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The effect of process parameters on chemistry, roughness and morphology of the siloxane films deposited by an atmospheric plasma jet system

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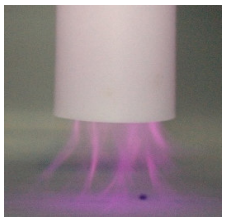
Introduction

An atmospheric pressure plasma jet system known as PlasmaStream™ has been used to deposit functional coatings on ceramic substrates. In this study the influence of plasma power and precursor flow rate on the properties of the deposited siloxane coatings are evaluated.



Close-up view of the nozzle of the Dow Corning PlasmaStream™ system

Influence of applied plasma power

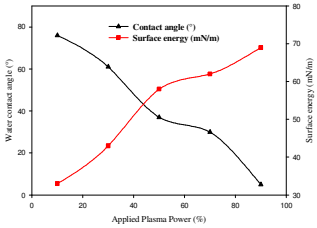
The atmospheric pressure RF (17- 19 kHz) discharge is formed as He/O_2 gas mixture is passed between two electrodes. The plasma jet is moved over the surface to be coated using a computer numerical control (CNC) system. Tetraethyl orthosilicate (TEOS) precursor is fed as droplets into He/O_2 plasma using a pneumatic nebulizer to deposit nm thick siloxane coatings at varying plasma power and precursor flow rates.

Deposition Conditions:

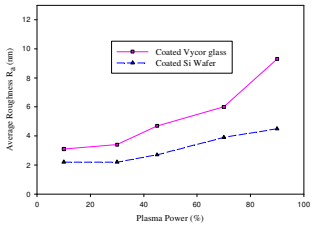
Plasma Power	: 10 to 90%	He flow rate	: 10 l/min
O_2 flow rate	: 100 ml/min	Nozzle Height	: 80 mm
TEOS flow rate	: 10 µl/min	CNC speed	: 25 mm/sec

Number of passes over substrate: 3

The surface energy of the coatings deposited at varying plasma power was determined using the contact angle measurement and found to increase from 33 to 69 mN/m with increasing power. This is attributed to an increase in the hydrophilic (SiO_x type) content in the film.



Dependence of water contact angle/surface energy on plasma power.

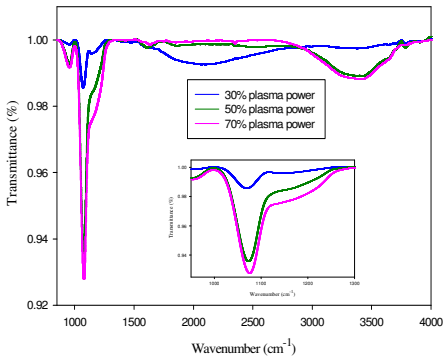


Influence of plasma power on average surface roughness (R_a)

The surface roughness of the deposited coating was found to increase with power as illustrated from the optical profilometer results.

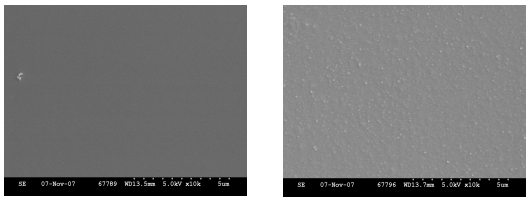
Film chemistry by Fourier Transform Infrared Spectroscopy

The increase in intensity of the Si-O-Si stretching frequency at 1060 cm^{-1} would indicate an increase in SiO_x content.



The FT-IR spectra of the films deposited at different plasma power (inset: the Si-O-Si stretching peak)

Morphology by Scanning Electron Microscopy

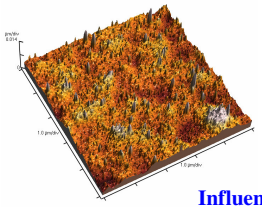


(a) (b)

SEM images of the films deposited at a. 10% and b. 50% plasma power

The presence of significant particulate formation is observed on the surface of the films which is due to excess gas-phase reactions.

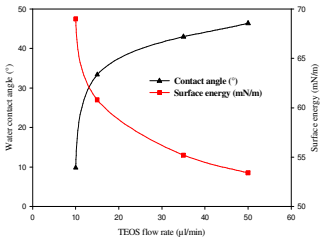
Morphology by Atomic Force Microscopy



Siloxane film (50 nm thick) deposited on Vycor glass substrate at 10% plasma power

Influence of TEOS flow rate

A further study of the influence of TEOS flow rates in the range 10 to 50 µl/min at 50% plasma power was carried out. Surface energy measurements indicate that the films deposited at lower TEOS flow rates were hydrophilic whereas the films deposited at higher flow rates were hydrophobic.



Dependence of water contact angle/surface energy on TEOS flow rate.

Conclusion

From this study it is concluded that the plasma power and the precursor flow rate has a significant effect on both the surface energy and roughness of the deposited coatings. Coatings with high surface energy was obtained under the conditions of high plasma power and low TEOS flow rate. This difference in coating chemistry is associated with the level of oxidation of the precursor in the plasma.

Acknowledgements

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