Silicon Nitride (SiN_xH_y) by Plasma-Enhanced Chemical Vapor Deposition

R. L. Manay[1], V. Y. Abellana[2], and R. V. Sarmago
Materials Science and Engineering Program
University of the Philippines Diliman, 1101 Quezon City, Philippines
E-mail: [1] rheamanay@yahoo.com, [2] vabellana@hotmail.com

INTRODUCTION

In the microelectronics industry, silicon nitride is greatly employed as an encapsulant for silicon integrated circuits, as a diffusion barrier for water and sodium, as passivation and gate dielectric material and as local oxidation masks in integrated circuit processing. Accordingly, the number of thin film fabrication techniques are extensive: direct thermal nitridation, ion-beam enhanced deposition, ion plating, hot filament-enhanced CVD, self-propagating high temperature synthesis, laser ablation and plasma-enhanced chemical vapor deposition (PECVD).

Silicon nitride (SiN_xH_y) films prepared by plasma-enhanced chemical vapor deposition (PECVD) are widely used in the passivation of integrated circuits because they have low deposition temperature and remarkable chemical, electrical and mechanical properties. The PECVD process is based on the dissociation of gas molecules by a radio frequency (RF) electric field. This field dissociates neutral atoms into ions and free electrons. High mobility electrons are accelerated in the electric field, and they crack neutral molecules by inelastic scattering in the plasma. Neutral atoms and charged ions then precipitate on the substrate surface and form an amorphous silicon nitride (SiN_xH_y) layer.

In this study, the main concern is the fabrication and characterization of silicon nitride (SiN_xH_y) thin film deposited on silicon substrate by plasma-enhanced chemical vapor deposition (PECVD).

METHODOLOGY

Prior to deposition, native oxide from the p-type silicon substrate (Si-substrate) were degreased using an acidic mixture to remove alkali ions, cations and metallic contaminants. Native oxides were removed by submerging into 1:10 HF solution, followed by a rinse in de-ionized (DI) water, and then the substrate was dried with nitrogen gas. Oxide removal was evident by the change from the hydrophilic oxidized surface to the hydrophobic bare silicon substrate. Great care was taken to avoid recontamination of the wafer.

The silicon nitride (SiN_xH_y) films were deposited by a Plasma Enhanced Chemical Vapor Deposition (PECVD), a reactor with capacitance-couple parallel electrodes. A gas mixture of SiH_4-NH_3-N_2 was used as gas reactant. Deposition conditions were as follows:

SiH_4 flow rate	200 sccm
NH_3 flow rate	20 sccm
N_2 flow rate	200 sccm
RF Frequency	13.56 Mhz
Gas Pressure	1 mbar
Substrate Temperature	300°C
Silicon substrate	P(100)/P(111)

Silicon nitride thin films were characterized using Fourier Transform Infrared (FTIR) analysis to investigate bonding and Auger Electron Spectroscopy (AES) analysis for the elemental analysis and stoichiometric determination.

Science Diliman (July-December 2001) **13:2,** 26-28

RESULTS AND DISCUSSION

Fourier Transform Infrared (FTIR)

IR absorption measurements indicated Si-N stretching bond at 850 to 875 cm-1 confirming the main component of the film is indeed Si-N bonds (Fig. 1). The 2150 to 2200 cm-1 validated the Si-H stretching mode. The N-H mode was validated by the 3300 to 3400 cm-1. While the 1150 cm-1 validated the N-H bending mode.

It has been reported by several authors (Yeh et al., 1996; Maeda & Itsumi, 1998) that Silicon Nitride (SiN_xH_y) thin films deposited by PECVD were characterized by a considerable amount of hydrogen atoms incorporated in the films. The source of H was undoubtedly the SiH_4 and NH_3 reactants.

Auger Electron Spectroscopy Results

The presence of nitrogen and silicon atoms was confirmed by the AES on the thin film (Fig. 2). In the survey scan mode, the AES could identify all elements present on the surface of the sample, except H and He because AES process involved at least 3 electrons, (the third electron ejected was the auger electron), and H and He, have 1 and 2 electrons respectively.

