Deposition rates and chemical compositions of C_4F_8 plasma polymerization films on trench sidewalls

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In the Bosch process, passivation films are deposited using C_4F_8 plasmas to protect the silicon sidewalls. In this study, deposition rate at each depth of the trench sidewall was measured and the chemical composition was analyzed to classify the precursor types produced in the C_4F_8 plasmas. The deposition rate at each depth is closely related to the sticking probability of the precursor. The results showed that polymerization reactions in the gas phase contributed significantly to the formation of precursor in the Bosch process.

1 Introduction

The Bosch process [1], suitable for processing high-aspect-ratio features, is used to fabricate trenches with high aspect ratios. This process involves three steps: passivation using C_4F_8 plasmas, film etching using ions in SF_6 plasmas, and Si etching using F-radicals in SF_6 plasmas. The sidewalls of silicon features are protected by passivation films during the process. In the C_4F_8 plasmas, a wide variety of precursors exist, and their sticking probabilities differ. In the shallow part of the trench, precursors with high sticking probability preferentially stick to the sidewalls, and a polymerized film with a large contribution of precursors with high sticking probability is deposited [2]. Since the precursors with high sticking probability are lost from the gas phase in the shallow part of the trench, the ratio of precursors with low sticking probability increases in a deep part of the trench, and the polymerized film with a large contribution of precursors with low sticking probability is deposited in the deep part of the trench. In this study, we measured the film thickness at different depths of the trench sidewalls under different discharge conditions to investigate the characteristics of the precursor produced in the C_4F_8 plasmas. The contribution of the polymerization reaction in the gas phase to the precursor formation was then discussed.

2 Experiment

An inductively Coupled Plasma (ICP) etcher RIE-800iPBC (Samco) for the Bosch process was used as a plasma generator. The distance from the ICP coil to the stage was 400 mm, which was longer than that of a typical ICP etching system. Passivation films were deposited on wafers and the sidewalls of trench illustrated in Fig. 1 using C_4F_8 plasmas. The passivation film thicknesses were measured by a reflectance spectrometer (FE-3000, Otsuka Electronics). The chemical compositions were analyzed by x-ray photoelectron spectroscopy (XPS: JPS-9010MX, JEOL).

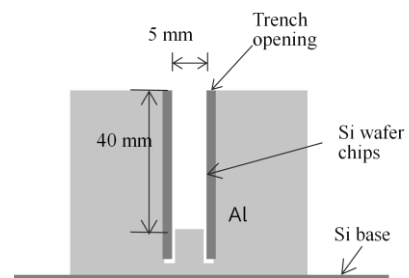

Fig. 1: Schematic of trench with a 5-mm gap and holder. Two diced silicon coupons were placed 5 mm apart, facing each other, in an aluminium holder.

3 Results and discussion

Analyses of the chemical composition of the C_4F_8 plasma polymerized film deposited on the wafer at flow rates of 50, 200, 800 sccm are shown in Fig. 2. At C_4F_8 flow rates of 50 and 200 sccm, the chemical composition is almost the same and the CF_2 bond content is high. At a flow rate of 800 sccm, the CF_2 bond content is lower and the C-CF_x bond content is higher than those at the other flow rates [3]. This difference is attributed to the different dissociation products of C_4F_8 molecules in the ICP region.

The Deposition rate of the polymerized film on the sidewalls of the trench (Fig. 1) is shown in Fig. 3. The deposition rate at the trench opening (0 mm) was highest at 50 sccm and lowest at 200 sccm. Among the three C_4F_8 flow rates, the film thickness thinned most rapidly with increasing depth at 800 sccm. This indicates that at this flow rate, precursor of films with high sticking probability and high C-CF_x bond content are produced. Comparing the film thickness deposited at flow rates of 50 and 200 sccm, which produce films with the same high CF_2 bond content in chemical composition, a relatively thick polymerized film was deposited at a deeper position with the flow rate of 50 sccm. The difference in the precursors produced at these two flow rates was caused by the difference in residence time in the downstream region of the plasma. When the residence time was longer, the polymerization reactions proceeded and largely less reactive precursors were produced.

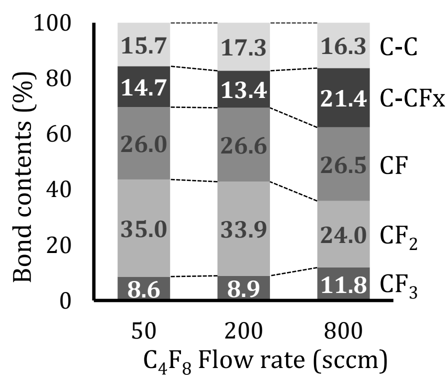

Fig. 2: Chemical composition of deposited films on wafer surface using C_4F_8 plasmas analyzed by XPS.

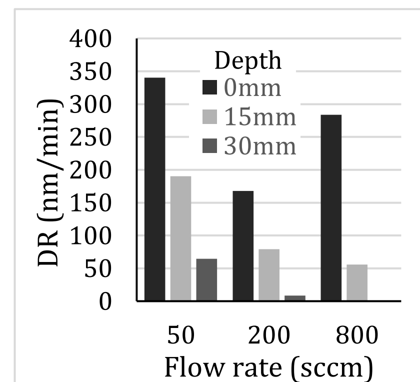

Fig. 3: Deposition rate (DR) of passivation films at sidewall depth of 0, 15, and 30 mm, and flow rate of 50, 200, and 800 sccm.

References

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