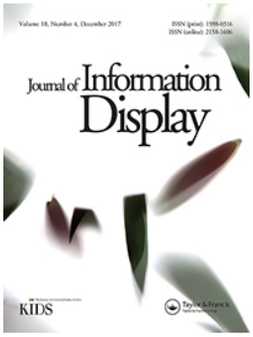

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Low-temperature poly-Si TFTs of metal source and drain using blue-laser-diode annealing (BLDA)

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ABSTRACT

Blue-laser-diode annealing (BLDA) in the continuous wave mode was performed for sputtered silicon (Si) films. Polycrystalline silicon (poly-Si) thin-film transistors (TFTs) were fabricated on a glass substrate. For the source and drain formation, titanium (Ti) was evaporated to make the metal directly contact the channel Si film without adopting n^+ doping. The improvement of the drain current was confirmed after hydrogen annealing at 400°C, and the typical poly-Si TFT characteristic with 50 cm^2/Vs deduced effective carrier mobility was successfully observed. As the low-cost TFT fabrication without ion implantation becomes feasible, the low-temperature fabrication of poly-Si TFTs using BLDA is expected.

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KEYWORDS
AMD; flexible display; material and components

1. Introduction

Low-temperature polycrystalline silicon (LTPS) thin-film transistors (TFTs) have been extensively investigated due to their potential for application in the active-matrix liquid crystal display and the active-matrix organic light-emitting diode. Compared with amorphous silicon (a-Si), the high mobility of LTPS TFT makes it possible to integrate the peripheral driving circuits on the identical panel. Although polycrystalline silicon (poly-Si) TFT is known to have higher stability than oxide or organic TFT, there is a need to lower its fabrication cost. In addition, for the next-generation display, it is necessary to fabricate high-performance TFTs on flexible panels, such as on bendable plastic sheets [1]. For the LTPS TFTs on plastic sheets, a much-lower-temperature fabrication process than that on a glass substrate is needed. Blue-laser-diode annealing (BLDA) was recently proposed as a new LTPS [2]. A Si film of uniform micrograins with improved electrical properties, which can hardly be formed through pulsed excimer laser annealing (ELA), can be formed reproducibly while keeping the surface smooth by adopting scanned BLDA [3]. Crystallization of the sputtered Si film even on a flexible plastic substrate using BLDA has been successfully performed [4]. The sputtered Si film is expected to be applied to advance TFTs or photosensors through an ultra-low-temperature process not only on glass but also on a plastic panel [4–8]. In this work, poly-Si TFT was fabricated for a radio-frequency(RF)-sputtered Si film using BLDA, and was later evaluated [9].

2. Experiment

Top-gate-structured poly-Si TFTs were fabricated on glass substrates using BLDA. For the TFT fabrication, a 50-nm-thick channel Si layer was deposited via RF sputtering using neon (Ne) gas at room temperature [9,10]. As the atomic radius of Ne is smaller than that of argon (Ar), the Ne atoms in the Si film are expected to be effectively effused during BLDA in spite of the fact that the amount of atoms incorporated into the film is higher for lower-mass Ne than for Ar [10–12]. On the other hand, for comparison, fine-grained poly-Si can be obtained not only for the CVD a-Si film but also for the sputtered a-Si film. The deposition temperature can be lowered for the Si film subjected to plasma-enhanced chemical vapor deposition (PE-CVD), but the a-Si film deposited via PE-CVD contains a considerable amount of hydrogen atoms. Therefore, in general, the PE-CVD Si film in the TFT fabrication process is required to be dehydrogenated at around 500°C for 1 h in ambient nitrogen (N_2) before ELA. In terms of the lower-temperature process, sputtered Si has a higher advantage for the future flexible panel. After the deposition of the Si films, a 445 nm blue-laser beam was irradiated at 600 × 2.4 μm^2 onto the

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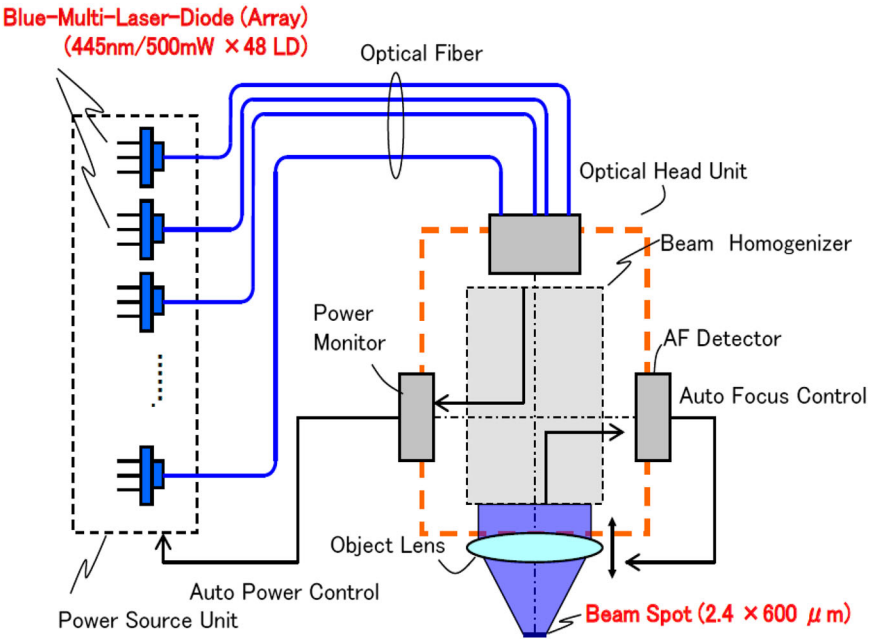

