*35th EPS Conference on Plasma Phys. Hersonissos, 9 - 13 June 2008 ECA Vol.**32D**, P-1.167 (2008)*

REMOVAL OF CARBON RESIDUALS FROM NARROW SPACES BY RF DISCHARGES

C. Stancu [1], A. C. Galca [2], G. Dinescu [1], C. Grisolia [3]

[1] *National Institute for Laser, Plasma and Radiation Physics, Atomistilor 409,*
PO-Box MG-16, 077125, Magurele, Bucharest, Romania
[2] *National Institute of Materials Physics, Atomistilor 105bis, PO-Box MG-7, 077125,*
Magurele, Bucharest, Romania
[3] *Association Euratom-CEA, CEA Cadarache, DSM/DRFC/SIPP, Saint Paul lez Durance,*
13108, France

INTRODUCTION

There are many applications where is necessary to remove organic residuals from small size polymer molding dies, surface modification inside narrow spaces (~e.g., for MEMS) or removal of the co-deposited layers enriched in tritium from the inside gaps of castellated tiles of the fusion machines. These applications can be approached by plasma cleaning. In this paper we present the results of a study regarding the adequacy of sub-atmospheric radiofrequency discharges for plasma cleaning of inter-tile spaces and gaps in castellated tiles. Various cleaning techniques already developed like laser, flash-lamp, oxidation and glow discharge [1] have the drawback of limited access in narrow spaces. The present approach is based on the capability of low and intermediate pressure radiofrequency discharges to spread in large volumes and burn inside narrow spaces.

Previously, the appropriate conditions for sustaining radiofrequency discharges inside gaps with shape and sizes similar to that ones encountered in the above mentioned applications (gap widths: 0.6 -2 mm) have been established, for argon and nitrogen gases [2].

PRINCIPLE OF INSIDE GAP PLASMA GENERATION

By assuming that the cleaning process is supported by the presence of plasma in the proximity of the co-deposited wall, the problem which has to be solved is the plasma sustaining inside the small width gaps. The transition region between the volumetric plasma and wall (plasma sheath), is the place of phenomena assuring the discharge maintenance through electron emission processes stimulated by plasma particles surface bombardment. A critical condition for plasma existence is that the given volume offers enough room for sheath development. The important length scales that control the plasma system behavior are the plasma sheath thickness (L_{sh}), and the size (width) of gap (D). In the usual case $D >> L_{sh}$, the gap width is much larger than sheath thickness and the plasma border is conformal in respect to the gap surface topography [3]. Contrary, for $D << L_{sh}$ the border cannot follow the surface topography and plasma does not develop inside the gap.

The problem of plasma development inside the gap is then translated in finding solutions to handle the sheath thickness for becoming smaller than the gap width. Roughly, the sheath thickness is comparable with the Debye length: this one scales with plasma parameters as $\lambda_d \sim (T_e/n_e)^{1/2}$. The use the injected RF power and pressure as handling parameters was applied here because, in given ranges of those parameters, the increase of power increases the electron density (via increase of the ionization rate) and the increase of pressure decreases the electronic temperature (via thermalization of electrons by collisions with the cold gas).

RESULTS AND DISCUTIONS

An Inside-Gap Plasma Generator (IGPG) system able to produce discharges inside gaps of various dimensions was designed and built up, The schematic of the IGPG setup is illustrated in Figure 1.

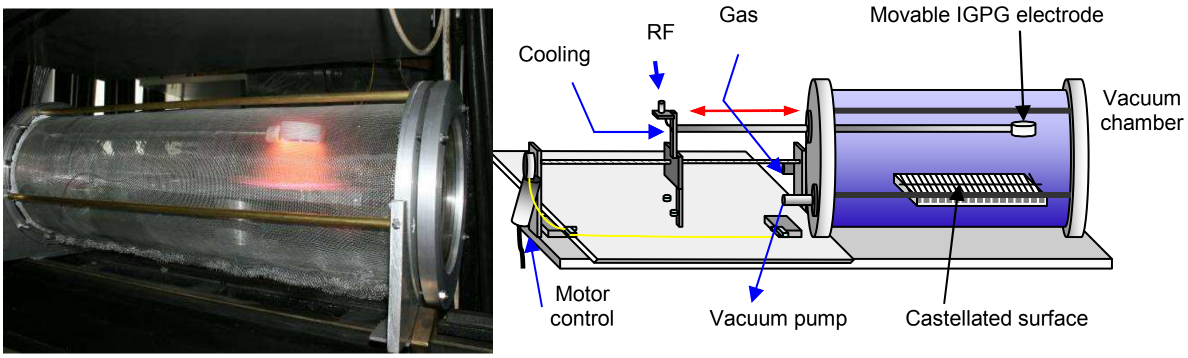

Figure1. The schematic of the IGPG setup (right) and its image in cleaning operation (left).

Castellated surfaces which can be mounted (10x10x10mm, 1.5 mm gap width) and dismounted from separate parts were designed and machined. The parts consisted of optical polished aluminium cubes and were vacuum coated with amorphous hydrogenated carbon by

PACVD. The coating was realized on all cube's sides in a PACVD reactor, with argon plasma injected with acetylene [4]. The coating thickness was measured by Atomic Force Microscopy and ellipsometry. It was 1.2 µm. The coated assembled castellated specimen (Figures 2a) was submitted to cleaning by IGPG in conditions of discharge generation inside the gaps (Figure 2b).

