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Large Area Doping Process for Fabrication of p-Si TFT's Using Bucket Ion Source and XeCl Excimer Laser Annealing

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A large area doping process for poly-crystalline Si (p-Si) TFT/LCD's has been developed. A large ion beam (150mm φ) extracted from the bucket ion source and a XeCl excimer laser were utilized for impurity doping and activation annnealing. A sufficiently low value of sheet resistance (500 ± 25 Ω / □) was obtained for an implantation time of 10s. The p-Si TFT's fabricated by using this technique have good characteristics and uniformity. This technique seems suitable for fabrication of large area p-Si TFT/LCD's.

1. INTRODUCTION

In recent years, a new type impurity doping technique for large area processing has been required because of the trend to larger substrate size of TFT/LCD's. The p-Si TFT's rather than amorphous Si (a-Si) TFT's are advantageous for large area TFT/LCD's due to their large carrier mobility. However, since the fabrication process of p-Si TFT's is based on an LSI process, some problems arise from enlargement of the substrate size. Some solution are needed, especially with regard to the impurity doping process. Conventional ion implanters are not suitable for large area processing; thermal annealing for activation of the impurities also causes some problems, including shrinkage or distortion of the glass substrates.

A low energy ion doping technique using a large ion beam without mass-separation has already been reported (1). We have also been proposed a ion doping technique with a bucket ion source on account of its good uniformity and large current of the ion beam (2). A laser annealing technique has been reported for lowering the process temperature (3) (4). However, it has been difficult to obtain a good uniformity regarding activation of impurities.

In this work, we utilized an XeCl excimer laser for impurity activation using a fly-eye lens integrater to homogenize the laser beam intensity and a bucket ion source for large area impurity doping. Then, we studied an application of this technique to fabrication of p-Si TFT's.

2. EXPERIMENTAL

The ion doping system employed here is shown in Fig. 1. A bucket ion source consists of a cylindrical plasma chamber (250mm diameter), 24 paramanent magnets surrounding the chamber, ion extraction electrodes, and a hot filament cathode. The discharge gas was 1% PH_3 diluted by He or H_2. The ion beam (150mm diameter) extracted from the arc discharge plasma was irradiated onto the sample without mass-separation. The ion acceleration voltage (Vacc) was 500V and the ion current density (jacc) was varied from 0.125mA/cm² to 0.5mA/cm².

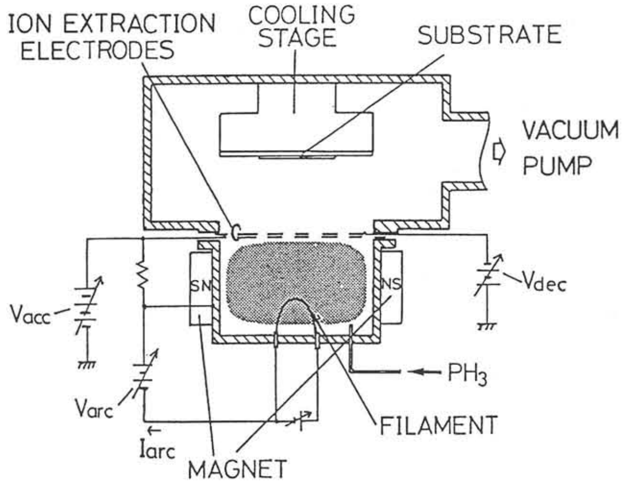

Fig. 1 A schematic diagram of ion doping system.

The sample films were prepared by low temperature recrystallization of LPCVD a-Si films. Details of sample preparation have been described elsewhere (5). The activation of implanted phosphorus ions was done by XeCl excimer laser irradiation. The laser power was 200mJ / cm². The laser beam intensity was homogenized by using a fly-eye lens integrater. The uniformity of the laser beam intensity was ±6% within an area of 8mm × 8mm. The laser repetition speed and the scanning speed of the stage were adjusted so that the overlap of the neighbouring beams was 0.6mm. The sheet resistance (ρ s) of the films was measured by a four point probe and the dopant concentration was obtained from SIMS analysis.

3. RESULTS

Figure 2 shows uniformity of the ion beam current measured by using a Farady cup array. Hydrogen was used as discharge gas. The uniformity was ±5.0% and ±8.3% for jacc of 0.125mA / cm² and 0.5mA / cm², respectively.

