Radical Control in a Hole to Break an Etch-Stop Barrier for High Selective HARC Etching

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INTRODUCTION

As the feature size of ULSI devices is scaled down to the 0.1-μm rules, a high-aspect-ratio contact hole (HARC) must be etched with high selectivity, high aspect ratio of over 15, and a bowing-free etched shape. We found that the CF_2/F ratio determines the photoresist selectivity and the CF_2/ion ratio determines the RIE-lag according to the double-near-surface model (1,3).

However, for more improvement of mask-selectivity and etched shape, and more reduction of under-layer damage, further understanding of etching mechanism in terms of the transport of radicals in a hole is necessary (2).

In this work, to meet these requirements, we studied etch-stop mechanism and proposed methods of improvement with wide etch-stop free margin.

ETCH-STOP MECHANISM

We assumed the dissociation species in plasma are CF_2, C, F, and O (3). The distribution of C intensity was found to have a peak at the central part in an etched hole, which was observed by AES measurement, as shown in Figure 1. This result can be explained by taking account of the transport of high-sticky radicals such as C, polymer removal by O and F radicals, and radical reflection at the sidewall in a hole (see Figure 2). We thus consider that this is a cause of the unexpected etch-stop that occurs at an aspect ratio of around four when O_2 flow rate or ion energy is a little low compared to the deposited polymer thickness.

EXPERIMENTAL AND RESULTS

We used an ultra-high-frequency ECR (UHF-ECR) plasma etching system with an $Ar/C_5F_8/O_2$ gas mixture for the HARC etch process (2,4). According to our etch-stop analysis, we introduce a breakthrough-step (BT-step), that is, change oxygen flow rate according to the profile of polymer thickness. As a result, we successfully etched a 0.09μm-ϕ hole with high mask-selectivity and a vertical profile, but etch-stop occurred at wide line pattern. We assume that polymerizing of low-sticky radicals such as CF_2 causes this etch-stop. To improve this etch-stop, we found a multi-step etching as shown in Figure 3 to be suitable. In this case, we changed Ar flow rate in addition to the BT-step, to control the amount of low-sticky radicals. This multi-step etching improved the wide line pattern etch while maintaining high mask selectivity and a good etched profile of the fine hole pattern, as shown in Figure 4.

Furthermore, we applied the bias-step etching to reduce under-layer damage. Figure 5 shows the TEM images of the bottom of a contact hole on a silicon substrate etched by the HARC process. It is clear that the lattice damage cannot be observed without any etch-stop.

REFERENCES

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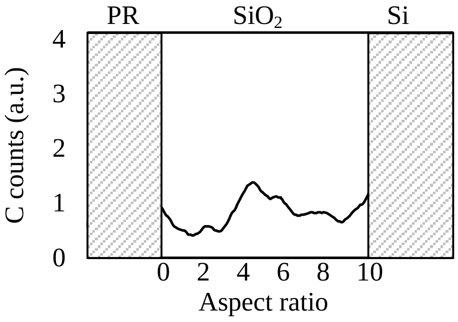


Figure 1. Auger Electron Spectroscopy. (0.2μm-ϕ hole sample)

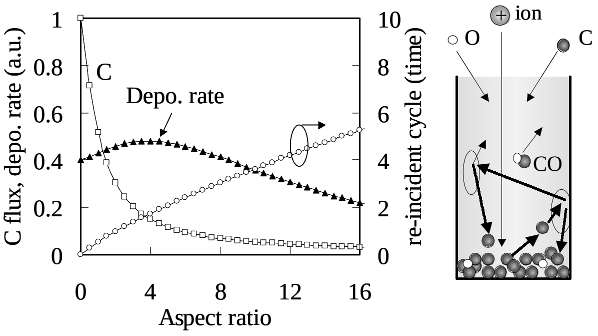


Figure 2. Calculated deposition rate in a hole. C rich deposition is piled up by re-incident phenomena.

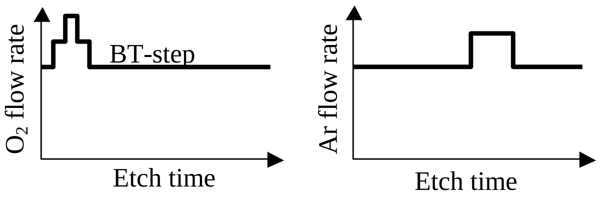


Figure 3. A diagram of multi-step etching.

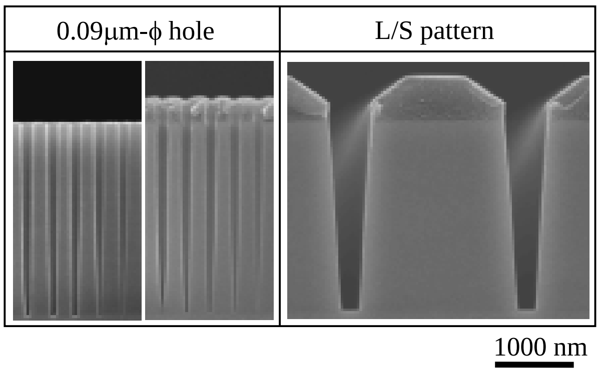
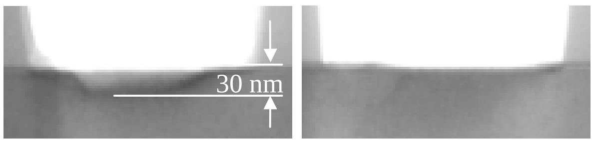


Figure 4. Etched profiles of fine hole and wide line patterns with multi-step etching.



(a) (b)

Figure 5. TEM images of the bottom of contact hole (a) without bias-step, (b) with bias-step.