Figure 1. BLDA system used for crystallization [13].

Si surface, and the Si films were crystallized at 5 W power. The adopted BLDA system is shown in Figure 1 [13]. The crystallinity of the Si film was evaluated through spectroscopic ellipsometry (SE) [14,15]. The detailed grain structure in the Si films was observed using transmission electron microscopy (TEM).

After patterning the channel Si layer, titanium (Ti) for the S/D region was deposited using vacuum evaporation. Figure 2 shows the schematic energy band diagram of the barrier for the electron between the Ti metal and the single crystal silicon (c-Si). Here, the work function of Ti is 4.33 eV, and the electron affinity of c-Si is 4.05 eV. The resultant barrier for the electron was lowered, and the quasi-Ohmic contact for the electron from the source into the Si channel was realized using the Ti metal. After the patterning of the Ti film, a 107-nm-thick SiO_2 film was deposited at room temperature using

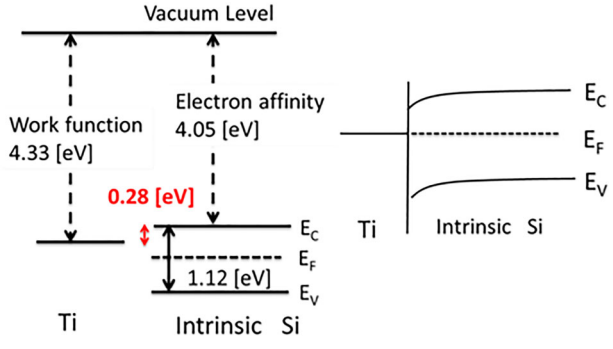

Figure 2. Energy band scheme for the quasi-Ohmic barrier between Ti and c-Si.

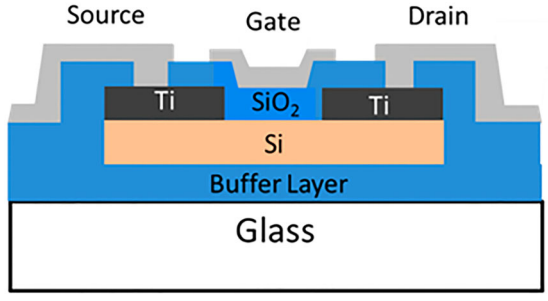

Figure 3. Cross-section of the fabricated TFT [9].

RF sputtering as the gate insulator. For the formation of 100-nm-thick gate oxide, a small amount of O_2 was incorporated into Ar gas during the RF sputtering to improve the gate voltage endurance. After the patterning of the silicon oxide (SiO_2) for contact holes, the aluminum (Al) electrodes were evaporated. Figure 3 shows the cross-sectional scheme of the fabricated TFT.

After completing the TFT fabrication, the transfer curves were measured after hydrogen annealing at 400°C in ambient H_2/N_2 (4%). The maximum process temperature for the TFT fabrication was below 400°C.

3. Results and discussion

Figure 4 shows the extinction coefficient (k) deduced from the SE analysis for the Si films before and after BLDA at 5 W. The extinction coefficient spectrum after BLDA showed the peak value at around 280 nm and the fine shoulder-peak near 360 nm [14,15]. In the figure,

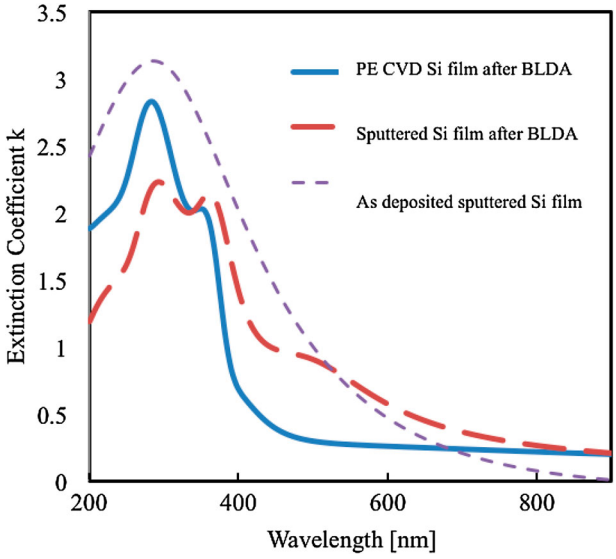

Figure 4. Extinction coefficient spectra of the Si films before and after BLDA.