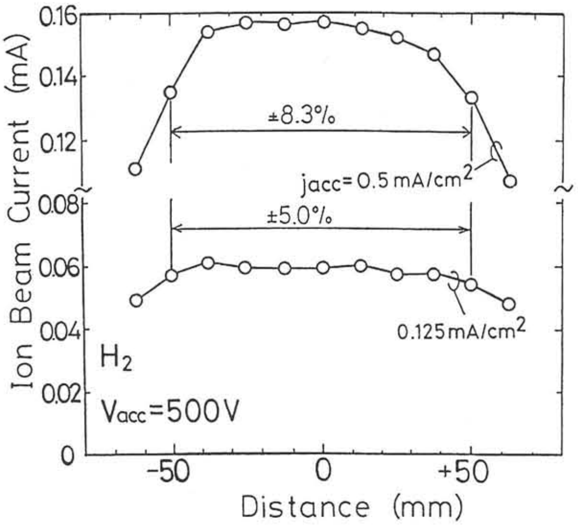

Fig. 2 Uniformity of ion beam at the current density (jacc) of 0.125mA/cm² and 0.5mA/cm².

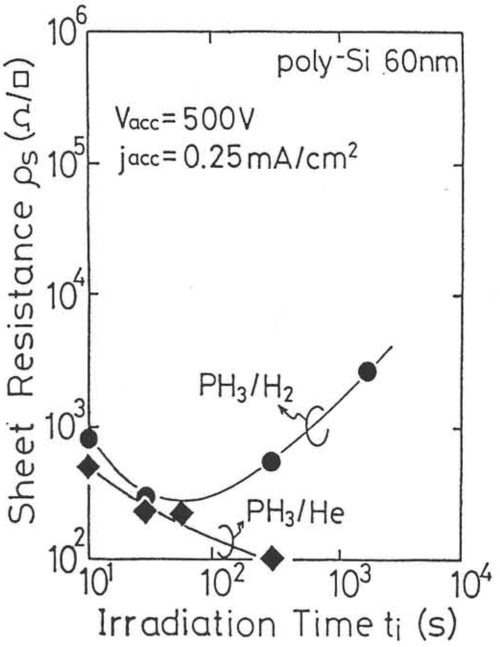

Fig. 3 The dependence of sheet resistance on irradiation time (ti). 1% PH_3 diluted by H_2 or He were used as doping gases.

Figure 3 shows relationships between the irradiation time (ti) and the sheet resistance (ρ s) of the doped p-Si films. Even though ti was a very short time of 10s, a sufficiently low value below 1000 Ω/□ was obtained. The concentration of ^{31}P in the films was 5×10^{15} cm^{-2} at ti of 10s. This result was noteworthy to achieve high productivity. When we used H_2 as dilution gas, ρ s had a minimum value at about ti of 30s and after that, increased with ti. When He was used as dilution gas, ρ s monotonously decreased with ti. From these results, it was likely that an increase in ρ s with ti resulted from surface etching of p-Si films; hydrogen ions or radicals might cause a surface etch originating from dissociation of H_2 gas.

Figure 4 shows uniformity of sheet resistance of doped p-Si films in an area of 100mm × 100mm. The uniformity was ±5% at ρ s of 500Ω/□.

Figure 5 shows uniformity of spreading resistance in an area of 10mm × 10mm including the overlap region of the laser beam. The measurement was carried out at intervals of 100 μm by using a two point probe. It seemed that overlapping of the laser beam dose not affect the uniformity of ρ s. In addition, we confirmed that the laser irradiation did not cause shrinkage or distortion of glass substrate.

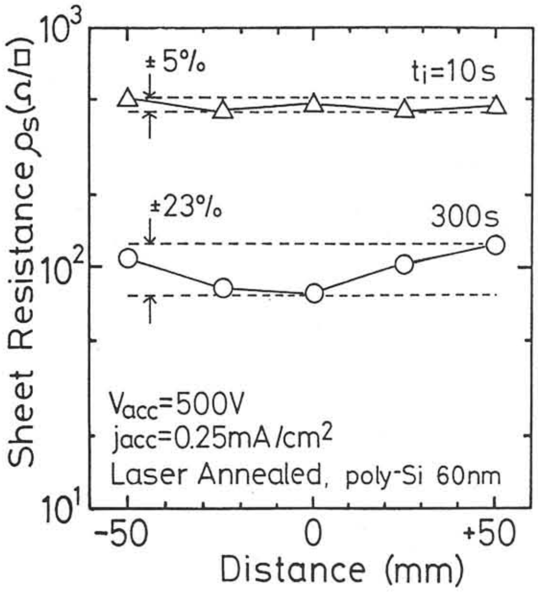

Fig. 4 Uniformity of sheet resistance of p-Si films within an area of 100mm × 100mm.

