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Evaluation of stress induced by plasma assisted ALD SiN film

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Introduction

Stress impression technique is essential to enhance carrier mobility in current LSI. Silicon nitride (SiN) is promising material for stressor. The deposition technique with low thermal budget and thin film with high thermal stability were desired for high performance devices.

Plasma assisted ALD (P-ALD) is superior to thermal ALD (T-ALD) in lower temperature processing and high controllability of film thickness. However this technique has possible disadvantages, such as reduction of film stress and poor thermal stability.

In this study, the strains induced by ALD SiN stressor were evaluated for optimization of the deposition conditions and investigation of the thermal stability.

Experiment

P-ALD Silicon nitride films were deposited on Si (001) substrate using batch-type ALD equipment. Precursors were dichlorosilane (SiH_2Cl_2) and ammonia (NH_3) gases, which were alternately supplied in the deposition chamber. Deposition temperatures were varied from 350 degC to 500 degC. Line & space patterned samples with post deposition annealing (PDA) were also prepared to investigate thermal stability. PDA conditions were 700 and 800 degC for 60 sec, and spike annealing at 900 and 1000 degC.

UV-raman measurements using Ar ion laser (λ = 364 nm) were performed for stress evaluation [1]. Film characteristics were also evaluated by X-ray reflectometry (XRR) and hard X-ray photoelectron spectroscopy (HAXPES).

Results and Discussion

Figure 1 shows stresses and densities of SiN films as a function of deposition temperature obtained by UV-raman and XRR measurement, respectively. The compressive stresses were confirmed and that showed maximal value in regard to deposition temperature. While, the film density linearly increased with increasing the deposition temperature.

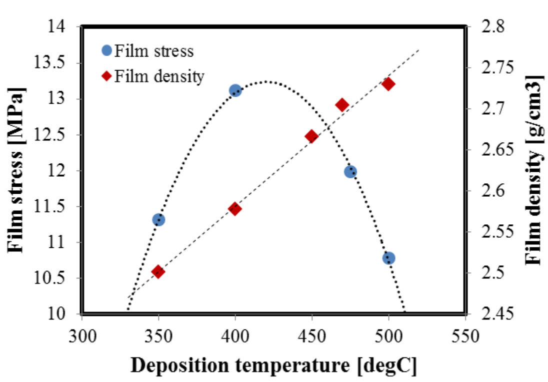

Fig. 1 Film stress and density of SiN film as a function of deposition temperature obtained by UV-raman and XRR measurement, respectively.

Figure 2 shows N1s photoelectron spectrum obtained from SiN film deposited at 450 degC. This spectrum shows asymmetric shape which was originated from mixture of $N-Si_3$ and $Si-N-H_2$ bonding states [1]. $Si-N-H_2$ ratios and FWHMs at various deposition temperatures were summarized in table 1. It indicates that $Si-N-H_2$ ratio was approximately-constant less than 450 degC and drastically decreased at 500 degC. In addition, FWHMs of N 1s spectra decreased less than 450 degC, which was attributed to improvement of bonding state homogeneity.These results indicated that the film stress was strongly influenced by film density and $Si-N-H_2$ ratio.

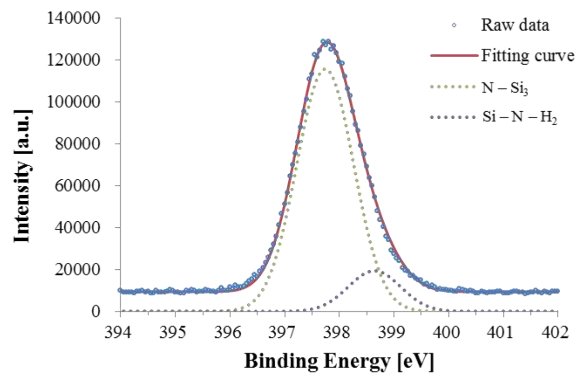

Fig. 2 N1s spectrum obtained by HAXPES measurement. Fitting curve including $N-Si_3$ and $Si-N-H_2$ spectra were also illustrated.

Table 1 Deposition temperature dependence of $Si-N-H_2$ ratio and FWHM in N1s photoelectron peaks obtained by HAXPES measurement

Deposition temp.	$Si–N–H_2$ ratio [%]	FWHM [eV]
350 degC	12.49	1.22
400 degC	12.14	1.20
450 degC	13.36	1.13
500 degC	4.27	1.17

Figure 3 shows thermal stability of stress in Si applied by patterned SiN film. The strain by P-ALD film depended on PDA temperature and thermal budget caused relaxation of stress. The stress decrement of P-ALD was larger than that of T-ALD. The stress of P-ALD was, however, maintained double that of T-ALD even after PDA process. Therefore, P-ALD is superior technique for deposition of SiN stressor.

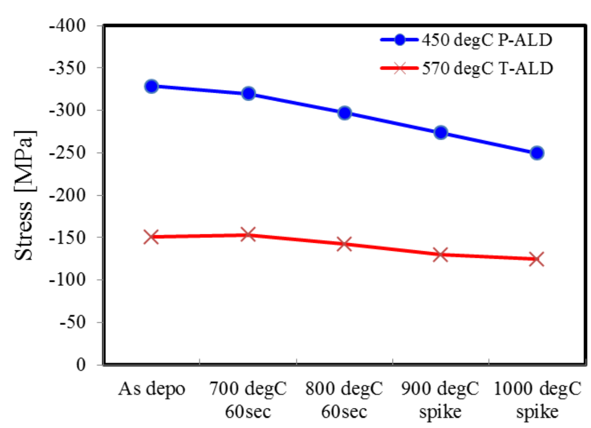

Fig. 3 Thermal stability of stress in Si applied by L/S patterned SiN film with comparing P-ALD and T-ALD.

References

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