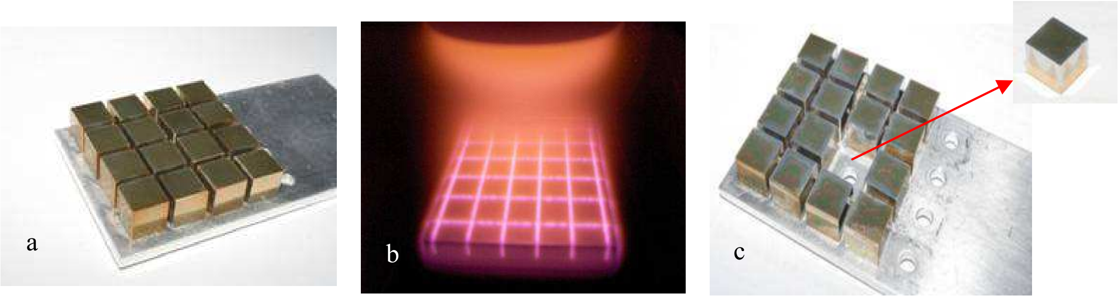

Figure 2. a) Image of a castellated surface formed by assembling of carbon covered individual cubes (10x10x10 mm); gap width 1,5 mm. b) Image of the castellated surface during plasma removal of hydrogenated carbon layers. c) Examination of a dismanted single cube after cleaning

The quantitative measurement of the material removal was performed with the ellipsometric technique. In order to determine the material removal rates, after cleaning at various times, the castellated piece was disassembled in cubes. A separate cube (Figure 2c) was chosen for quantitative measurement of the cleaning process.

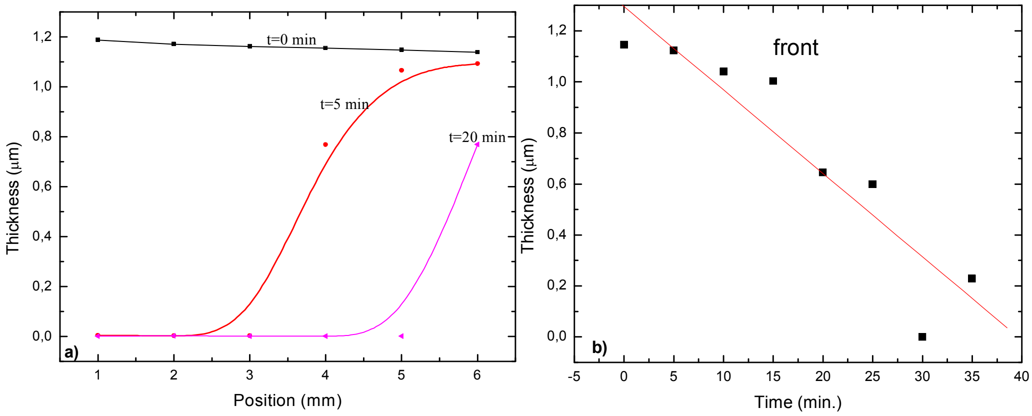

Figure 3. a) Dependence of layer thickness upon deepness, on lateral side and for different treatment times; b) Dependence of layer thickness, on the front side, upon the time

The obtained dependence of the thickness of the remaining layer upon the position (i.e. upon gap deepness) for different times is shown in Figure 3a, while the dependence of thickness upon time for the front side is shown in Figure 3b. It is seen that in less than 5 minutes the layer, initially 1.2 µm thick, is completely removed up to 3 mm deepness. In this portion the removal rate is about 0.24μm/min. As concerning the front side the removal rates is about 0.03μm/min.

The highest removal rates are obtained at the gaps upper margins. This is very convenient for application in cleaning of fusion machines, because the co-deposited layers on the real castellated tiles are thicker in these regions.

CONCLUSIONS

The potential of the IGPG tool for cleaning surfaces inside gaps was demonstrated. Experiments were performed in order to assess at laboratory scale the effectiveness of the IGPG tool in modification/removal of carbon from surfaces. In a set of previously experiments the removal of carbon from graphite surfaces was measured by gravimetry. The erosion rate was about 12nm/min.

In the experiments performed on castellated surfaces, it is proved that the cleaning process is effective, the removal rate depending on deepness: the cleaning proceeding faster at the upper gap margins.

REFERENCES

[1] C. Grisolia, G. Counsell, G. Dinescu, A. Semerok, N. Bekris, P. Coad, C. Hopf, J. Roth, M. Rubel, A. Widdowson, Fusion Engineering and Design, 82, 15-24 (2007) 2390-2398

[2] C. Stancu, I. Luciu, R.E. Ionita, B. Mitu, G. Dinescu, Proceedings of the 28th ICPIG, July 15-20, 2007, Prague, Czech Republi*c*, pages 27-28.

[3] C-K Kim, D.J. Economou, J. Appl. Phys. 91, 5, (2002), 2594-2603

[4] B. Mitu, S. I. Vizireanu, C. Petcu, G. Dinescu, M. Dinescu, R. Birjega, V. S. Teodorescu, Surf. Coat. Tech., vol 180, 238-243, 2004.