DEVELOPMENT AND CHARACTERISATION OF KOH RESISTANT PECVD SILICON NITRIDE FOR MICROSYSTEMS APPLICATIONS

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I. INTRODUCTION

Silicon nitride deposited by means of low pressure chemical vapor deposition (LPCVD) is commonly used in microfabrication as construction or masking material in wet bulk micromachining due to its magnificent chemical resistance. However, the use of LPCVD silicon nitride poses several disadvantages. The inherent resistance to most chemicals makes it difficult to pattern by photolithography and wet etching, and due to the required process temperature of 750-900°C LPCVD silicon nitride is inapplicable for certain applications. Alternatively, silicon nitride can be formed at lower temperatures by plasma enhanced chemical vapor deposition (PECVD).

Due to the inclusion of hydrogen PECVD silicon nitride should be represented by the formula $Si_xN_yH_z$. The hydrogen content greatly affects film properties such as stress level, refractive index and etch rate in aqueous HF solutions [1,2,3]. In addition PECVD silicon nitride films generally tend to suffer from poor chemical stability making them unsuitable for e.g. etch mask applications.

This paper presents the development of a PECVD silicon nitride for application as construction and KOH etch mask material in a CMOS post process. The important film parameters for the given application are low deposition temperature, low compressive film stress, and low KOH etch rate. The influence of various process parameters on film properties such as refractive index, thickness, residual stress level, KOH etch rate, buffered oxide etch (BOE) rate has been investigated. In addition infrared absorption spectra of the silicon nitride films have been obtained using Fourier transform infrared spectroscopy (FTIR). The IR absorption spectra are analyzed and correlated with the properties of the silicon nitride.

II. EXPERIMENTAL

The silicon nitride films were deposited using a PECVD cluster system from Surface Technology Systems (STS Multiplex CVD). All experiments were performed at 300°C using either low frequency (380 kHz), high frequency (13.56 MHz) or mixed frequency excitation of a gas mixture of silane (SiH_4), ammonia (NH_3), and nitrogen (N_2). The process parameters subject to investigation were: gas mixture (gas flows), chamber pressure, and R.F. power. The low frequency experiments have been performed according to a fractional factorial experimental design where process parameters have been varied within the ranges specified in table 1.

Factor	Minimum	Center	Maximum
SiH_4 flow	30 sccm	40 sccm	50 sccm
NH_3 flow	20 sccm	70 sccm	120 sccm
N_2 flow	1000 sccm	1500 sccm	2000 sccm
Pressure	250 mTorr	375 mTorr	500 mTorr
R.F Power	20 W	50 W	80 W

Table 1: Process parameters for low frequency recipes.

III. RESULTS AND DISCUSSION

Silicon nitrides deposited from recipes using low or mixed frequency excitation exhibited better chemical resistance to KOH than similar recipes using high frequency excitation. Hence, the development was focused on recipes using low or mixed frequency excitation. The influence of process parameters on film properties was found to be independent of the used excitation scheme.

Within the investigated parameter space the residual stress level of the silicon nitride film showed significant dependence on chamber pressure and R.F. power. For increasing power and pressure the film stress decreased towards less compressive values. Contrarily the KOH etch rate was shown to increase with increasing power and chamber pressure. Thus, for the given application requiring both low film stress and low KOH etch rate a suitable trade off regarding process pressure and RF power has to be made. In addition R.F. power was found to be the main factor influencing deposition rate. Independent of other process parameters the deposition rate increased with increasing power.

FTIR measurements on films deposited by low frequency indicated nitrogen rich silicon nitride films. As shown in figure 1 the FTIR spectrum is dominated by a N-H peak at 3350cm^{-1}, a Si-N peak around 900cm^{-1}, a Si-O peak at 1100cm^{-1} and a N-H peak at 1150 cm^{-1}.

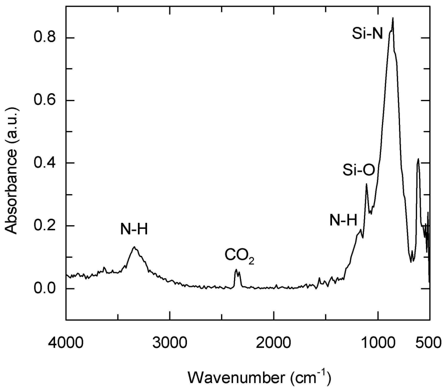

Figure 1 *FTIR spectrum of N-rich PECVD silicon nitride.*

The twin peaks around 2350cm^{-1} originate from CO_2 present in the ambient environment. The Si-H peak expected around 2200cm^{-1} was below detection limit in most films. This FTIR spectrum revealing a N-rich silicon nitride corresponds very well to the obtained low refractive index varying between 1.86 and 1.93 [4]. The refractive index was found to increase with increasing SiH_4/NH_3 gas flow ratio. Furthermore, the BOE rate was found to decrease with increasing refractive index, thus corresponding to an increased silicon content.

FTIR measurements on silicon nitride deposited by mixed frequency are currently in progress. The obtained refractive index for these films varies from 1.93-2.25, thus suggesting a larger silicon content than similar low frequency recipes [4].

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V. REFERENCES

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