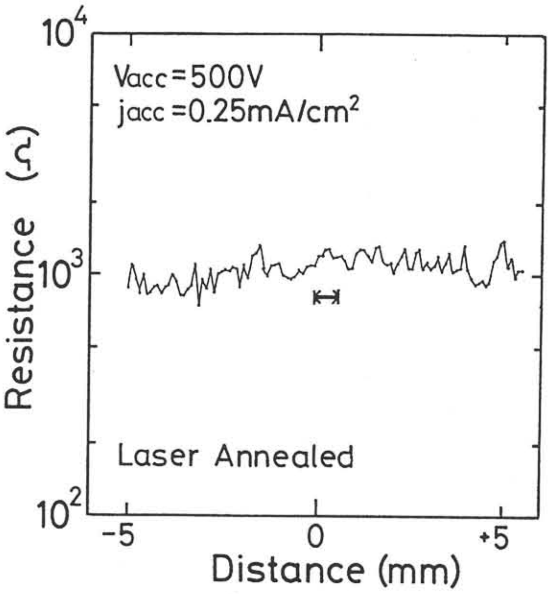

Fig. 5 Uniformity of sheet resistance in an area including the overlap region of the laser beam. The arrow indicates this overlap area.

4. DEVICE FABRICATION

We applied this process to the fabrication of p-Si TFT's where the TFT's had a conventinal co-planar electrode structure. The active layer of the p-Si film (60nm thickness) was formed by low temperature recrytallization of LPCVD a-Si film. The gate oxide film (100nm thickness) was deposited by APCVD. The source, drain, and gate regions were formed by using the process described above. The irradiation time was 30s. After fabrication of TFT's, hydrogen passivation was performed to improve the device characteristics.

Figure 6 shows a drain current (I_D)-gate voltage(V_G) characteristic of a fabricated TFT. Table I summarizes the characteristics of the TFT. The uniformity of the characteristics was ±15% within an area of 100mm × 100mm. Futhermore, a low energy ion doping technique was advantageous to reduce the OFF current because it made it possible to reduce the active layer thickness. These

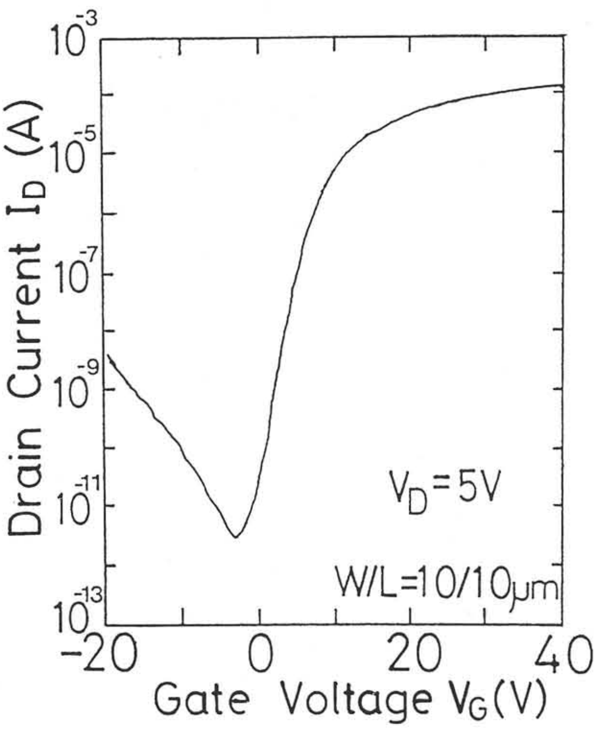

Fig.6 The drain current (I_D) vs gate voltage (V_G) characteristic of the fabricated TFT.

Table I Characteristics of the fabricated TFT.

μ_{FE}	V_{TH}	$I_{ON}(V_G=20V)$	$I_{OFF}(V_G=0V)$
28.0 (cm²/v·s)	6.5 (V)	4.7×10^{-5} (A)	2.2×10^{-11} (A)

results showed that this technique was applicable and suitable to fabrication of p-Si TFT/LCD's.

5. SUMMARY

A large area doping process for p-Si TFT/LCD's, utilizing a bucket ion source and XeCl excimer laser annealing, has been developed. This process has advantages for high productivity and good uniformity of p-Si TFT's. Increasing trend in LCD size is possible from the laser activation process and the improved TFT characteristics.

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