Etch Rates and Etch Selectivities of a Nonvolatile Hafnium Oxide Etchant

John S. Starzynski

Honeywell Electronic Chemicals
Honeywell Technology Center, MN14-2B45
12001 State Highway 55, Plymouth, MN 55441

INTRODUCTION

Materials that possess a high dielectric constant will soon replace silicon dioxide as the gate dielectric for some integrated circuit (IC) devices. One such dielectric material that is being intensely investigated is hafnium oxide (HfO_2). The dielectric constant of HfO_2 is an order of magnitude larger than that of SiO_2. Transistors incorporating HfO_2 as the gate dielectric will possess the same performance as transistors with a SiO_2 gate one-tenth as thick.

HfO_2 is very difficult to dry etch since no volatile hafnium containing compounds are known. Therefore a wet etchant is needed to remove the HfO_2 from the source and drain regions of transistors during IC manufacturing. To minimize the field oxide loss, this etchant must possess a high HfO_2 to thermally grown SiO_2 (TOx) as well as a high HfO_2 to tetraethylorthosilicate-based oxide (TEOS) etch selectivity. Dilute aqueous hydrofluoric acid (HF) solutions will etch HfO_2. Unfortunately, the HfO_2 to TOx etch selectivity is approximately 1:10 and the HfO_2 to TEOS etch selectivity is approximately 1:100 for dilute aqueous HF etchants.

Replacing water with a non-aqueous solvent such as an alcohol will improve the HfO_2 to SiO_2 etch selectivity. Researchers at IMEC have reported a HfO_2 to TOx etch selectivity of 3:1 and a HfO_2 to TEOS etch selectivity of 1:1 [1].

Alcohol-based etchants can be difficult to use due to their volatility and flammability. The etch rates and etch selectivities of a nonflammable and nonvolatile HfO_2 etchant is reported in this paper.

EXPERIMENTAL

Room temperature etch rates and etch selectivities of HfO_2, TOx, and TEOS as function of the concentrations of three components dissolved in a nonflammable and nonvolatile solvent were measured employing design of experiment (DOE) methodology. A Box-Behnken three-level design was utilized for fitting the second-order response surfaces.

RESULTS AND DISCUSSION

A HfO_2 to TOx etch selectivity of 17:1 and a HfO_2 to TEOS etch selectivity of 6:1 was obtained. These selectivities are significantly higher than those obtained employing either alcohol or water based etchants.

A response surface plot of the HfO_2 etch rate as a function of component A concentration and component B concentration is presented in figure 1. The etch rate varies from approximately 20 to 40 Å/minute. This etch rate range is optimal since IC devices will contain HfO_2 films with a thickness of approximately 100 Å.

CONCLUSION

A nonflammable and nonvolatile HfO_2 etchant has been developed. The HfO_2 to TOx etch selectivity and HfO_2 to TEOS etch selectivity that this etchant possess is significantly higher than that possessed by either aqueous or alcohol based etchants**.**

REFERENCES

[1] M. Claes, et al., 204th Electrochemical Society Meeting Abstracts, Volume 2003-02 (2003).

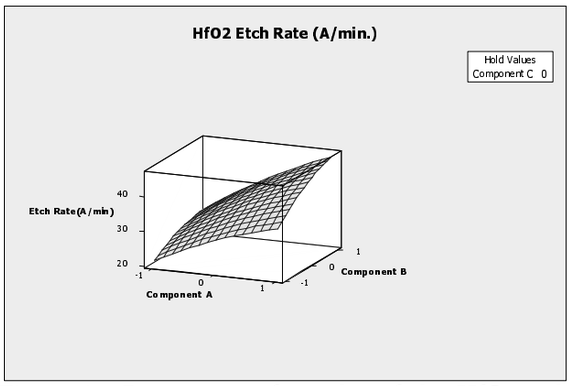

Figure 1. Response surface plot of the HfO_2 etch rate as a function of component A concentration and component B concentration dissolved in a nonvolatile solvent.