



Reduced leakage current of nickel induced crystallization poly-Si TFTs by a simple chemical oxide layer

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ABSTRACT

Ni-metal-induced crystallization (MIC) of amorphous Si (α -Si) has been used to fabricate low-temperature polycrystalline silicon (poly-Si) thin-film transistors (TFTs). However, the leakage current of MIC-TFT is high. In this study, a chemical oxide layer was used to avoid excess of Ni atoms into α -Si layer during MIC process, which was simple and without extra expensive instrument. The minimum leakage current and on/off current ratio were significantly improved.

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1. Introduction

Low-temperature polycrystalline silicon (LTPS) thin-film transistors (TFTs) have attracted considerable interest for high resolution integrated active-matrix organic light-emitting diodes (AMOLED) because they exhibit good electrical properties and can be used in the realization of system-on-glass (SOG) [1]. In various technologies for achieving large-area poly-Si, metal-induced crystallization (MIC) has potential due to low cost, good uniformity, low crystallization temperature ($\sim 500^\circ\text{C}$) and short crystallization time (0.5–5 h) [2,3]. However, the leakage current of MIC-TFT is high. This is because Ni residues in the poly-Si film increase the leakage current and shift the threshold voltage [4,5]. The Ni residues could be reduced by gettering method or metal diffusion filter layer (MICC). Gettering method was an efficient technology to capture Ni residues from poly-Si, but the process was complex and the on current of poly-Si films decreased [6]. MICC used a SiNx cap layer to reduce Ni diffusion into poly-Si film, however that still needed high temperature and long annealing time, and the Ni degree of reduction is not conspicuous [7,8]. Besides, these two methods need extra expensive and complicated vacuum instrument.

In this letter, a simple chemical oxide layer was introduced between α -Si layer and Ni layer to avoid excess of Ni atoms into α -Si

layer during MIC process. It was found that the minimum leakage current of poly-Si TFT was greatly reduced. The manufacture processes were very simple and without extra expensive instrument.

2. Experimental

N-channel poly-Si TFTs were investigated in this study. A 100-nm-thick undoped α -Si layer was deposited onto a 500-nm-thick oxide-coated Si wafer by low pressure chemical vapor deposition (LPCVD) system. To form chemical oxide MIC poly-Si (CF-MIC), samples were dipped into a chemical solution of $3\text{H}_2\text{SO}_4:1\text{H}_2\text{O}_2$ for 20 min to form a chemical oxide filter layer on the top of α -Si. The transmission electronic microscopy (TEM) cross-section image of chemical oxide layer was shown in Fig. 1. To examine the quality of chem-SiO₂, after the chem-SiO₂ layer was formed, platinum was deposited on top of the chem-SiO₂ for image contrast in TEM sample preparation. A 5-nm-thick Ni film was then deposited and subsequently annealed at 500°C for 1 h in N₂ for crystallization of α -Si. The unreacted Ni film and chemical oxide layer were then removed by wet etching.

The islands of poly-Si regions on the wafers were defined by Reactive ion etching (RIE). After cleaning process, a 100-nm-thick tetraethylorthosilicate/O₂ (TEOS) oxide layer was deposited as the gate insulator by plasma-enhanced chemical vapor deposition (PECVD). Then a 100-nm-thick poly-Si film was deposited as the gate electrode by LPCVD. After defining the gate, self-aligned

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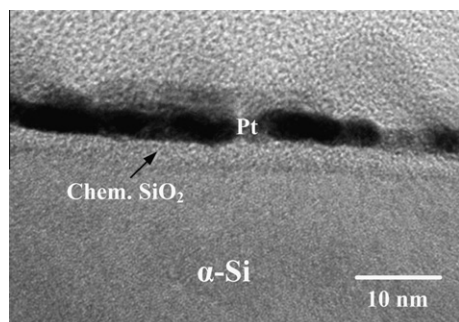


Fig. 1. TEM cross-section image of chemical oxide layer. Platinum film deposited on the top of the chem-SiO₂ layer was for the TEM sample preparation.

35 keV phosphorous ions were implanted at a dose of $5 \times 10^{15} \text{ cm}^{-2}$ to form the source/drain and gate. The dopant activation was performed at 600 °C for 24 h. A 500-nm-thick TEOS oxide layer was deposited as the passivation layer by PECVD, followed by a definition of contact holes. A 500-nm-thick Al layer was then deposited by thermal evaporation and patterned as the electrode. Finally, sintering process was performed at 400 °C for 30 min in N₂ ambient.

It is worthy to note that this CF-MIC process does not need any additional annealing step and expensive vacuum equipment, and is compatible with conventional MIC processes.

For the purpose of comparison, solid phase crystallization (SPC) TFT, and conventional MIC TFT without chemical oxide layer were also fabricated under the same conditions.

3. Results and discussion

A relation of chemical oxide thickness, as investigated/measured by TEM, versus immersed time is shown in Fig. 2. It was found that oxide thickness increased with immersed time and saturated around 3.4 nm when the time reached 10 min. This is because the chemical oxide growth was controlled by diffusion of reactants through the pre-existing oxide layer [9]. Since oxide thickness was saturated when time reached 10 min, in this work, 20 min was chosen as the immersed time to gain stable oxide thickness.

