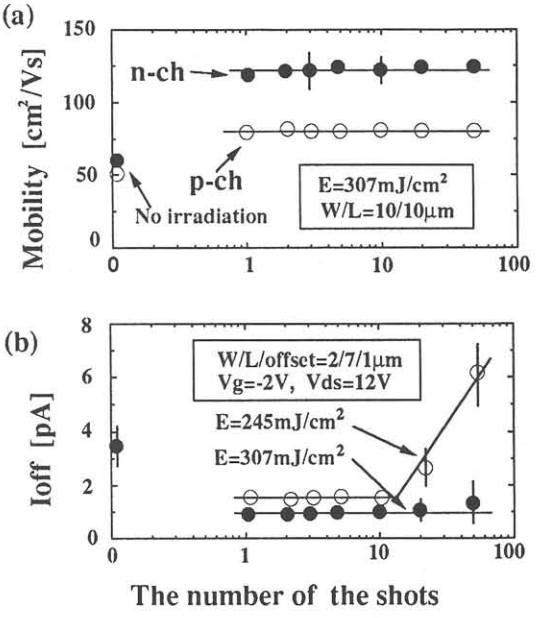

Fig.3. The mobility (a) and the leakage current (b) as a function of the number of the shots.

(a) Before irradiation (b) Irradiation at 307mJ/cm² (c) Irradiation at 355mJ/cm²

Fig.4. Plan-view TEM micrographs of the solid phase crystallized poly-Si films, irradiated at the different energy densities.

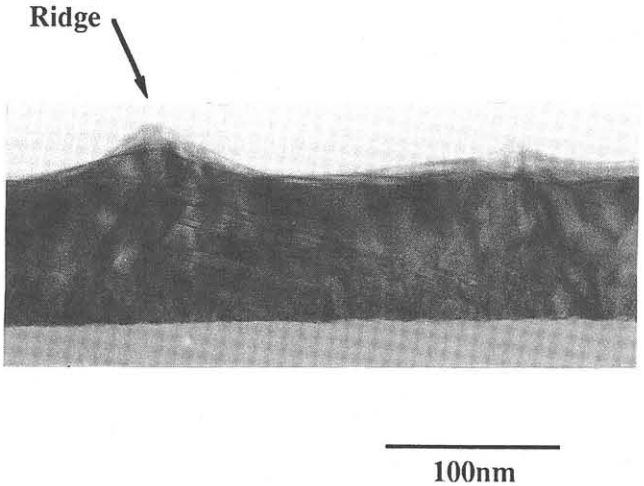

Fig.5. Cross-sectional TEM micrograph of the poly-Si film, irradiated at 245mJ/cm².

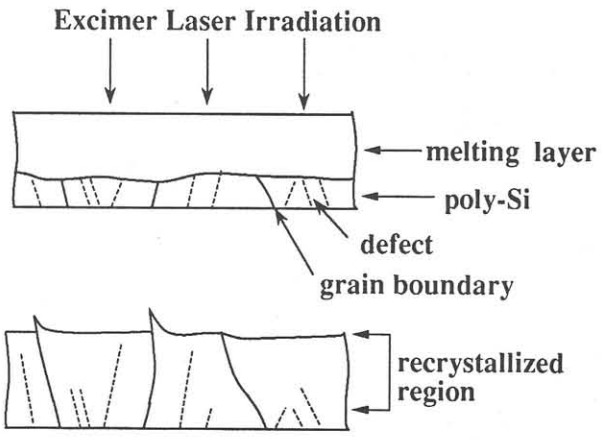

Fig.6. Schematic diagram of the crystallization process during and after ELA.