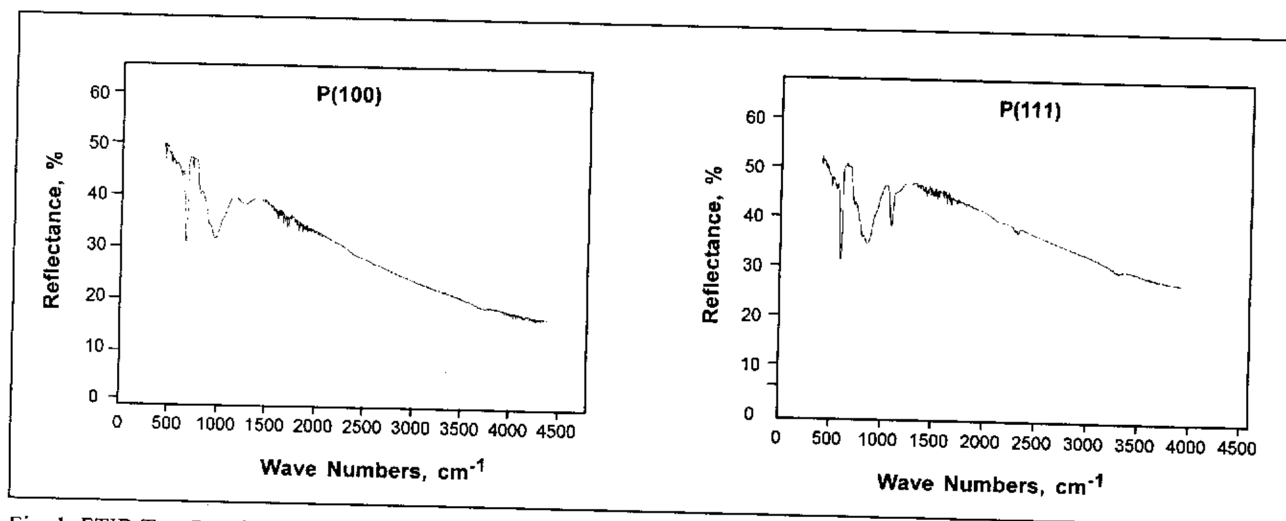

Fig. 1. FTIR Test Results for P(100) and P(111)

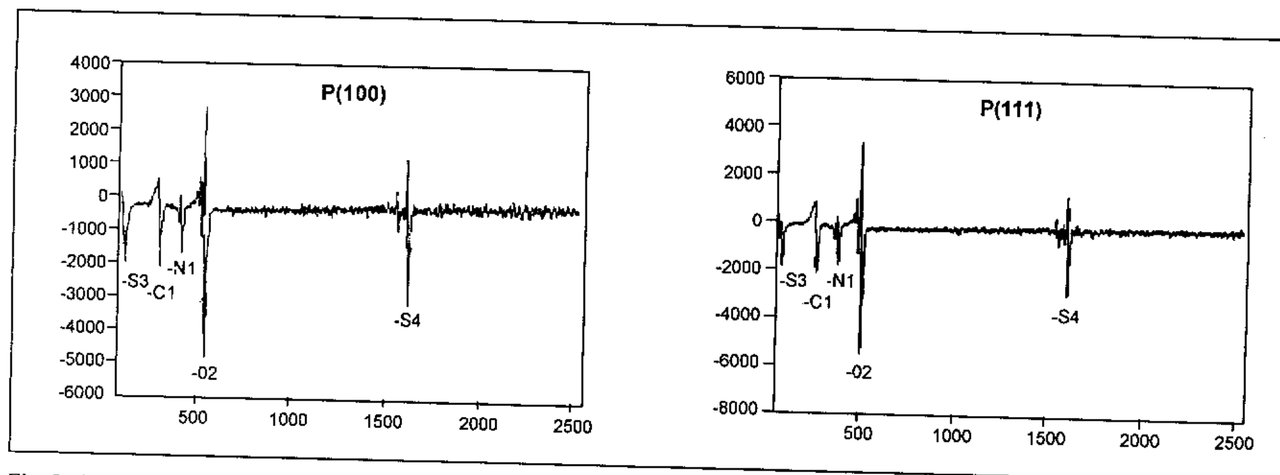

Fig. 2. AES Results for P(100) and P(111)

Usually AES detects C that may range from 10 to 50% depending on the sample (Table 1). This was due to air/environment exposure. Considering that the C and O contaminants were absorbed from the atmosphere during storage and handling.

Table 1. Percentages of elements present on the sample surface

Substrate C	C (at %)	N (at %)	O (at %)	Si (at %)
P (100)	23.84	7.72	24.88	43.56
P(111)	24.47	8.15	27.64	39.74

CONCLUSION

The Deposition of silicon nitride (SiN_xH_y) was confirmed by the FTIR and AES results thus attaining the main objective. However, the empirical formula SiN_xH_y can not be determined since Si to N was obscured by the (1) presence of contaminants, and (2) limitation of the AES in providing hydrogen atomic % concentration.

FTIR results confirmed the Si-N bonding and remarkable amount of H in the form of Si-H and N-H. AES results also showed that the thin films contained excess stoichiometric Si. These results confirm the findings of other researchers (Landford & Rand, 1978; El-Kareh, 1995), that PECVD-deposited nitride films were "not stoichiometric" and commonly denoted by SiN_x or $Si_xN_yH_z$ to distinguish them from "stoichiometric" nitrides (Si_3N_4).

ACKNOWLEDGMENTS

The authors would like to acknowledge L. Davila of the L.C. Laboratory for the FTIR and Ms. Emilie Dy and Mr. Enrico Garcia of Intel-Cavite for the Auger Electron Spectroscopy.

REFERENCES

El-Kareh, B., 1994. Fundamentals of Semiconductor Processing Technologies. New York, Kluwer Academic Publishers: 616 pp.

Lanford, W.A., & M.J. Rand, 1978. The hydrogen content of plasma-deposited silicon nitride. *J. Appl. Phys.* 49 (4): 2473-2477.

Maeda, M. & M. Itsumi, 1998. Thermal dissociation process of hydrogen atoms in plasma-enhanced chemical vapor deposited silicon nitride films. *J. Appl. Phys.* 84 (9): 5243-5247.

Yeh, W., R. Ishihara, S. Morishita, & M. Matsumura, 1996. Low-temperature chemical-vapor-deposition of silicon nitride film from hexachloro-disilane and hydrazine. *Jpn. J. Appl. Phys.* 35: 1509-1512.