Literature Digest
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Plasma Etching – Modeling

"Molecular dynamics simulation of ion bombardment on hydrogen terminated Si(001) 2x1 surface"
K. Satake, D. B. Graves
J. Vac. Sci. Technol. A 21 (2003) 484

The impact of H_2^+ and SiH_3^+ ions onto Si(001)2x1 surfaces with incident energies between 10 and 40 eV is modeled. This study is relevant for PECVD growth of SiH films in hydrogen and silane based plasmas. Some conclusion can also be drawn regarding the degree of substrate damage such as hydrogen insertion or silicon displacement for silicon overetches on very thin gate oxides.

"Fluorocarbon plasma etching and profile evolution of porous low-dielectric constant silica"
A. Sankaran, M. J. Kushner
Appl. Phys. Lett. 82 (2003) 1824

The Monte-Carlo Feature Profile Model (MCFPM) was used in combination with the Hybrid Plasma Equipment Model (HPEM) to study the pore effect in etching of porous low k silicon oxide in a inductively coupled CHF_3 plasma. While the etch rates for the porous material where found to be generally higher than for than for non-porous oxide, the etch rate does generally not scale with the pore size or density. When the thickness of the polymer layer that is formed on the etched surface is larger than the radius of the pores, the mass-corrected etch rate is higher because of a more optimal angle of incidence of the ions. For pores that are larger than the polymer layer, a lower rate of ion activation, less favorable angles of incidence and ion shadowing reduce the etch rate.

"Qualitative modeling of silica plasma etching using neural network"
B. W. Kim, K. H. Kwon
J. Appl. Phys. 93 (2003) 76

The etch rate and anisotropy behavior of a CF_4/CHF_3 silica etch process in an inductively coupled reactor was investigated in a 2^3 matrix experiment and modeled with a backpropagation neural network (BPNN). Good agreement with the experimental results and predictability were obtained by simultaneous optimization of the training tolerances and the gradients of the activation functions. This work is relevant for the development of etch chamber controllers.

Plasma Etching – Silicon

"Chemical Topography analyses of silicon gates etched in $HBr/Cl_2/O_2$ and $HBr/Cl_2/O_2/CF_4$ high density plasmas"
L. Vallier, J. Foucher, X. Detter, E. Pargon, O. Joubert, G. Cunge, T. Lill
J. Vac. Sci. Technol. A 21 (2003) 904

Resist patterned silicon surfaces etched in $HBr/Cl_2/O_2$ plasma mixtures with and without CF_4 addition have been studied with XPS. The main finding is that depending on the O_2 and CF_4 amount in the gas mixture, the sidewall passivation layer can be either SiO_x-like or fluorocarbon rich. In all cases, the sidewall layer is transformed into a SiO_2 material during the subsequent fluorine free soft-landing step. Since the the SiO_x peak area originating from the resist does not change in intensity during the softlanding step, it is concluded that the sidewall transformation during the overetch step is caused by surface oxidation rather than etch by-product re-deposition. For all cases, the composition of the ion bombarded and sidewall layers differed significantly. This suggests that in all cases, the passivation layer is not formed by direct etch product re-deposition but rather by deposition from the gas phase. Another interesting observation is that the sidewall composition for the traditional $HBr/Cl_2/O_2$ silicon etch process is very similar for different plasma sources under similar plasma conditions (ICP and helicon sources are compared). It is speculated that the basic passivation mechanism is the same for all high densitiy reactors.

Plasma Etching – Dielectrics

"Silicon nitride etching in high- and low-density plasmas using $SF_6/O_2/N_2$ mitures"
C. Reyes-Bentanzo, S. A. Moshkalyov, J. W. Swart, A. C. S. Ramos
J. Vac. Sci. Technol. A 21 (2003) 461

The etch rates of silicon, silicon nitride and silicon oxide in high and low density O_2/N_2 based plasmas with small additions of SF6 has been studied. The experiments were carried out in two different types of reactors: ECR and CCP. Higher Si_3O_4/Si (up to 20) and Si_3O_4/SiO_2 (up to 70) selectivities have been obtained for the ECR source. The etch mechanism of Si_3N_4 in O_2/N_2 based plasmas is believed to involve the reaction of NO with nitrogen atoms on the surface. Plasma emission studies suggest that the reaction of vibrationally hot N_2 molecules and O atoms is the main source of NO in the high density ECR reactor while metastable N_2 molecules participate in the formation of NO in low density plasma. In the presence of SF_6, this reaction path becomes dominant also for high density reactors. The addition of SF_6 leads to a higher nitride etch rate for small added flows but also to the total loss of any selectivity to silicon. The addition of SF_6 leads to a strong reduction of the plasma electron density due to enhanced electron attachment.

