Deposition of SiO_2 like films with a miniaturized non thermal atmospheric Pressure Plasma Jet (APPJ)

J. Schäfer[1], R. Foest[1], A. Quade[1], A. Ohl[1], K. D. Weltmann[1]

[1]INP Greifswald, D-17489 Greifswald, Felix-Hausdorff-Str. 2, Germany
Tel. +49 3834 554300, Fax +49 3834 554300

Thin films produced by plasma-assisted deposition of silicon-organic compounds have found a broad spectrum of applications. According to the varying chemistry of the film material, applications stretch over a wide range from polymer-like films with applications as corrosion protection to quartz-like (SiO_2) films with applications as barrier coatings or to increase the scratch resistance of polymers.
Gradient films with varying chemical composition over the film height are of particular interest to provide both, a good adhesion to the (often polymeric) base material and a satisfactory film density. The deposition of multilayer films, a sequence of films with alternating organic-inorganic composition, e.g. for superior gas permeation barriers triggers another request. For process simplicity, it is preferable to deposit these films out of one raw material by a controlled variation of the deposition conditions.
While the deposition of polymer-like films with a high organic content is easily accomplished under normal pressure conditions, the production of pure SiO_2 films represents a challenge as silicon oxide (SiO_x) films produced out of silicon-organic molecules often exhibit a high inherent carbon content, compared to films deposited under vacuum.
The deposition of SiO_2 films with a non-thermal, RF capillary jet at 27.12 MHz at normal pressure will be demonstrated. The jet has been operated in locked mode,, which is characterized by regularly rotating filament patterns. The design of the plasma source is specifically appropriate for local surface modification or coating of 3-D objects.
The gas mixture for film deposition is constituted of argon, oxygen and small admixtures of octamethycyclotetrasiloxane (OMCTS, $Si_4O_4C_8H_{24}$).
The parametric study reported here focuses on the optimization of the deposition process by analyzing the chemical and morphological surface properties of the coating and relating them to the appearance and macroscopic properties. The film morphology is characterized by means of scanning electron microscopy (SEM) and the chemical composition of the films is analysed by XPS and FTIR microscopy. The analysis of the optical modes of vibrational states of Si-O structures in the FTIR spectrum helps to explain the observed correlation between the structural properties obtained by SEM and FTIR spectra.

This information is directly linked to the structural properties of the larger molecular network observed by SEM and displays a consistent image of the dependence of the deposition parameters on the studied films.

The experiments with OMCTS led to deposition rates from 10 to 45 nm/min. XPS analysis reveals an exceptionally low carbon content of the films. The XPS signal remains well below detection limit, which is estimated to 0.6 % (XPS atoms).

The experiments were carried out with the plasma operating in ambient atmosphere without additional containment under normal laboratory conditions.
The results of the experiments demonstrate that the surface temperature T and the oxygen concentration Q have a decisive influence on the film properties.