Cyclic etcing of SiO_2 contact holes using heptafluoropropyl methyl ether plasmas

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Abstract: As an alternative to high global warming potential materials such as SF_6 and C_4F_8, heptafluoropropyl methyl ether (HFE-347mcc3) was used for cyclic etching of SiO_2 contact holes. Etch profiles of the contact holes at various flow rates of the discharge gas in the deposition step revealed that bowing and narrowing occurred at lower and higher flow rates of HFE-347mcc3, respectively.

Keywords: Plasma etching, heptafluoropropyl methyl ether, cyclic etching, contact hole

1. Introduction.

During etching of SiO_2 contact holes, ions collide with the mask, causing damage and corrosion to the mask. This leads to pattern deformations such as bowing, necking, and etch stops, which cause defects [1, 2].

To solve this problem, a cyclic etching process, which consists of the alternating steps of depositing a passivation layer on the mask and etching the contact holes, has been introduced. The conventional cyclic etching process used high global warming potential (GWP) materials such as C_4F_8 and SF_6, which have a negative impact on global warming [3, 4]. Therefore, development of cyclic etching processes using low-GWP alternatives is necessary.

In this study, cyclic etching of SiO_2 contact holes was conducted using heptafluoropropyl methyl ether (HFE-347mcc3), whose GWP is much lower than those of C_4F_8 and SF_6 [5, 6]. Etch profiles of the contact holes obtained at various flow rates of the discharge gas in the deposition step were investigated to understand the shape evolution of the SiO_2 contact holes during cyclic etching.

2. Experiment

Cyclic etching was performed in an inductively coupled plasma (ICP) system shown in Fig. 1. In the deposition step, a mixture of HFE-347mcc3/Ar was used. The flow rates of HFE-347mcc3/Ar were varied from 5/25 to 12/18 sccm. The pressure and the source power were fixed at 30 mTorr and 250 W, respectively. In the etching step, a mixture of HFE-347mcc3/O_2/Ar was used. The flow rates of HFE-347mcc3/O_2/Ar were fixed at 8/2/20 sccm. The pressure was fixed at 10 mTorr, the source power at 250 W, and the bias voltage at -1200 V. Durations of deposition and etching steps were fixed at 7 and 30 s, respectively. The number of cycles were 24, and the corresponding total etch time was 12 min.

Fig. 2 shows the cross-sectional scanning electron microscopy (SEM) image of the patterned sample before etching. A 2400-nm-thick SiO_2 film for contact-hole etching was on a Si substrate. A 1350-nm-thick ACL with a hole diameter of 200 nm was used as a mask.

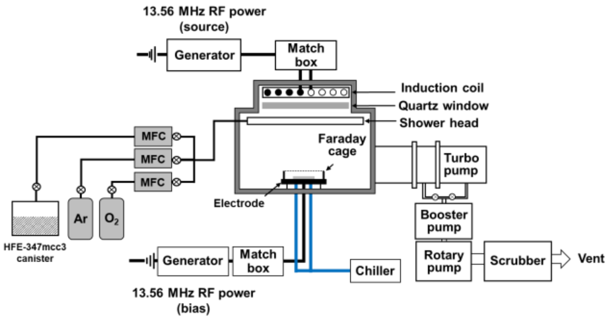

Fig. 1. Schematic diagram of an ICP system.

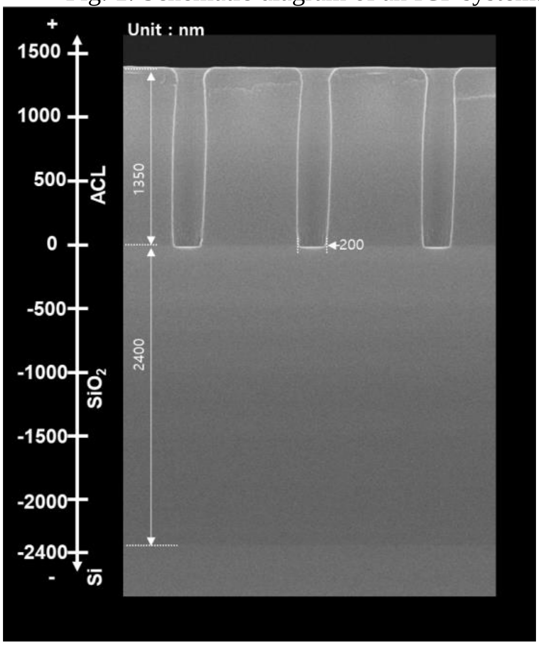

Fig. 2. A cross-sectional image of SiO_2 contact holes before etching.

3. Results

Fig. 3 shows SEM images of SiO_2 contact holes after cyclic etching at various flow rates of HFE-347mcc3/Ar in the deposition step. In all cases, the top diameter of the SiO_2 hole slightly decreased to 196 nm (from 200 nm before etching). When the flow rates of HFE-347mcc3/Ar were 5/25 sccm in the deposition step, the SiO_2 contact hole had a bowing, and the maximum diameter of the bowing was 213 nm. When the flow rate of HFE-347mcc3 increased to 8 sccm (HFE-347mcc3/Ar = 8/22), bowing decreased and the maximum diameter of the bowing was 197 nm, which was only 1 nm larger than that at the top. When the HFE-347mcc3 flow rate further increased, the

SiO_2 contact hole formed a narrowing, and the hole diameter kept decreasing with the vertical position.

The shape evolution of contact-hole etch profiles with increasing HFE-347mcc3/Ar ratios in the deposition step may be attributed to increased etch resistance and/or decreased etch ability of the sidewalls of contact holes.

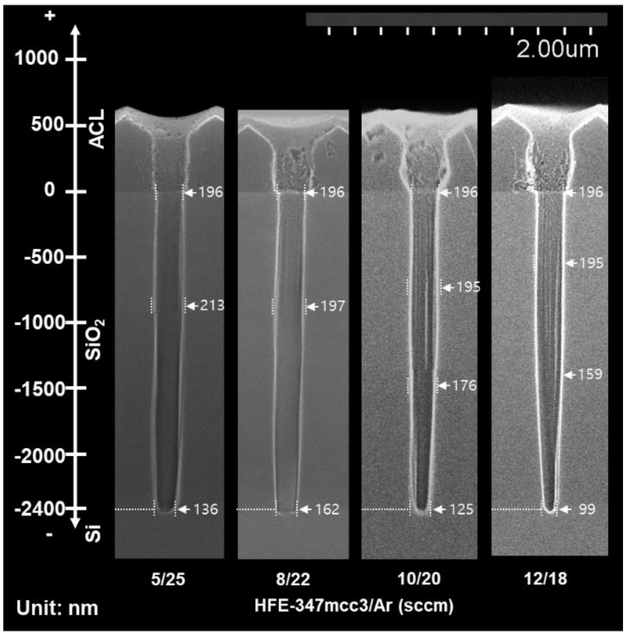

Fig. 3. Cross-sectional images of SiO_2 contact holes after cyclic etching at various flow rates of HFE-347mcc3/Ar in the deposition step.

4. References

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