"Effects of Ar and O_2 additives on SiO_2 etching in C_4F_8-based plasmas"
X. Li, L. Ling, X. F. Hua, M. Fukasawa, G. S. Oehrlein, M. Brela, H. M. Anderson
J. Vac. Sci. Technol. A 21 (2003) 284

ICP C_4F_8 plasmas with Ar or O_2 additions revealed that the CF and CF_2 densities are increased when Ar is added to the plasma because of the plasma density increase. When O_2 is added to the plasma, the CF and CF_2 densities decreased while COF_2 increased. The selectivities of SiO_2 to Si and resist increase for larger amounts of Ar addition and decrease when oxygen is added. Ellisometry and XPS were used to study the thickness and composition of the fluorocarbon surface layer. Ar addition leads to a reduction of the fluorine content and increase in thickness which could explain the improved selectivities. It would be interesting to compare these results to CCP plasmas because of their larger industrial relevance for the etching of silicon oxides.

Plasma Etching – Chamber Wall Effects

"Variation of polysilicon etch rate depending on the surface condition of the etching reaction chamber"
W. G. Lee, Y. B. Kang
Electrochemical and Solid State Letters 6 (2003) G49

The results of this investigation confirm the significance of chamber wall effects in silicon etching. A clean, or fluorine rich, chamber wall leads to lower etch rates which can be restored by seasoning, i.e. covering the wall with silicon containing etch by-products. Likewise, the etch rate can be restored by increasing the source power (in the given specific case by 20%). The authors conclude that the actual power delivered to the plasma is lower when the chamber wall surface is fluorine rich. Changes in the recombination of etch species on the chamber wall for different wall coverages are not considered by the authors of this article.

Devices – SOI

“Quantum transport in a nanosize-on-insulator metal-oxide-semiconductor field-effect transistor”
M. D. Croitoru, V. N. Gladilin, V. M. Fomin, J. T. Devresse, W. Magnus, W. Schoenmaker, B. Soree
J. Appl. Phys. 93 (2003) 1230

In this paper, the current flowing through a nanosize SOI CMOS transistor is determined from the numerical solution of the quantum Liouville equation. Device characteristics as a function of channel length are obtained under consideration of electron scattering due to ionized impurities, acoustic phonons and surface roughness at the Si/SiO_2 interface. It is shown that the scattering mechanism tend to reduce the ballistic component of the transport. The ballistic component increases with decreasing channel length. The authors come to the conclusion that in order to benefit from the SOI architecture, the thickness of the channel should be reduced to 10 nm or less.

Devices – SiGe

Experimental study of the oxidation of silicon germanium alloys”
S. J. Kilpatrick, R. J. Jaccodine, P. E. Thompson
J. Appl. Phys. 93 (2003) 4896

This paper reports on the in situ oxidation of Si-Ge alloys grown epitaxially on a Si(100) substrate. The Ge concentration was varied between 1.8 % to 16.8 %, the oxidation temperature between 400 and 800 ºC with oxygen partial pressures between 10^{-6} to 10^{3} Torr. At higher temperatures, the oxide was almost pure SiO_2 with no more than several ppm Ge. At lower tempartures, mixed oxides with variable GeO_2 mole fraction were found. Ge pile-up at the oxide – SiGe interface was confirmed with stronger pile-up for the oxides grown at higher temperatures. The mixed oxides show poor quality, which could be attributed to trapped charges and perhaps atomic scale roughening.

Devices – High k materials

“Physical and electrical properties of reactive molecular-beam-deposited aluminum nitride in metal-oxide-silicon structures”
L.-Å. Ragnarsson, N.A. Bojarczuk, M. Copel, E.P. Gusev, J. Karasinski, S. Guha
J. Appl. Phys. 93 (2003) 3912

AlN seems to be another high k material not suited for the use in advanced devices due to low electron mobilities. Ragnarsson and co-workers from IBM Yorktown report that the mobility of AlN is even lower than for Al_2O_3 and Y_2O_3. Since AlN grown on Si will have a thin interface layer of Si_3N_4, it is however difficult to say whether the low mobility is a property of AlN or the interface layer. AlN on HF last Si, grown and annealed at 650ºC has however shown a four to five orders lower leakage current than SiO_2. The paper indicates that the mobility issues of many high k materials could have a common reason related to the fact that the main origin of the high k value is the larger ionic polarizability of these materials. Therefore their longitudinal-optical phonons have lower energies and the electron-phonon coupling is stronger than in SiO_2. This so called remote phonon scattering has been predicted for HfO_2 and ZrO_2 (M. V. Fischetti, J.Appl. Phys. 90 (2001) 4587).

Photolithography

"Controlling CD variations in a massively parallel pattern generator"
J.-Z. Luberek, A.-M. Carroll, T. Sandstrom, A. Karawajczyk
Proceeding of SPIE (Microlithography XV), vol. 4691 (2002) p. 671

This paper has been published at last years SPIE conference. It was included in this review because of recent announcements that Intel and Micronic Laser Systems AB of Sweden, the company that published this article, entered into a joint development agreement. Micronic is developing a massively parallel pattern generation system based on a micro-mechanical spatial light modulator (SLM). This SLM acts as a small, programmable photomask. The system is able to produce any of 64 gray levels or "black" on each micro-mirror. The pixel size in the image plane is 100 nm. The effective pattern address grid is 1.56 nm. The SLM has over one million micromirrors. Because the illumination in the system is partially coherent, with a coherence length exceeding the mirror dimension, light from each mirror interferes with light from it's near neighbors. Therefore the imaging system does not resolve individual mirrors, which moderates the effect in the printed pattern of poorly-behaved mirrors.