THE USE OF C_4F_6 PLASMAS AS AN ALTERNATIVE TO PERFLUOROCARBONS FOR HIGH ASPECT RATIO CONTACT HOLE ETCHING

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A high aspect ratio contact hole etching of dielectrics (e.g., SiO_2) is one of the key processes in developing the next generation ultra large scale integrated devices because of the rapid shrinkage of the design rule to the nanometer level. Perfluorocarbons (PFCs) such as CF_4, C_2F_6, and c-C_4F_8 are widely used as etchant gases for contact hole etching. These PFCs, however, are considered to be problematic from an environmental viewpoint because of their long atmospheric lifetimes and high global warming potentials (GWP) [1, 2]. Several classes of environmentally benign chemistries have been examined as alternatives to PFCs, and unsaturated fluorocarbons (UFCs) such as C_3F_6 and C_4F_6 are one of the attractive candidates.

In this study, we reports on an etching of a SiO_2 contact hole with a diameter of 0.17 μm and an aspect ratio of 15 using $C_4F_6/O_2/Ar$ and $C_4F_6/O_2/Ar/CH_2F_2$ plasmas (UFC-containing plasmas). A SiO_2 contact hole etching in a c-$C_4F_8/O_2/Ar/CH_2F_2$ plasma (PFC-containing plasma) was also conducted to compare the etch profiles and contact resistances obtained in the two different gas discharges: $C_4F_6/O_2/Ar/CH_2F_2$ and c-$C_4F_8/O_2/Ar/CH_2F_2$ plasmas.

Fig. 1 shows the SEM micrographs of the 0.17-μm diameter contact holes etched in $C_4F_6/O_2/Ar$ plasmas without and with CH_2F_2 addition, respectively. In the absence of CH_2F_2 gas (Fig. 1 (a)), it can be seen that erosion of the PR layer occurs around the contact hole so severely that it is not likely to maintain the CD of the deep contact hole. On the contrary, for the case of adding 20 sccm of CH_2F_2 gas to a $C_4F_6/O_2/Ar$ plasma (Fig. 1 (b)), relatively thick fluorocarbon films are deposited on the PR layer and around the contact hole. This resulted in maintaining the CD after ashing the PR layer and cleaning the fluorocarbon films.
Fig. 2 shows the SEM micrograph of the deep contact hole, with a diameter of 0.17 μm and an aspect ratio of 15, etched in a $C_4F_6/O_2/Ar/CH_2F_2$ plasma. We obtained a bowing-free deep contact profile with a contact profile angle of 89.5 ° at 20 sccm of CH_2F_2 gas.
It is seen from Fig. 3 that the contact resistance distributions of a contact hole (0.19 μm diameter) etched in $C_4F_6/O_2/Ar/CH_2F_2$ and c-$C_4F_8/O_2/Ar/CH_2F_2$ plasmas reveal that the resistance difference is within spec. (about 1.2 Ω).

In conclusions, the use of C_4F_6 gas as an etchant gas for a high aspect ratio contact hole etching can be a good alternative to PFC gases.

References

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2. R. Chatterjee, S. Karecki, R. Reif, V. Vartanian, and T. Sparks, *J. Electrochem. Soc*,**149**, pp.G276-G285 (2002).

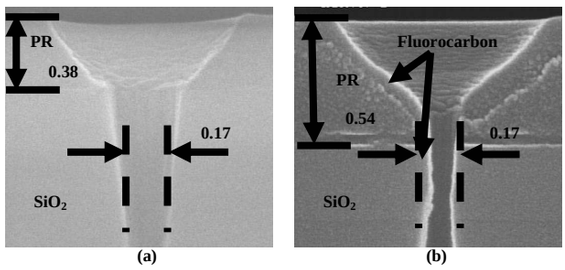

Fig.1 SEM micrographs of the etched contact holes with 0.17-μm diameter using (a) $C_4F_6/O_2/Ar$ and (b) $C_4F_6/O_2/Ar/CH_2F_2$ plasmas. Thickness of the initial PR layer was 0.56 μm. The flow rate of CH_2F_2 in case (b) was 20 sccm.

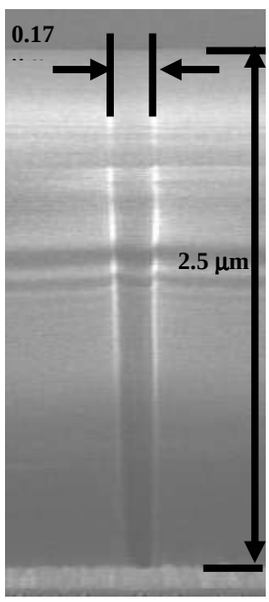

Fig.2 SEM micrograph of the 0.17 μm diameter contact hole etched in a $C_4F_6/O_2/Ar/CH_2F_2$ plasma. The aspect ratio and the contact angle of the hole were 15 and 89.5 °, respectively. The flow rate of CH_2F_2 was 20 sccm.

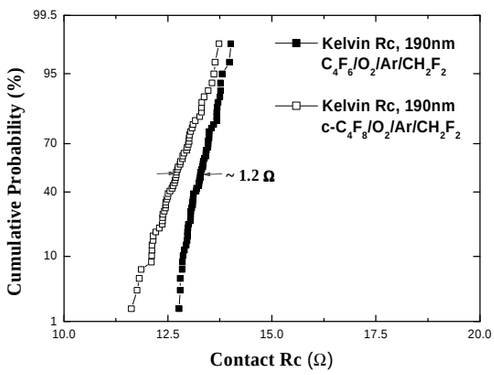

Fig.3 Contact resistance distributions of a contact hole etched in $C_4F_6/O_2/Ar/CH_2F_2$ (filled rectangles) and c-$C_4F_8/O_2/Ar/CH_2F_2$ (open rectangles) plasmas.