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C-MOS Self-Aligned Low Temperature Poly-Si TFTs Fabricated by Laser Annealing of Poly-Si Films

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C-MOS self-aligned poly-Si TFTs for integrated drivers and poly-Si TFTs for pixels have been made using a low temperature (600°C) process with laser annealing. LPCVD poly-Si film deposited on a glass substrate was selectively recrystallized by laser irradiation. Impurity ions were implanted into the source and drain regions and were activated by XeCl excimer laser annealing. The above-mentioned technique is very effective for fabricating self-aligned pixel TFTs and C-MOS TFTs for integrated drivers, both of which have little parasitic capacitance.

1. INTRODUCTION

Laser annealing is an effective method for forming high performance TFTs which enable the low temperature fabrication of active matrix liquid crystal displays (AMLCDs) with integrated drivers[1]. Self-aligned TFTs can be produced by using LPCVD poly-Si[2]. Such as-deposited poly-Si self-aligned TFTs can achieve sufficient on currents, low off currents, and reduced capacitance which make them suitable for pixel TFTs in high resolution AMLCDs. Further, by using laser annealing around only the periphery of the substrates, it is possible to fabricate C-MOS self-aligned poly-Si TFTs for use as driver elements[3]. By combining the as-deposited poly-Si pixel TFTs with peripheral laser recrystallized TFTs, it is possible to realize a high resolution AMLCD with integrated drivers.

2. ANNEALED POLY-Si EXPERIMENTS

A 25nm poly-Si film was deposited by LPCVD at 600°C on hard glass. This film was recrystallized by 50ns-FWHM pulses of a XeCl excimer laser in vacuum. The laser beam intensity was unified with a beam homogenization system. The uniformity of the laser beam intensity was ±5%. We have investigated the laser beam intensity between 0 to 500mJ/cm². The laser recrystallized poly-Si characteristics were researched by TEM, Raman scattering, STM, and ellipsometry.

Poly-Si grain size and crystalline volume fraction are dependent upon the laser beam energy during recrystallization. Fig.1 shows the relation between laser energy and TEM grain size and crystallinity determined by Raman spectroscopy. Crystallization threshold was laser energy density 260mJ/cm². The grain size and the crystalline volume fraction increase with laser energy density from 260mJ/cm² to 370mJ/cm². Although the thickness of the poly-Si layer was only 25nm, grain size can reach 200nm. These values rapidly decrease with irradiation above 400mJ/cm² because of amorphization. Fig.2(a) and Fig.2(b) are plane view TEM micrographs of poly-Si recrystallized at 310 and 370mJ/cm², respectively. From TEM analysis, it was observed that the grains of films annealed at 310mJ/cm² are of equiaxed morphology with clear boundaries. The poly-Si annealed at 370mJ/cm² has obscure grain boundaries and gives the 39cm²/V·sec n-channel TFTs. The obscure poly-Si grain boundaries are the same as seen in other recent work[4].

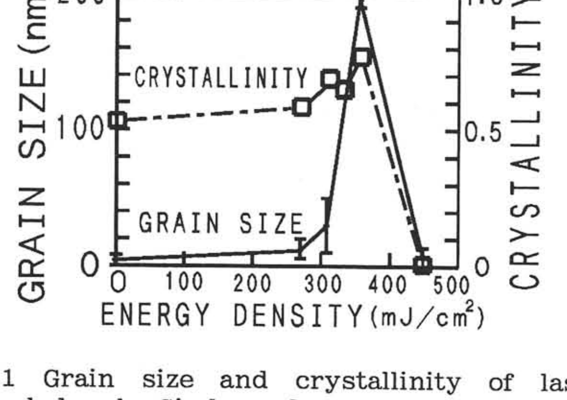

Fig.1 Grain size and crystallinity of laser anneeled poly-Si dependence on laser energy density.

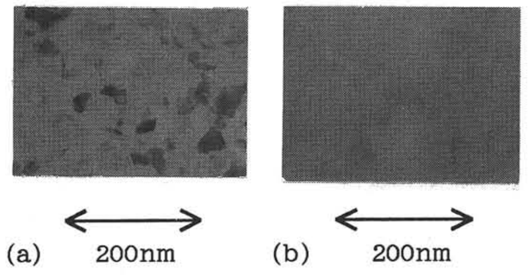

Fig.2 TEM micrograph of laser annealed poly-Si films. (a) 310mJ/cm^2 (b) 370mJ/cm^2

