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Evaluation of PECVD a-SiC:H as a Cu Diffusion Barrier Layer of Cu Dual Damascene Process**Soo Gun Lee, Hyeok-Sang Oh, Hong-Jae Shin, Jin-Gi Hong, Hyeon-Deok Lee and Hokyu Kang**

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1. Introduction

Copper is a prime candidate as an alternative ULSI interconnection materials since it offers both higher conductivity and better electromigration resistance over current aluminum alloys. However, many process integration issues exist, one of which is the rapid drift of copper ions in SiO₂ under the influence of electric fields. Copper diffusion in dielectric may give rise to unanticipated yield or reliability problems. Hence a diffusion/drift barrier is necessary to prevent copper movement into interlevel dielectric. The primary candidate for the barrier/etch stop layer required in damascene process is silicon nitride. However, silicon nitride has a high dielectric constant. To reduce the effective dielectric in the copper damascene structure, the silicon carbide which is prepared by PECVD using 3 methyl silane source has been studied for the dielectric copper diffusion barrier[1,2]. In this paper, the mechanism for decreasing the dielectric constant of a-SiC:H is briefly discussed. The silicon carbide is applied for diffusion barrier of two-level Cu dual damascene process. Some electrical properties will be compared with that of silicon nitride barrier dual damascene process.

2. Experimental

A-SiC film was deposited using Dow Corning organosilicon gas, 3-methyl-silane(3MS), in an Applied Materials P5000 PECVD chamber. The film thickness and optical constants were measured using a reflectometer. FTIR spectroscopy was used to investigate molecular bonding in the film. The dielectric constant was measured using Mercury C-V plotter. The silicon to carbon ratio was measured by XPS(x-ray photoelectron spectroscopy) and the hydrogen concentration was measured by ERD-TOF(Elastic Recoiled Detector-Time of Flight)[3].

3. Results & Discussion

Figure1 shows the variation of dielectric constants of a-SiC:H as a function of 3MS flow rate with He, H₂ and N₂ carrier gases. The lowest and the highest dielectric constant obtained with N₂ and H₂ carrier gas respectively. The changes of the refractive indexes of a-SiC:H is also included in the lower part of figure1. The refractive indexes of a-SiC:H have highest with H₂ carrier gas and lowest with N₂ carrier gas. Dielectric constant is composed of orientational, ionic and electronic polarizations, which is the equal to the square of refractive index at visible light range. So, the reduction in dielectric constant for a-SiC:H is believed to be partly due to the decrease of electronic

polarization. However, the dramatic decrease in dielectric constant relative to the previously reported a-SiC cannot be explained by the reduction in electronic polarization only. Figure2 shows the relationship between the dielectric constant and the peak intensity ratio of Si-CH₃ to Si-C in FTIR spectrum. The peak intensity ratio of a-SiC:H decreases with increase of the dielectric constant. Regardless of the carrier gas, the data are fitted on single line. The previous studies showed that the terminating CH₃ group lower the crosslinking and the density of the material[4]. Figure 3 shows a dielectric constant as a function of film density, including the SiC with H₂, H₂ and N₂ carrier gases. The dielectric constant change linearly with the density of a-SiC:H films. The effect of porosity on dielectric constant can be estimated using a simple model, such as the Bruggeman's effective medium approximation. The reduction in dielectric constant of a-SiC:H using 3MS gas is suggested to be largely due to the decreased density by incorporation of Si-CH₃ groups.

Figure.4 is the cross-sectional schematic representation of the test structure of two-level Cu dual damascene structure. The various thickness of a-SiC and the 700 Å of PECVD SiN is test as the Cu diffusion barrier layer for the M1 and M2 layers. The HDP-FSG is used as IMD materials. Figure 5 and 6 shows the distributions of the interlayer capacitance between the M1 and M2 area pattern and that of interline capacitance between M1 lines. The mean value of capacitance with a-SiC is 8% lower than that with PECVD SiN. The leakage current distribution with various diffusion barrier layer are compared at figure 6. As shown in figure6, the leakage current with a-SiC barrier are lower by 1 order than PECVD SiN barrier. In the samples with SiC barrier, the parasitic capacitance and the leakage current are not increased after 400°C anneal for 10 hour.

4. Conclusion

The reduction in dielectric constant of a-SiC:H using 3MS gas is suggested to be largely due to the decreased density by incorporation of Si-CH₃ groups. The value of capacitance with a-SiC is 8% lower than that with PECVD SiN. The leakage current with a-SiC barrier are lower by 1 order than PECVD SiN barrier. In the samples with SiC barrier, the parasitic capacitance and the leakage current are not increased after 400°C anneal for 10 hour.

