Silicon Nitride Films Prepared at a Low Temperature (≤ 200 ℃) for Gate Dielectric of Flexible Display

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Abstract

The silicon nitride films for gate dielectric were deposited by catalytic chemical vapor deposition at low temperature (≤200 ℃). The mixture of SiH_4*,* NH_3 *and* H_2 *was used as source gases. The current-voltage (I-V) and the capacitance-voltage (C-V) characteristics of the films were measured. The breakdown voltage and the flat band voltage shift of samples were improved by increase of the* NH_3 *contents and* H_2 *dilution ratio. The defect states were analyzed by photoluminescence (PL) spectra. As the defect states decreased, the breakdown voltage and the flat band voltage shift increased.*

1. Introduction

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Silicon nitride thin films for gate dielectric have been used in thin film transistor (TFT) for flat-panel display applications. The high resistivity and stability were required for the application. Plasma-enhanced chemical vapor deposition (PECVD) technique at temperatures from 300 to 500 ℃ is conventionally used for the deposition of SiN_x films on glass [1-3]. Recently, as development of flexible display had been attracted, the SiNx film deposited on plastic substrate was required. Thus, the low temperature (≤200 ℃) process is necessary. The SiNx films prepared by PECVD at substrate temperature of 300 to 500 ℃ had enough resistivity and stability to use TFT devices. However, the properties of the SiN_x films deposited by PECVD at temperature below 200 ℃ are not as good as the SiN_x deposited at temperature of higher than 300 ℃.

In this work, we deposited SiN_x films using catalytic chemical vapor deposition (Cat-CVD) technique at temperatures below 200 ℃. This technique had advantage that can be prepared high quality films at low substrate temperature because of using radicals decomposed by heated filament (catalyst) of higher than 1600 ℃ [4-7].

2. Experimental

The SiN_x films were deposited by Cat-CVD using a mixture of SiH_4, NH_3 and H_2. P-type (100) silicon wafer and tungsten filament were employed as a substrate and a catalyst, respectively. The tungsten filament had diameter of 0.4 mm and length of 430 mm. This filament was electrically heated as temperatures of 1750 ℃. The distance between of the filament and substrate was 50 mm. The substrate was continually heated by the radiation from this filament. However, the substrate temperature was maintained to less than 200 ℃ by water cooling system. The substrate temperature was monitored by using a thermocouple for performing deposition process. It was tested that Polyethersulphone (PES) substrate was not strained for deposition process. The SiH_4 gas flow rate was fixed at 2 sccm. NH_3/SiH_4 flow rate ratios were controlled from 9 to 49. The photoluminescence (PL) spectra of the samples were measured by using He-Cd laser having a wavelength of 325 nm. Metal-insulator-semiconductor (MIS) structures were fabricated to measure current-voltage (I-V) and capacitance-voltage (C-V).

3. Results and discussion

Fig. 1 shows the breakdown voltages of H_2-diluted and undiluted silicon nitride films prepared at various NH_3/SiH_4 flow rate ratio. The H_2-diluted films have H_2 dilution ratio of 90%. The breakdown voltage increases with NH_3/SiH_4 flow rate ratio. The breakdown voltage of H_2-diluted films was about 4.0 MV/cm at NH_3/SiH_4 flow rate ratio of 49. When

NH_3/SiH_4 flow rate ratio of H_2-diluted and undiluted films were same, the breakdown voltages of H_2-diluted films were higher than that of undiluted films. These results suggest that H_2 dilution of the source gas and increase of NH_3/SiH_4 flow rate ratio help increase of the breakdown voltages.

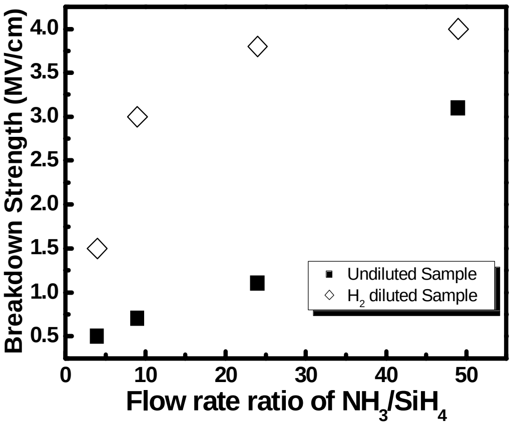


Fig. 1. The breakdown voltages of H_2 diluted SiN_x films by NH_3/SiH_4 flow rate ratio

