Extended Abstracts of the 1996 International Conference on Solid State Devices and Materials, Yokohama, 1996, pp. 634-636

Application of SiOF Film Deposited Using TEOS/TEFS/O_2 System to Multi-Level Interconnection Designed with 0.25μm Rule

Hiroshi KUDO[a], Yukihiro SATHO, Hisashi MIYAZAWA, Hideki HARADA, and Atsuo SHIMIZU

[a]*Thin Film Technology Department and Process Integration Department, Process Development Division, Fujitsu Limited, 1015 Kamikodanaka, Nakahara-ku, Kawasaki 211, Japan*

We deposited SiOF films using TEOS/TEFS/O_2 system as a new chemistry. This chemistry gave SiOF films with low water absorptivity which was almost equal to that of TEOS-NSG and also had superior capability of gap filling. We fabricated three-level interconnection using CMP process. We succeed in reducing total capacitance between Al wirings by 10 %, compared to that of TEOS-NSG.

1.INTRODUCTION

To get high-speed integrated circuits, how to reduce the wiring signal propagation delay (wiring delay) will be a key with increasing the number of interlayer dielectrics. The wiring delay depends heavily on capacitance between parallel interconnection metal lines. Insulating materials with low dielectric constants make possible to reduce the wiring delay in the interconnection layers. Recent works have indicated that the incorporation of fluorine in plasma-deposited SiO_2 (hereafter denoted as "SiOF") can reduce the effective dielectric constant below 4.0.[1-4]

However, the dielectric constant of SiOF increases monotonically when exposed to atmosphere because of the high water absorptivity. The characteristics of SiOF films including dielectrical stability have been discussed using conventional chemistry such as TEOS/O_2/C_2F_6 system, so far.[5-7] The control of the water absorption is a key to integrate SiOF into actual device process.

Triethoxyfluorosilane(TEFS) is very attractive, because that can become the silicon source at the same time that it itself is fluorine source. On this account, the plasma chemistry changes greatly, so that it is expected that the hygroscopic property of SiOF films are improved.

In this work, we have investigated the hygroscopic and gap filling property of SiOF films deposited using the chemistry of TEOS/TEFS/O_2. The result showed the TEFS added SiOF (hereafter denoted as "TEFS-SiOF") film had low water absorptivity which was almost equal to that of TEOS-NSG and also had superior capability of gap filling. Furthermore, we fabricated three-level interconnection by CMP process, using the TEFS-SiOF film having dielectric constant of 3.6. The total capacitance between the Al wirings was reduced by 10%, compared to that of TEOS-NSG.

2. EXPERIMENTAL

The deposition of SiOF films was performed by adding TEFS as a fluorine and silicon source to a conventional TEOS/O_2 gas mixture in a parallel plate plasma chamber having a dual frequency configuration. TEOS and TEFS supplies were done using a direct injection system which consists of a liquid mass flow meter and a vaporizer. Helium gas as a carrier was introduced into the vaporizer to stabilize the flow rate of TEOS and TEFS.

The preparation of silicon substrates used for dielectric measurements is as follows. The substrates were p-type (100) with a resistance of 10Ω cm. Boron ions were implanted into the substrates at 40 keV acceleration energy by a dose of $5\times10^{15}cm^{-2}$, then the substrates were annealed at 1000 ℃ for 30 minutes in dry nitrogen. 1.0 μm-thick aluminum films were deposited on the backside of the substrates by sputtering. Gold was evaporated on top of the SiOF films as electrodes through a metal mask which has a number of circular windows with 1.0 mm in diameter to measure dielectric constants.

3. RESULTS

Figure 1 shows change in dielectric constant as a function of mol mixture ratio of TEFS/(TEOS+TEFS). The dielectric constant was decreased by about 3.5 at the mol mixture ratio of 100%.

We compared the dielectrical stabilities for both films deposited using TEFS and C_2F_6. Figure 2 shows changes of dielectric constant of these samples when exposed to atmosphere. The both films included fluorine of 6 atomic % had dielectric constant of 3.6 just after the deposition. The dielectrical stability of TEFS-SiOF film was more stable than that of the film added C_2F_6. The increment of the dielectric constant of TEFS-SiOF film for one week was 0.15 which was almost equal to that of TEOS-NSG film.

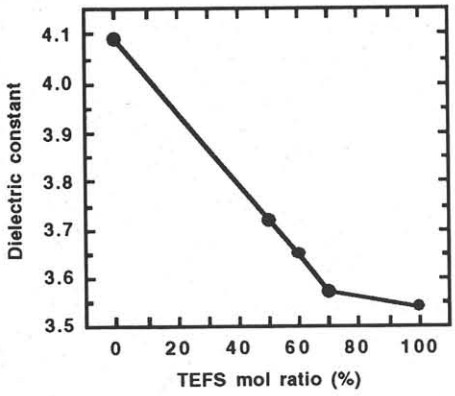

Figure 1. Change in dielectric constant as a function of mol mixture ratio of TEFS.

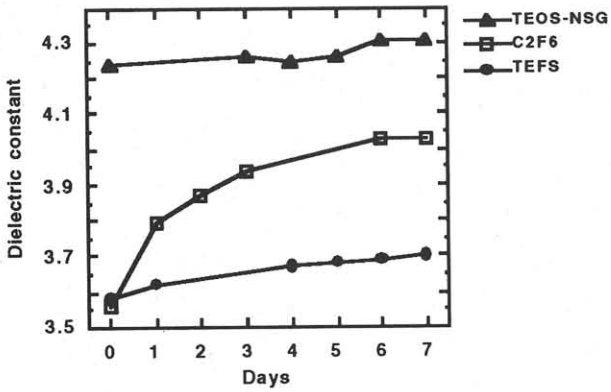

Figure 2. Change of dielectric constants of the SiOF films when exposed to atmosphere.