3. LASER RECRYSTALLIZED POLY-Si TFT

3-1. LASER ANNEALED TFT FABRICATION

The main features of the present process include the use of a LPCVD poly-Si layer, selective recrystallization of the channel poly-Si by XeCl laser annealing, and the use of self-aligned structure employing XeCl laser annealing for activation of source and drain region ion implanted impurities. Fig.3 shows a cross-sectional view of the TFT process utilizing the above features. The structure is staggered, self-aligned type which allows the simultaneous fabrication of both pixel TFTs and integrated driver elements on the same glass substrate. Undoped poly-Si film is deposited to a thickness of 150nm on a SiO_2-coated hard glass substrate at 600℃ using LPCVD with SiH_4 as a source gas. After the 150nm poly-Si was patterned for source and drain regions, undoped 25nm poly-Si is deposited and covers the first poly-Si islands. Following LPCVD deposition, the poly-Si layer is laser annealed in vacuum at a laser energy of 370mJ/cm^2 at room temperature. The laser beam intensity is homogenized as mentioned previously. After SiO_2 deposition of an ECR-CVD gate insulator layer at 180℃, a n-type poly-Si gate electrode is formed. $^{11}B^+$ and $^{31}P^+$ are implanted to form self-align source and drain regions at energies of 40keV and 120keV, respectively with a dose of $3\times10^{15}cm^{-2}$ while covering the opposite type TFT with photo-resist. For activation of the impurities in poly-Si, TFTs are irradiated by a XeCl excimer laser at 400mJ/cm^2. The sheet resistance of the boron doped and phosphorus doped 25nm poly-Si is 2k$\Omega/\square$ and 4k$\Omega/\square$, respectively. After opening the contact-hole in source and drain regions, an Al metal contact is formed. Finally, the completed device is subjected to a final hydrogenation step by ECR plasma.

3-2. LASER ANNEALED TFT CHARACTERISTICS

Fig. 4 shows the dependence of mobility and off current of n-channel TFT on laser energy density. Here, the off current is defined as the drain current at gate voltage (Vgs) -10V from the minimum current and at a source-drain voltage (Vds) of 4V. As shown in Fig. 1 and Fig. 4, the mobility, grain size, and crystalline volume fraction increase as energy density

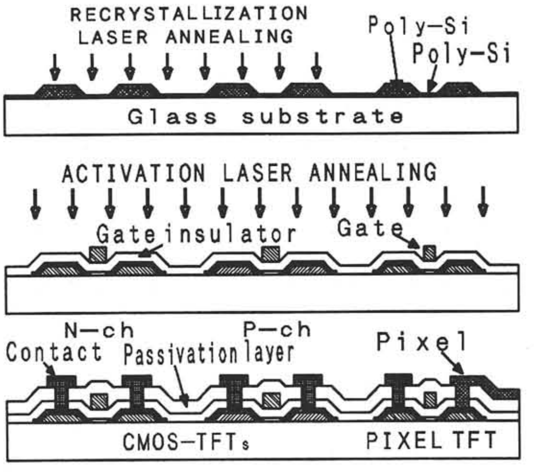

Fig.3 Process flow for self-aligned TFT with laser selective irradiation.

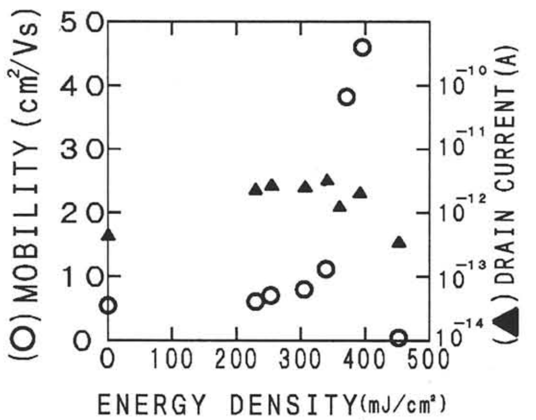

Fig.4 Mobility and off current of poly-Si TFT.

changes from 260 to 370mJ/cm^2. Over 410mJ/cm^2, poly-Si changes to amorphous-Si, and mobility rapidly decreases. On the other hand, off current does not drastically change. This fact shows that the mobility depends on the properties of the channel poly-Si and off current depends on the properties of the gate-drain overlap region after the activation laser annealing treatment.

