PLASMA-SURFACE INTERACTIONS

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Abstract. Materials processing is at a crossroads. Currently much of industrially viable materials processing is via plasmas. However as this processing has reached the nano-scale, development of industrially viable processes has become more and more difficult. In part this is because of all of the free parameters that exist in plasmas. To overcome this economic issue, tool vendors and semiconductor companies have turned to complex computational models of processing plasmas. For those models to work, one requires a through understanding of all of the gas-phase and surface-phase processes that are exhibited in plasmas. Unfortunately, these processes are not well understood.

Fortunately, one can examine the influence the plasma properties on the desired surface processes and through this ultimately optimize manufacturing. It is well known that the surface processes (etch or deposition), occur in the top few mono-layers of the surface. For example, growth of a film will require that molecules from the gas-phase land and bond on the surface. In order to understand the mechanism of deposition and etch on a surface, we begin with a basic reaction rate density

$$R_{\text{particle}} = \int_0^\infty \sigma(\varepsilon, T) n_{bonds} v_{particle} n_{particle} f_{particle}(\varepsilon) d\varepsilon \qquad (1)$$

Here $\sigma(\theta, \varepsilon, T)$ is defined as the cross section of a particle either filling or creating an available bond site on the a surface of temperature T, n_{bonds} is the density of surface bonds, $v_{particle}$ is the gas particle velocity, $n_{particle}$ is the gas particle density and $f_{particle}(\varepsilon)$ is the gas energy distribution function. Assuming that the fraction of bond sites that are open is Θ, then at any given time the open bond density will be $\Theta\ n_{bonds}$ and the closed bond density is $(1 - \Theta)\ n_{bonds}$. Under the assumption that most of these processes occur at open bond sites, our group has arrived at a general formula for the process rate (here applied to C_xF_y etch of SiO_2) of:

$$\text{Process Rate} = \begin{bmatrix} \sum \frac{K_{ions}}{\rho_{C_xF_y}} \langle\Gamma_{ions}\rangle S.C_{ions} + \sum_{deposit} \frac{K_{C_xF_y}}{\rho_{C_xF_y}} \langle\Gamma_{C_xF_y}\rangle S.C_{C_xF_y} \\ -\sum \frac{K_{ions}}{\rho_{C_xF_y}} \langle\Gamma_{ions,FC}\rangle Y_{ions,FC} - \sum_{etches} \frac{K_{C_xF_y}}{\rho_{C_xF_y}} \langle\Gamma_{C_xF_y}\rangle Y_{C_xF_y} \\ -\sum \frac{K_{C_xF_y}}{\rho_{SiO_2}} \langle\Gamma_{ions,SiO_2}\rangle Y_{ions,SiO_2} - \sum_{etches} \frac{K_{C_xF_y}}{\rho_{SiO_2}} \langle\Gamma_{C_xF_y}\rangle Y_{C_xF_y,SiO_2} \end{bmatrix}$$

$$(2)$$

Here, S.C or Y $\approx \langle R_{particle}\Theta * n_{surface}\rangle$ is the deposition sticking coefficient or etch yield, K_X is a species dependent proportionality constant, $\langle\Gamma_X\rangle$ is the particle flux, and ρ_X is the surface material density.

In this paper we will examine the implications of Equation 2. Specifically we will examine how the surface interactions set how process tools work. From this we will examine the potential future of the plasma-processing field.