Thin Film Deposition Processes in the Afterglow of a Microwave Plasma

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Reaction processes between plasma excited species and reactant gases in plasma afterglow thin film deposition have been investigated. Three test cases of AlN deposition from trimethyl aluminum(TMA), SiN_x and Si deposition from silan(SiH_4) have been considered. For AlN and SiN_x deposition, fast N-consuming gas phase dissociation reactions are observed. From gas titration, chemiluminescence spectra, and film properties it is determined that for TMA, N dissociates TMA through reactions with methyl groups at a characteristic rate of $3_x 10^{-12} cm^3 s^{-1}$. For SiN_x deposition, it is concluded that SiH_4 decomposition is initiated by reactions with excited molecular nitrogen($N_2 A^3 \Sigma_u^+$)created from atomic three body recombination in the afterglow. In contrast to the dielectrics, for SiH_4 in the H_2 afterglow, H atom reactions are found to be not important. The reaction mechanism is predicted to involve reactions between silane radicals created from optical dissociation of silane by radiation from the plasma.

For thin film formation, gas phase processes are unfavourable and it is concluded that for dielectric deposition in the afterglow a low pressure ECR plasma is preferred. For low pressure deposition highly uniform insulating films(AlN: $\rho > 10^{15} \Omega cm$)are obtained. On the other hand, for Si deposition plasma radicals are not necessary for film deposition and it is concluded that afterglow deposition is not a viable deposition process. The results of the afterglow deposition experiments show that compared to PECVD the reaction processes are easily understood indicating that afterglow deposition is valuable for investigating reactions involving plasma excited species.