ION ENERGY DISTRIBUTIONS IN PULSED MICROWAVE AND DUAL-MODE MICROWAVE/RADIOFREQUENCY PLASMAS

O. Zabeida, A. Hallil, J.E. Klemberg-Sapieha, M. R. Wertheimer and L. Martinu

Groupe des Couches Minces (GCM) and Department of Engineering Physics and Materials Engineering - École Polytechnique, Montréal, QC H3C 3A7, Canada.

High frequency plasmas have been extensively used for materials processing operations such as plasma-enhanced chemical vapor deposition, etching, and surface modification. Plasma interacts with exposed surfaces via energetic particles (electrons, ions, fast neutrals), and free radicals and photons, which control, in synergy, the surface effects. Bombardment by ions is of particular importance: it leads to densification, due to resputtering and knock-in effects in deposition, to reactive ion etching, and to significant surface modification of materials such as metals and polymers [1,2]. In a plasma excited continuously at a single discharge frequency, the energy and flux of the individual species cannot be decoupled. Two approaches may be used to control them separately: (i) dual-mode microwave/radiofrequency (MW/RF) plasma, in which a RF-powered substrate holder-electrode is exposed to the principal MW discharge [3-6]; and (ii) a pulsed regime, where the power is applied only for a fraction of time [7-9]. The effect of ion bombardment in these two situations on the deposition of functional coatings and surface treatment of polymers has been studied [3,7,9,10].

In the present work we use a MW/RF (2.45 GHz/13.56 MHz) plasma system in which we investigate the effect of plasma parameters (gas, pressure, substrate bias, pulsed vs. continuous modes, duty cycle, and pulse frequency) on the energy and flux of ions, and on the nature of species arriving at the exposed substrate surface. We determine the ion energy distribution functions (IEDFs) by means of a multigrid ion energy analyzer [6-8] and a Hiden mass spectrometer/energy analyzer [9], for discharges containing Ar, N_2, He, and NH_3, excited in different modes of operation. The results for different ion species (for example N^+, N_2^+, Ar^+) show structured IEDFs at the RF-powered electrode, while a single peak shape is observed at the grounded one. In continuous MW/RF plasma the ion flux is substantially higher than in the pulsed mode, the latter one giving rise to dramatic changes in the shape of the IEDFs. It is shown that the ions in the low energy portion of the IEDF originate from the time period between the individual power pulses, and their relative contribution increases with decreasing the duty time. We discuss the behavior of individual ionic species in argon and nitrogen discharges in terms of their selective effects on the chemical structure of polymer surfaces, such as polycarbonate and polyethylene-terephthalate.

References

[1] S.M. Rossnagel, J.J. Cuomo, and W.D. Westwood, eds., *Handbook of Plasma Processing Technology*, Noyes Publications, Park Ridge, NJ, 1989.

[2] M.R. Wertheimer, L. Martinu, and E.M. Liston, in *Handbook of Thin Film Process Technology*, IOP Publishing Ltd., Bristol 1996, Chapter E3:0, pp. 1-38.

[3] L. Martinu, J.E. Klemberg-Sapieha, O.M. Küttel, A. Raveh, and M.R. Wertheimer, J. Vac. Sci. Technol. A **12**(4), 1360 (1994).

[4] O.M. Küttel, J.E. Klemberg-Sapieha, L. Martinu, and M.R. Wertheimer, Thin Solid Films, **193/194**, 155 (1990).

[5] P. Reinke, S. Bureau, J.E. Klemberg-Sapieha, and L. Martinu, J. Appl. Phys., **78**, 260 (1995).

[6] P. Reinke, O. Zabeida, B. Andreani, S. Bureau, and L. Martinu, *Proc. 12th International Symposium on Plasma Chemistry*, Vol. 1, Minneapolis, University of Minnesota, 1995, p. 499.

[7] O. Zabeida, J.E. Klemberg-Sapieha, and L. Martinu, *Proc. 41st Ann. Tech. Conf., Society of Vacuum Coaters*, (1998), p. 336.

[8] O. Zabeida and L. Martinu, *J. Appl. Phys.*, **85**(9), 6636 (1999).

[9] A. Hallil, O. Zabeida, J.E. Klemberg-Sapieha, M. Wertheimer, and L. Martinu, *Proc. 42 Ann. Tech. Conf., Society of Vacuum Coaters*, (1999), in press.

[10] L. Martinu, in *Plasma Treatments and Deposition of Polymers*, R. d'Agostino, F. Fracassi, and P. Favia, eds., Kluwer Academic Publishers, Dordrecht, (1997), p. 247.