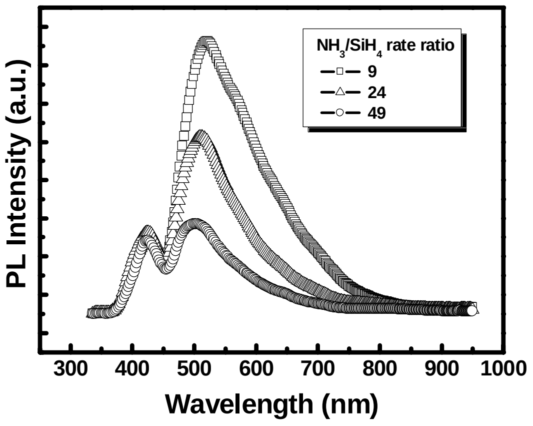
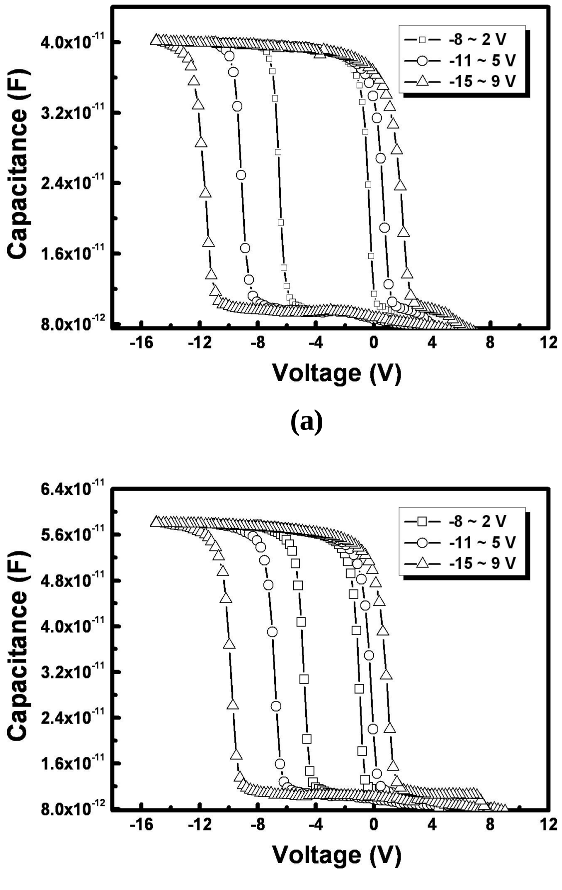


Fig. 2. The PL spectra of H_2 diluted SiN_x films by NH_3/SiH_4 flow rate ratio

Fig. 2 shows the PL spectra of 90% H_2-diluted silicon nitride films prepared at various NH_3/SiH_4 flow rate ratio. Two characteristic PL peaks at the wavelength of 420 nm and 510 nm. Deshpande et al. reported that the PL peak at 420 nm and 510 nm due to the existence of nitrogen dangling bonds and silicon dangling bonds, respectively [8]. The PL peaks at 420 nm were not changed, but the PL peaks at 510 nm were changed. As the NH_3/SiH_4 flow rate ratio increased, the intensity of PL peaks of 510 nm decreased. This result suggests that increase of NH_3/SiH_4 flow rate ratio helps decrease of silicon dangling bonds. In other word, we supposed that the breakdown voltages presented in Fig. 1 increased by decrease of silicon dangling bonds.



(a)

(b)

Fig. 3. The C-V characteristics of H_2 diluted SiN_x films prepared at NH_3/SiH_4 flow rate ratios of (a) 9 and (b) 49

Fig. 3 shows the C-V characteristics of the samples prepared at two levels of NH_3/SiH_4 flow rate ratios. The NH_3/SiH_4 flow rate ratios of sample A in Fig. 3(a) and sample B in Fig. 3(b) were 9 and 49, respectively. Counterclockwise hysteresis loops were observed at both C-V curves of samples A and B. The memory windows of sample A were lager than sample B for the same sweep voltages. At both of samples, the magnitude of the flat band voltage shifts under reverse bias was larger than under forward bias. The sign of the flat band voltage appeared to be negative. These results supported that the silicon dangling bonds decreased by increase the NH_3/SiH_4 flow rate ratio.

4. Summary

The silicon nitride (SiN_x) films were fabricated by Cat-CVD technique using the mixture of SiH_4, NH_3 and H_2 as source gas. The breakdown voltage characteristics increased with NH_3/SiH_4 flow rate ratios. The H_2 diluted SiN_x films were observed to have better properties than undiluted SiN_x films. The SiN_x films deposited at NH_3/SiH_4 flow rate ratios of 49 and H_2 dilution ratio of 90 % show the breakdown voltage as higher as 4 MV/cm. The existence of silicon and nitrogen dangling bonds inside the SiN_x films were analyzed by PL spectra. There cause hysteresis in C-V curves. The memory window in C-V curve decreased with silicon dangling bonds inside SiN_x film.

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5. References

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