PECVD POROUS CARBON DOPED OXIDE DEPOSITION FROM NEW PRECURSORS AND REACTOR CLEANING EMISSION CHARACTERIZATION

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Continued scaling of interconnect geometry will require even further reduction of the dielectric constant (k) of the bulk insulator. Materials with k values less than 2.5 are expected for 300 mm technology and devices manufactured at the 65 nm node and beyond. Nano-porous carbon doped oxides (SiOC:H) deposited by plasma enhanced chemical vapor deposition (PECVD) are currently being investigated. Such film deposition is achieved using original molecules as precursors and an innovative porogen approach. The dielectric constant of these materials is decreased by reducing the material polarisability and density with respect to SiO_2 and by introducing porosity. This implies silyl-alkyl group incorporation (e.g. Si-CH_3), a specific precursor structure providing steric hindrance and sacrificial hydrocarbon components[1]. However, the increasing carbon content of these SiOC:H materials decreases the oxygen/fluorine reactor cleaning efficiency when compared with SiO_2. Consequently, perfluorocarbon (PFC) emissions are increasing, degrading the environmental impact.

This paper presents the reactor exhaust characterization during film deposition and reactor cleaning step performed with the decamethylcyclopentasiloxane (D5). This new organo-silicon precursor is expected to induce a constitutively porous material through its cyclic molecular structure and to serve as a potential matrix for the porogen incorporation. The study of the byproducts is expected to give insight into the molecule reaction path thus providing a preliminary environmental impact evaluation and process improvements.
The emissions were assessed using Fourier transform infrared spectroscopy (FTIR) and quadrupole mass spectroscopy (QMS), following the SEMATECH protocol for exhaust characterization.

The film deposition was carried out in a capacitively coupled 13.56 MHz AMAT 200mm DxZ™ chamber. Deposition parameters such as RF power, pressure and carrier flow were evaluated in terms of impact on the process emissions and deposition rate. As low plasma power levels were used to preserve precursor molecule structure, the D5 reacted in little quantity, and was altered only through Si-CH_3 bond cleavage in the plasma, yielding C_2H_6 and C_2H_4 traces. The preservation of cyclic D5 structure and poor dissociation was confirmed by the FTIR spectra which were very similar with or without plasma (Fig. 1). The deposition rate was more sensitive to RF power changes than to gas carrier flow or pressure modifications.

The reactor cleaning was based on two consecutive phases: a first step of oxygen plasma cleaning (O_2 ashing) to achieve a partial oxidation of the material thus improving the efficiency of the second NF_3/O_2 plasma step and reducing the PFC emissions. The monitoring of the byproducts such as O_2, by QMS and HF, CO_2, CO, CF_4, SiF_4 by FTIR (Fig. 2) assessed the utilization efficiency of the cleaning gases (O_2 and NF_3) for three different plasma modes: remote, RF in situ, or remote and RF in situ (Table 1). This results showed NF_3 to be an appropriate cleaning gas because of high dissociation rate, SiF_4 ratio and low CF_4 concentration (<10 ppmv).

These exhaust analyses provide a better understanding of the reaction mechanism. They showed the precursor siloxane cycle preservation in the plasma and assessed a better cleaning through RF or mixed RF/RPS plasma. Finally these data will help develop dielectric porous ultra low-k materials for the 65 nm node, on 300 mm platform, when processed with a sacrificial hydrocarbon precursor.

[1] K.Maex, M.R. Baklanov, D. Shamiryan, F. Iacopi, S.H Brongersma, Z.S. Yanovitskaya, Low dielectric constant material for microelectronics, Journal of Applied Physics, Vol 93 (11), June 2003, pp 8793-8841.

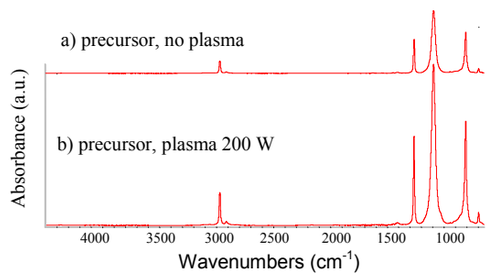

Fig. 1 FTIR spectra of exhausts during the film deposition: a) without plasma and b) power @ 200 W

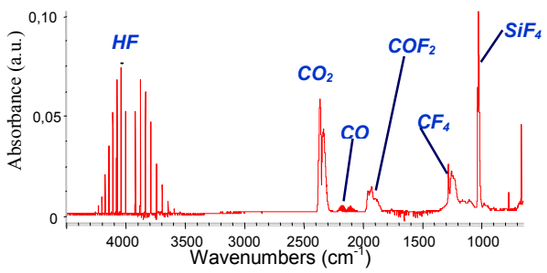

Fig. 2 FTIR spectrum of exhausts: byproducts of the NF_3/O_2 cleaning phase with remote plasma

Table 1 Reaction rate of oxygen and fluor for different plasma modes during cleaning

Reaction rates (%)	**Remote**	**RF**	**Remote/RF**
O_2 O_2 ashing	1-2	3-4	3-4
O_2 NF_3/O_2 phase	10	19	19
NF_3 dissociation NF_3/O_2 phase	99.9	90	99.9