The gap filing capability of TEFS-SiOF film with dielectric constant of 3.6 is shown in figure 3. The space of line to line and the height were 0.6 and 1.3 μm, respectively. We could fill the space without forming the void. This chemistry showed superior capability of gap filling.

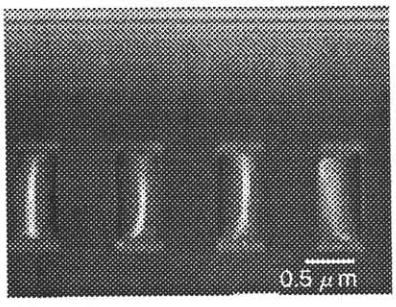

Figure 3. The gap filing capability of TEFS-SiOF film with dielectric constant of 3.6.

Figure 4 shows the process for the fabrication of three-level interconnection consisted of TEFS-SiOF film. The interlayer dielectric laminated with structure of NSG(0.05um)/TEFS-SiOF(0.35um)/NSG(1.2um) was deposited on patterned Al wirings. The upper NSG film was polished of 1 μm by CMP, so that the film 0.2 μm thick was left on the TEFS-SiOF film. Such a capping layer prevents from Al wiring peeling due to the reaction of metal with fluorine.

Figure 5 shows the pattern of Al wiring consisted of three layers. The spaces of line to line were from 0.45 to 1.32 μm and the height was 0.55 μm.

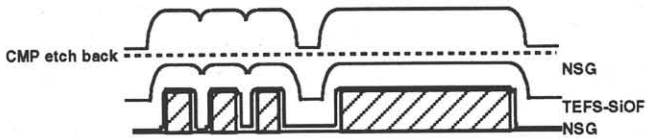

Figure 4. Process for the fabrication of three-level interconnection

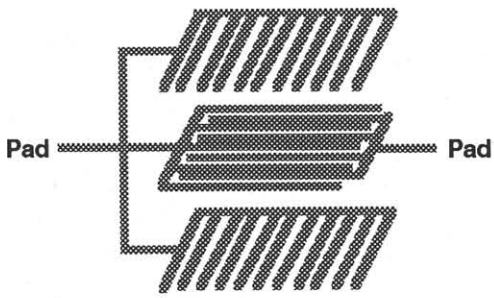

Figure 5. Al wiring pattern consisted of three layers.

Figure 6 shows total capacitances between Al wirings and the relative ratios of the capacitance compared to that of TEOS-NSG. We confirmed the total capacitance was reduced by 10 % at the space of 0.45 μm.

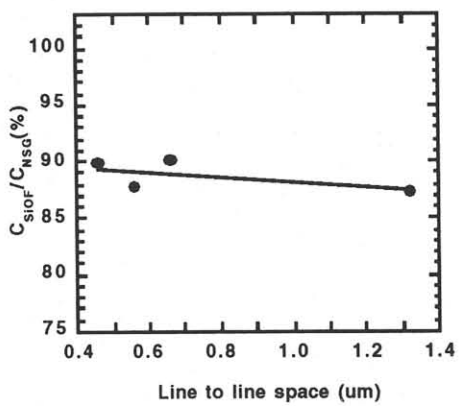

Figure 6. The relative ratios of the capacitance between Al wirings

4.CONCLUSION

In this work, we deposited SiOF films using the chemistry of TEOS/TEFS/O_2. This chemistry gave SiOF films having low water absorptivity which was almost equal to that of TEOS-NSG. And this chemistry also had superior capability of gap filling. We could fill the space of line to line having aspect ratio of 1.3, not to form the void. We fabricated three-level interconnection by CMP process, using the film having dielectric constant of 3.6. We succeed in reducing total capacitance by 10 %, compared to that of TEOS-NSG.

Acknowledgement

Thanks are due to Dr. M. Yamada and Dr. Y. Furumura for his valuable discussion.

References

1)T. Usami, K. Shimokawa and M. Yoshimaru : Ext. Abstr. 1993 Int. Conf. Solid State Devices and Materials, Chiba, 1993 (Business Center for Academic Societies Japan, Tokyo,1993), p.161.

2)T. Fukada and T. Akahori : Ext. Abstr. 1993 Int. Conf. Solid State Devices and Materials,Chiba, 1993 (Business Center for Academic Societies Japan, Tokyo,1993), p.158.

3)L. Q. Qian, H. W. Fry, G. Nobinger, J. T. Pye, M. C. Schmidt and J. Cassillas: Proc. DUMIC Conf. (1995) p.50.

4)S. Takeishi, R. Shinohara, H. Kudo, A. Tsukune, Y. Satho, H. Miyazawa, H. Harada and M.Yamada: Proc. DUMIC Conf. (1995) p. 257.

5)T. Usami, K. Shimokawa and M. Yoshimaru: Tech. Rep. IEICE SDM94-146 (1994) No.11, 43.

6)H. Kudo, R. Shinohara, S. Takeishi, N. Awaji and M. Yamada: Ext. Abstr. 1995 Int. Conf. Solid State Devices and Materials, Osaka, 1995 (International House, Japan, Osaka, 1995), p.605.

7)H. Kudo, R. Shinohara, S. Takeishi, N. Awaji and M. Yamada: Jpn. J. Appl. Phys. Vol. 35 (1996) pp.1583-1587.