A Fabrication of High Break-down Voltage MIM Capacitors for IPD Applications

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Abstract : For the Radio Frequency Integrated Passive Device (RFIPD) application, we have successfully developed and characterized high break-down voltage metal-insulator-metal (MIM) capacitors with 2,000 Å plasma-enhanced chemical vapor deposition (PECVD) silicon nitride which deposited with SiH_4/NH_3 gas mixing rate, working pressure, and RF power of PECVD at 250 °C chamber temperature. At the PECVD process condition of gas mixing rate (0.957), working pressure (0.9 Torr), and RF power (60 W), the AFM RMS value of about 2,000 Å silicon nitride on the bottom metal was the lowest of 0.862 nm and break-down electric field was the highest of about 8.0 MV/cm with the capacitance density of 326.5 pF/mm^2.

Key Words : RFIPD, MIM, PECVD, Break-down electric field, Capacitance density

1. Introduction

Growing demand for mobile and wireless communication systems has generated a lot of interest in low-cost, high-quality, high-yield fabrication technologies. In this study, MIM capacitors with 2,000 Å silicon nitride are manufactured by SiH_4/NH_3 gas mixing rate, working pressure, and RF power of PECVD process. We obtained good MIM capacitor in which their break-down voltage are very high (8.0 MV/cm) and their capacitance are about 326.5 pF/mm^2. In the case of 13.06 pF MIM capacitor (200 μm × 200 μm), an up to 148 V break-down voltage can be obtained.

2. Experiment

In order to improve the break-down electric field, silicon nitride is deposited at 250 °C by PECVD whose process factors consist of SiH_4/NH_3 gas mixing rate, working pressure, and RF power. The Refractive Index (RI) of the deposited nitride can be measured by ellipsometer, and the surface smoothness of silicon nitride can be measured by atomic force microscopy (AFM).

3. Result and Discussion

The break-down voltage mainly depends on nitride surface morphology and the Si-H bonding of silicon nitride. PECVD process conditions of the insulator layers and the properties of these insulator layers are summarized in Table 1. Fig. 1 shows the break-down electric field of MIM capacitors for these two different conditions. Obviously, the break-down electric field of film 2 is much better than film 1. Since the amount of Si in the film increases, while that of N decreases, the refractive index of the Si_3N_4 thin films is increasing as the increased SiH_4/NH_3 flow ratio. The increase of refractive index is due to the decreased N-H bonding that occurs with decreasing N content [1]. Usually, the increase in the pressure can increase the refractive index, which is attributed to the increase in the Si content. By increasing the working pressure of PECVD, the number of ions generated in the plasma increases, which results in a larger ion flux reaching the substrates.

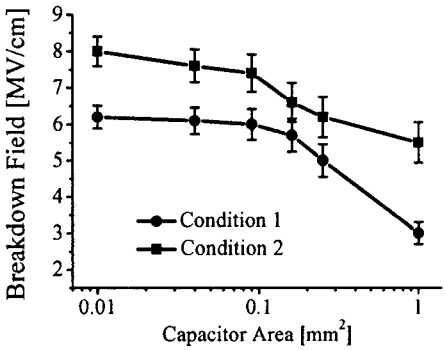

Fig.1 Break-down voltage of MIM capacitor by condition 1 and 2

Table 1 PECVD conditions and the properties of Si_3N_4 film

	SiH_4/NH_3	Pressure	RF	RI	RMS	Break-down Field
1	1.507	1.9	25	1.96	1.125	6.2 MV/cm
2	0.957	0.9	60	1.88	0.862	8.0 MV/cm

4. Conclusion

MIM capacitor with a high break-down voltage is realized. The refractive index of silicon nitride is reduced with decreasing the SiH_4/NH_3 gas-mixing rate, while the density of Si_3N_4 is increased by in good control of the working pressure and RF power of the PECVD. As the SiH_4/NH_3 gas-mixing rate is decreasing, the smoothness of silicon nitride thin films are increased and the break-down electric field is improved.

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References

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