References

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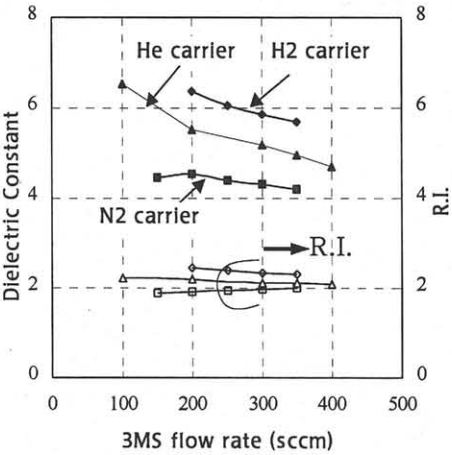


Figure.1 Variations of dielectric constant and R.I. of a-SiC:H as a function of 3MS flow rate with vairous carrier gas

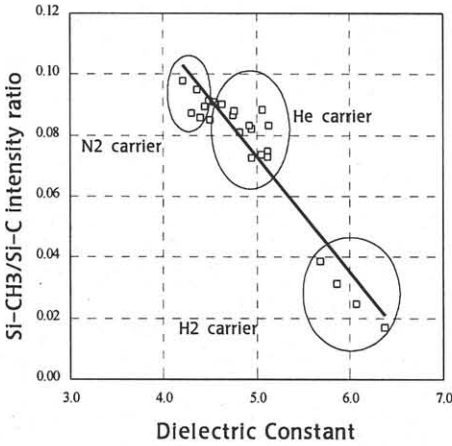


Figure.2 Si-CH3/Si-C peak intensity ratio of FTIR spectrum vs. dielectric constant

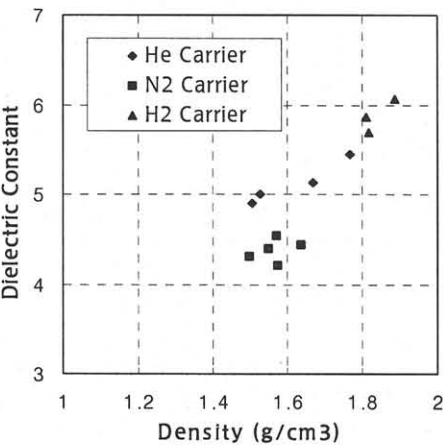


Figure.3 Dielectric constant as a function of film density

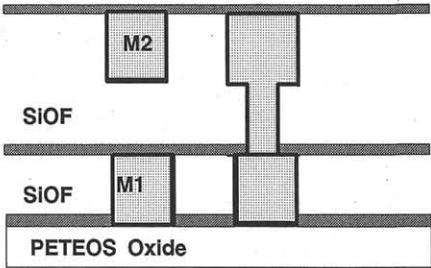


Figure.4 A cross-sectional schematic repretation of the test structure of Cu dual damascene structure

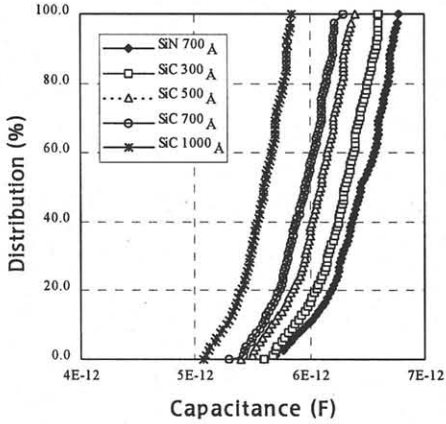


Figure.5 Distributions of interlayer capacitance with various thickness of SiC barrier and SiN barrier

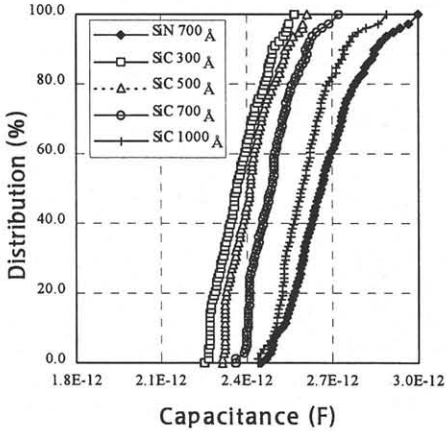


Figure.6 Distributions of intraline capacitance with various thickness of SiC barrier and SiN barrier

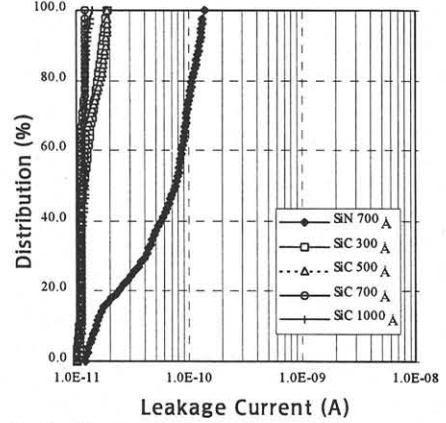


Figure.7 Distributions of interlayer leakage current with various thickness of SiC barrier and SiN barrier