Reactive Ion Etching of TaN for a Metal Gate Electrode and ZrO₂ and Gd₂O₃ for High-k Gate Insulators

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Abstract

Reactive ion etching (RIE) characteristics of tantalum nitride (TaN) for a metal gate electrode and zirconium oxide (ZrO₂) and gadolinium oxide (Gd₂O₃) for high-k gate insulators have been studied. TaN was etched by chlorine-based RIE after removing native oxide layer. The etched profile of TaN was controlled by the ratio of BCl₃ and Cl₂ gases. Etching rates of both ZrO₂ and Gd₂O₃ were lower than that of SiO₂, which indicates that high etching selectivity to ZrO₂ and Gd₂O₃ can be obtained in the etching of the gate electrode. Because of the low etching rate, the selective removal etching of the high-k gate dielectric film on Si substrate is difficult especially for Gd₂O₃. For ZrO₂, however, it will be possible by using CF₄ deposition on Si surface.

Introduction

High-k gate insulators such as Al₂O₃, ZrO₂, HfO₂, and rare earth metal oxides Ga₂O₃, La₂O₃, etc., have been extensively studied to overcome the leakage current issue of ultra-thin SiO₂ in sub 100nm CMOS devices. Applications of metal gate electrode to the CMOS devices have also been investigated to suppress the gate depletion in poly-Si gates. Most reports about high-k films and gate metal materials have been concerned about the comparison of the materials, the method of the film deposition, the control of the interfacial layer growth and the electrical characteristics [1-2]. However, RIE of those materials is also important for future CMOS fabrication. The purpose of this paper is to investigate the RIE characteristics of ZrO₂, Ga₂O₃ and TaN films and to have a view of the gate electrode patterning and the high-k film removing processes.

Experiments

100-nm-thick ZrO₂ and TaN (TaN0.6N0.4) films were prepared by sputtering onto n-Si (100) substrate. 50-nm-thick Ga₂O₃ film was prepared by electron beam evaporation onto n-Si (100). The dry etcher used in this study has a coil for the inductively coupled plasma formation will be done by wet etching.

Results and Discussions

Table 1 shows the etching rates of TaN for different RIE gas chemistries. It is clearly found that the lower tapered profile is obtained with increasing the ratio BCl₃/Cl₂. This taper angle change is accounted for the generation of the non-volatile reaction products containing B-N bonds, which were confirmed by XPS analyses.

Conclusions

RIE characteristics of TaN, ZrO₂ and Gd₂O₃ were studied. It has been shown that TaN RIE using chlorine-based plasma is applicable to the gate electrode patterning in the respect of the etching rate and the profile controllability. For ZrO₂ and Gd₂O₃, it has been found that both the etching rates are lower than that of SiO₂. This indicates that high etching selectivity to the under-layer can be obtained for the gate electrode etching. However, the low etching rates can cause difficulty in the selective removal etching of the high-k film against Si substrate. Therefore, the high-k film removal after the gate electrode formation will be done by wet etching.

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References