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Effects of Nitrogen Concentration on the Electrical Properties of HfN Gate Insulator Formed by ECR Plasma Sputtering

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1. Introduction

Scaling down an equivalent oxide thickness (EOT) of high-κ gate insulator beyond 0.5 nm is a great challenge for next generation CMOS technology because of the formation of an interfacial layer (IL) between high-κ/Si interfaces. The IL with low dielectric constant increases the EOT [1]. We have reported that 0.5 nm EOTs were obtained by using hafnium nitride (HfN) gate insulator formed by electron-cyclotron-resonance (ECR) plasma sputtering with the N_2 flow ratio (N_2/Ar+N_2) of 28% (0.20 Pa) and the atomic concentration of Hf:N of 1:1.18 with relative dielectric constant (κ) as 26 [2]. Hf_3N_4 was reported as the stoichiometric structure, and increasing the N concentration would lead to higher dielectric constant [3,4].

In this paper, the effect of nitrogen concentration dependence on the electrical characteristics of HfN gate insulator were studied.

2. Experimental Procedure

First, p-Si(100) was cleaned by SPM and DHF. Then HfN film was deposited by ECR plasma sputtering. The HfN films (4 nm) were deposited by varying Ar/N_2 gas flow ratio of 15/10 sccm (40%N_2) and 15/12 sccm (44%N_2) with the same gas pressure of 0.19 Pa. The deposited HfN films were annealed in the Ar/4.9%H_2 forming gas (FG) ambient (1 SLM) at 600°C/30 min. Then Al electrode was deposited by evaporation through a shadow mask. Finally, the C-V and J-V characteristics of Al/HfN/p-Si(100) MIS diodes were measured.

3. Results and Discussion

Figure 1 shows the C-V and J-V characteristics of Al/HfN/p-Si(100) MIS-diode. It was found that the EOT of HfN gate insulator was decreased from 1.0 nm to 0.73 nm by increasing the N_2 gas flow ratio from 40% to 44%, although the leakage current density was increased from $5x10^{-5}$ A/cm^2 to 0.37 A/cm^2 (@V_{FB} - 1V) as shown in Fig. 1(b).

4. Conclusions

We investigated an effect of nitrogen concentration on the diode characteristic of HfN gate insulator formed by ECR plasma sputtering. By using HfN gate insulator with high N_2 gas flow ratio of 44% (0.19 Pa), the EOT of 0.73 nm with leakage current density of 0.37 A/cm^2 were obtained.

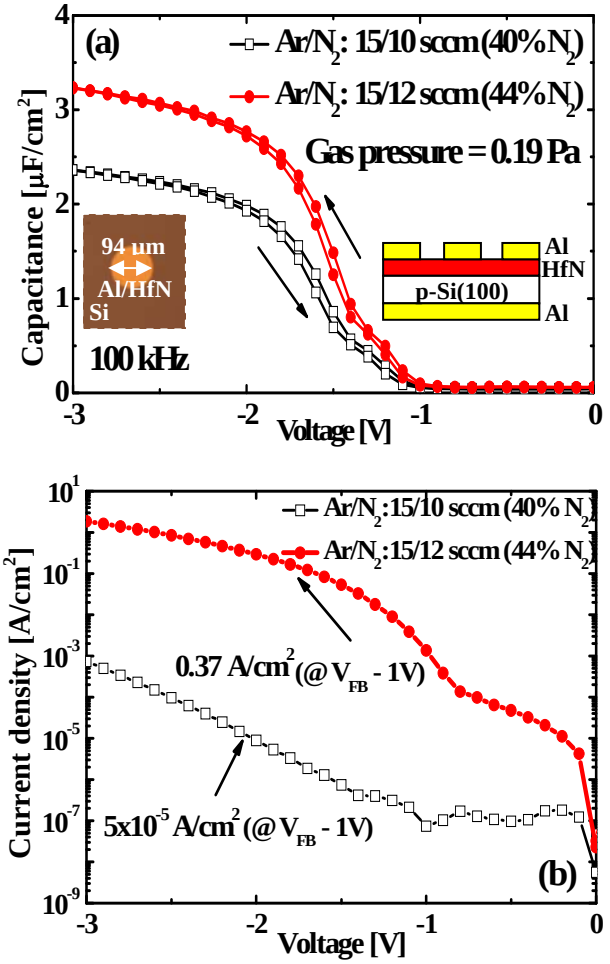

Fig. 1. Electrical characteristics of Al/HfN/p-Si(100) MIS-diode with different N concentration annealed in Ar/4.9%H_2 FG ambient at 600°C/30 min. (a) C-V characteristics (100 kHz) and (b) J-V characteristics.

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