Fig. 3 shows X-ray photoelectron spectroscopy (XPS) of Si2p peak for the chemical oxide on top of α -Si layer. By fitting, it was observed Si, SiO and SiO₂ peaks are located at binding energy of 99.6, 101.7 and 103.2 eV, respectively [10–12]. We believe that the signal of Si peak was from the bottom layer (α -Si) because

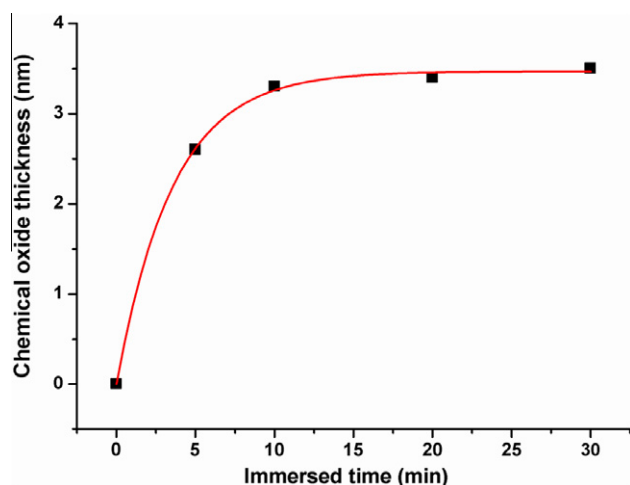


Fig. 2. Formation thickness of chemical oxide versus immersed time.

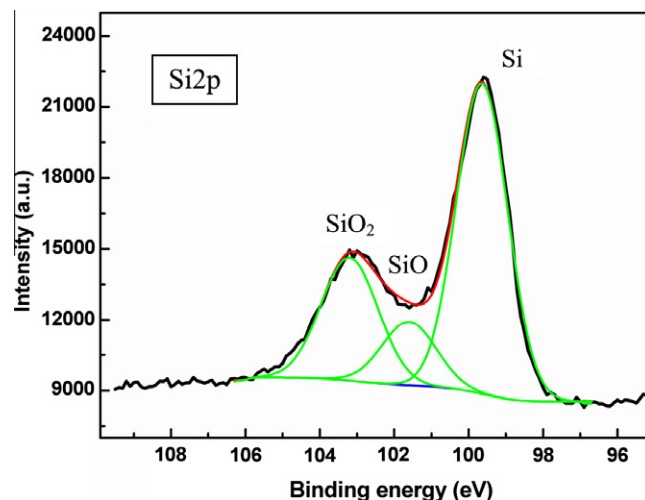


Fig. 3. X-ray photoelectron spectroscopy (XPS) of Si2p peak for the chemical oxide on top of α -Si layer.

the thickness of chemical oxide layer is less than XPS sampling depth. In other words, the chemical oxide was composed of SiO and SiO₂.

To investigate the effect of chemical oxide on the reduction of Ni residues, samples were purposely dipped into a silicide-etching solution (HNO₃:NH₄F:H₂O = 4:1:50) after unreacted Ni film and chemical oxide layer were removed. As shown in Fig. 4, numerous holes were observed. These holes were residues of Ni silicides that had been etched away by the silicide-etching solution. The Ni residues in CF-MIC were much lower than those in conventional MIC. This reduction must be due to the introduction of chemical oxide layer in CF-MIC processes. Oxide filter layer can avoid Ni directly contact with α -Si and remove unreacted Ni easily from surface.

Secondary-ion mass spectroscopy (SIMS) depth profile was also used to analyze the Ni concentrations (residues) in Si films (without silicide-etching process). As expected, Ni content in CF-MIC was much less than that in MIC as shown in Fig. 5. Obviously, chemical oxide layer can reduce the Ni concentrations in Si films. This is because the diffusivity of Ni in α -Si is 10^8 times higher than that in SiO₂ at 500 °C [13,14]. As a result, chemical oxide as a filter, which can retard the in-diffusion of Ni into Si. In other words, Ni concentrations in Si films were reduced.

The effect of immersed time on the reduction of Ni concentration is shown in Fig. 6. The Ni concentration, as estimated by Ni intensity at 50 nm deep, was found to decrease with the increasing of immersed time and then saturate after 10 min. This is because in CF-MIC process, Ni need diffuse through oxide layer to crystallize α -Si. As shown in Fig. 2, oxide thickness increased with immersed time. Therefore, the Ni concentration decrease with immersed time

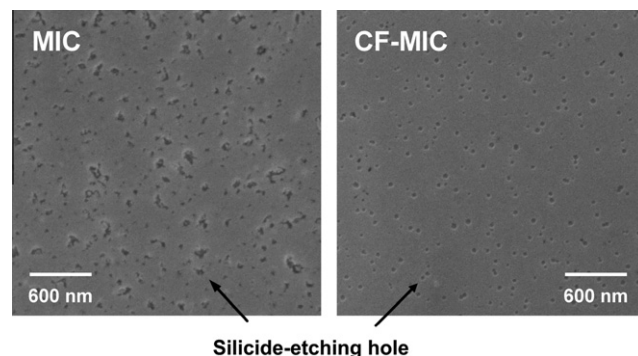


Fig. 4. SEM of the silicide etching holes after metal induced crystallization of poly-Si with and without chemical oxide layer.

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