Drain current-gate voltage characteristics of n-channel as-deposited and laser-annealed poly-Si TFTs are shown in Fig.5(a) whille laser-annealed p-channel TFT characteristics are shown in Fig.5(b). The as-deposited self-aligned n-channel TFTs have excellent off current as low as 0.8pA (Vds=4V,Vgs=-10V). The laser annealed TFTs have good balance between n-channel and p-channel characteristics with mobilities of 39 and 33cm^2/V·sec, respectively, and therefore are well-suited for use in C-MOS driver circuits which can drive the shift register at 10MHz with a 16V supply voltage[5]. The on/off current ratio is 10^8 in n-type TFTs.

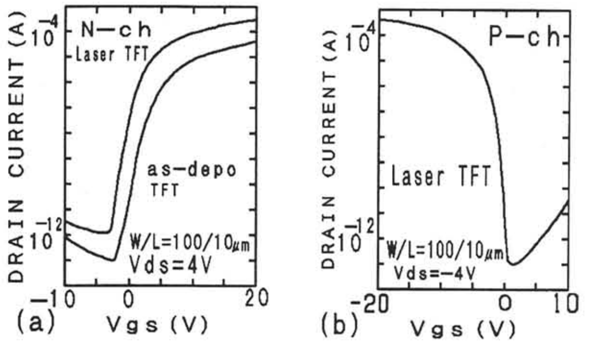

Fig.5 Drain current-gate voltage characteristics (a) n-channel and (b)p-channel of poly-Si TFT.

4. UNIFORMITY OF ANNEALED POLY-Si FILM

In pulse laser annealing, the beam edges often cause trouble in deviation of the TFT characteristics. In particular, deviation results from the region in which the second pulse overlaps the edge area of the first pulse.

Fig.6 shows tensile stress and half width measured by Raman spectroscopy in the poly-Si recrystallized by XeCl laser beam edge where the energy density decreases from a maximum to zero between 1mm. The beam size of the argon laser for Ramam scattering was 10 μm and the measurement interval was 20 μm.

In Fig. 6, the open circles (○) show the tensile stress in the poly-Si as measured across the area of the second pulse when the beam has a trapezoidal energy distribution and indicate high tensile stress is generated in the recrystallized poly-Si around the first edge. The closed circles (●) show the tensile stress when the laser beam distribution is rectangular and indicate that slight edge stress remains. (Zero represents the position of the edge of the first pulse so that the region from 0 to -200 μm represents the overlap region of the first and second pulse while the region from 0 to +200 μm represents the region of the poly-Si film annealed only by the second pulse.)

From half-width data of a trapezoidal energy distribution(○), the first edge region contains amorphous-Si from approximately + 30 μm to -150 μm.

Although laser irradiation with a rectangular energy distribution is a more effective annealing method, it is not possible to completely remove the edge influence. This data shows that it is difficult for pulsed laser annealing to form completely uniformly crystallized poly-Si.

We propose that the peripheral driver circuits be separated into blocks and only these circuit blocks be irradiated by the pulse laser beam with a rectangular energy distribution. In this manner, the beam edges are between the blocks and the detrimental edge effects are negated.

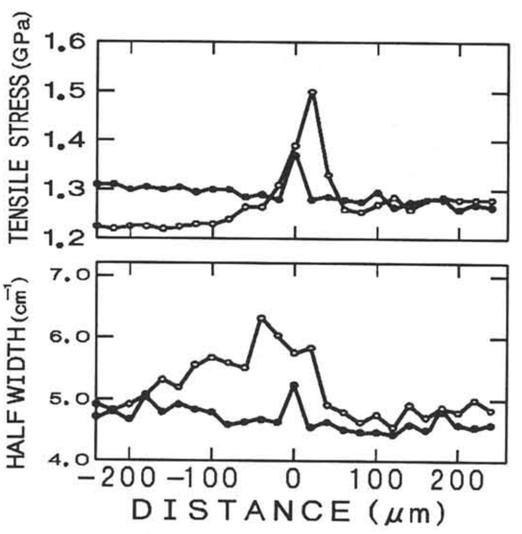

Fig.6 Tensil stress and half width measured by Raman spectroscopy of laser annealed poly-Si around first edge region.

5.CONCLUSION

We suggest that only peripheral driver circuits be fabricated with laser annealing according to the following two reasons. First, laser annealed TFTs have high mobility and as-deposited TFTs have excellent low off current. The second reason is that complete uniform for pixel TFTs can not be achieved by using laser irradiation.

Using the novel combination of as-deposited poly-Si and laser recrystallized poly-Si described above, the present work has demonstrated new fabrication method capable of producing high performance C-MOS self-aligned TFTs which are ideally suited to the realization of low temperature processed AMLCDs with integrated drivers.

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