In-situ Formation of HfN, Gate Stack Structures Utilizing ECR Plasma Sputtering
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1. Introduction
Scaling down an equivalent oxide thickness (EOT) of metal/high-κ gate stack beyond 0.5 nm is a great challenge for next generation CMOS technology because of the formation of low-κ interfacial layer (IL) between high-κ/Si interfaces [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 Al electrode [2]. In this paper, in-situ formation of high thermal stability metallic-phase HfN, (x < 1) on HfN gate insulator for gate-first process [3] was investigated utilizing ECR plasma sputtering.

2. Experimental Procedure
First, p-Si(100) substrates were cleaned by SPM and DHF. Then HfN gate insulator (4.9 nm) was deposited by ECR plasma sputtering with the gas pressure of 0.20 Pa (Ar/N₂: 20/8 sccm) [4]. The metallic-phase HfN, electrode (70 nm) was in-situ deposited with the gas pressure of 0.17 Pa (Ar/N₂: 20/0.4 sccm). After gate electrode patterning by lithography, HfN gate stack was patterned by DHF (1%) for 140 s. Finally, backside Al contact was deposited by evaporation. The sample with Al electrode (ϕ = 94 µm) deposited by evaporation through a shadow mask was fabricated for comparison [5]. The C-V and J-V characteristics of HfN/p-Si(100) MIS-diodes were measured. The x-ray photoelectron spectroscopy (XPS) was carried out to evaluate the depth profile of HfN gate stack.

3. Results and Discussion
Figure 1 shows the depth profile of HfN gate stack. The metallic-phase HfN, electrode and HfN gate insulator has N/Hf atomic ratio of 0.68:1 and 1:1, respectively. The oxygen content at the HfN/Si interface is below 3.6%. This means, in-situ deposition of HfN gate stack can suppress the oxygen incorporation and IL formation, which can improve the electrical properties of HfN MIS-diode.

4. Conclusions
We investigated the in-situ formation of HfN gate stack utilizing ECR plasma sputtering. The in-situ deposition of HfN electrode can suppress the oxygen incorporation and IL formation, which can improve the electrical properties of HfN MIS-diode.

Acknowledgements
The authors would like to thank Prof. Emeritus H. Ishiwara of Tokyo Institute of Technology, Prof. Emeritus T. Ohmi and Dr. T. Suwa of Tohoku university, and Dr. M. Shimada and Mr. I. Tamai of MES-AFTY for their support.

References