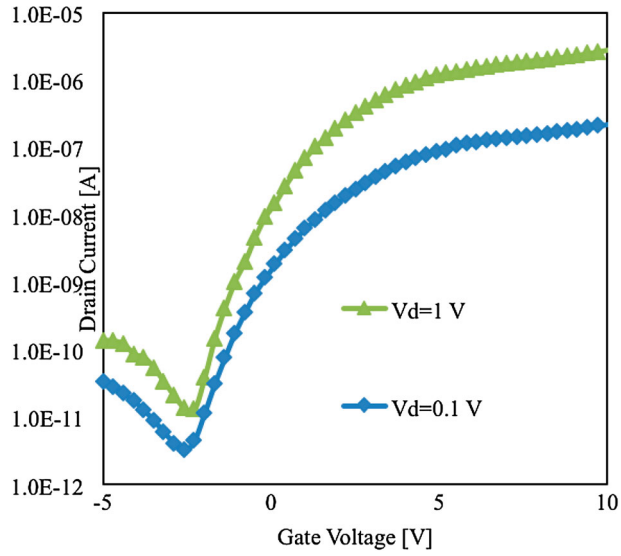

Figure 6. Dependence of the $V_g - \log I_d$ characteristics on the H_2 annealing time ($L/W = 20/5$ μm) [9].

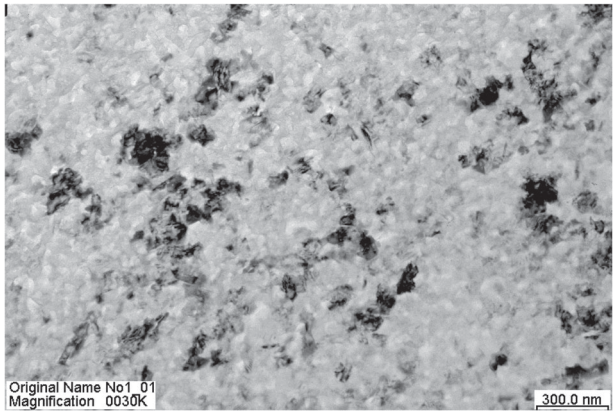

Figure 5. TEM image of the Si film crystallized via BLDA at 5 W.

the Si film deposited via PE-CVD using SiH_4 at 250°C is shown for comparison. The Si film formed via BLDA was considered clearly poly-crystallized. The crystallinity of Si films deposited via sputtering, however, is generally inferior to that of the films deposited via PE-CVD [2,9]. The grain size of the poly-Si film observed from the TEM image after BLDA for the sputtered film is not large, as shown in Figure 5.

Figure 5 shows the $V_g - I_d$ characteristic of the TFT ($L/W = 20/5$ μm) after hydrogen annealing and Al electrode patterning. Before hydrogen annealing, the typical TFT characteristics had not been obtained. As shown in Figure 5, the grain size is generally less than 100 nm, and the film contained slightly small defects. Such crystal defects originated from the grain boundaries and the Si/SiO_2 interface were compensated for by terminating them with hydrogen atoms. As a result, the improvement of the performance was confirmed after hydrogen annealing, and the typical TFT characteristics were successfully obtained. From the transfer curve, the effective deduced carrier mobility after hydrogen annealing was 50 cm^2/Vs, and the threshold voltage was 1.8 V at the 0.1 V drain voltage. Figure 6 shows the $V_g - I_d$ characteristic of the TFT ($L/W = 20/5$ μm) after hydrogen annealing for 90 min at 400°C [9]. If poly-Si TFT used a CVD Si film, higher than 100 cm^2/Vs effective mobility would be obtained [16]. Although the poly-Si TFT's performance was inferior to that of the TFT formed using the PE-CVD Si film, it is easier to realize poly-Si TFTs on a polymer panel.

Although the characteristics of the TFT for sputtered Si films are inferior to those of the TFT for the PE-CVD Si films, the sputtering process has a higher advantage in terms of the lower-temperature fabrication process for ongoing TFTs on a flexible panel.

4. Summary

A RF-sputtered amorphous silicon (a-Si) film was crystallized using BLDA. The LTPS (poly-Si) thin-film transistor (TFT) of metal source/drain (S/D) was fabricated through a low-temperature process. As a result of the low barrier for electrons from titanium (Ti) into the poly-Si channel without adopting n^+ electrodes, the drain current remarkably increased after hydrogen annealing, and improved TFT characteristics were successfully obtained.

TFTs using BLDA are expected to be applied to the next-generation display.

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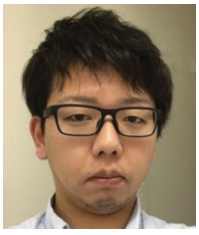
Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors



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