# Koszalin University of Technology

## Institute of Mechatronics, Nanotechnology and Vacuum Technique

***OPTIMIZATION OF THE PLASMA ELECTROSTATIC FILTER USING TAGUCHI METHOD***

***Author: Viktor Zavaleyev***
***Supervision: Jan Walkowicz***


International Conference and School on Plasma Physics and Controlled Fusion and 4-th Alushta International Workshop on the Role of Electric Fields in Plasma Confinement in Stellarators and Tokamaks Alushta (Crimea), Ukraine, September 13-18

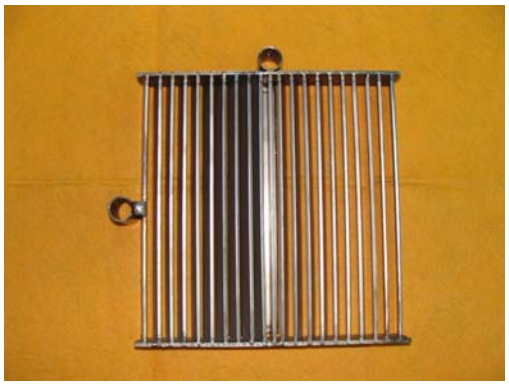
1. INTRODUCTION

2. EXPERIMENTAL TECHNIQUES

3. RESULTS AND DISCUSSION

4. CONCLUSIONS

# 1. INTRODUCTION



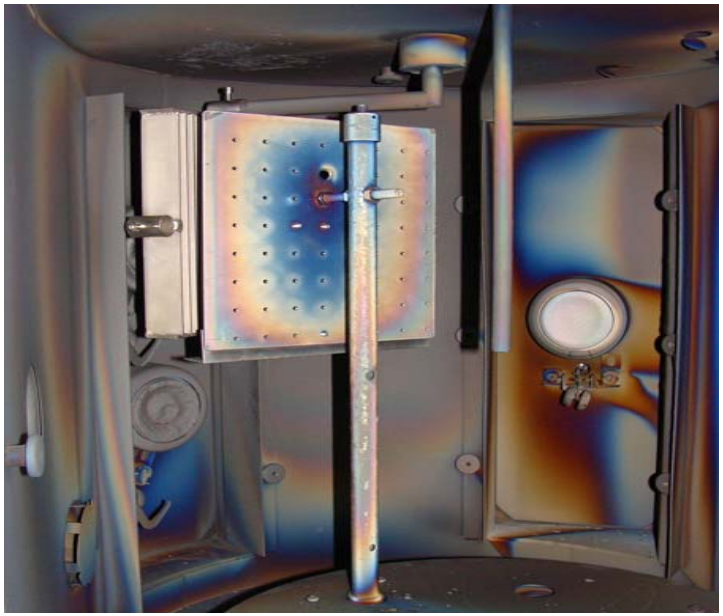
10mm

15mm

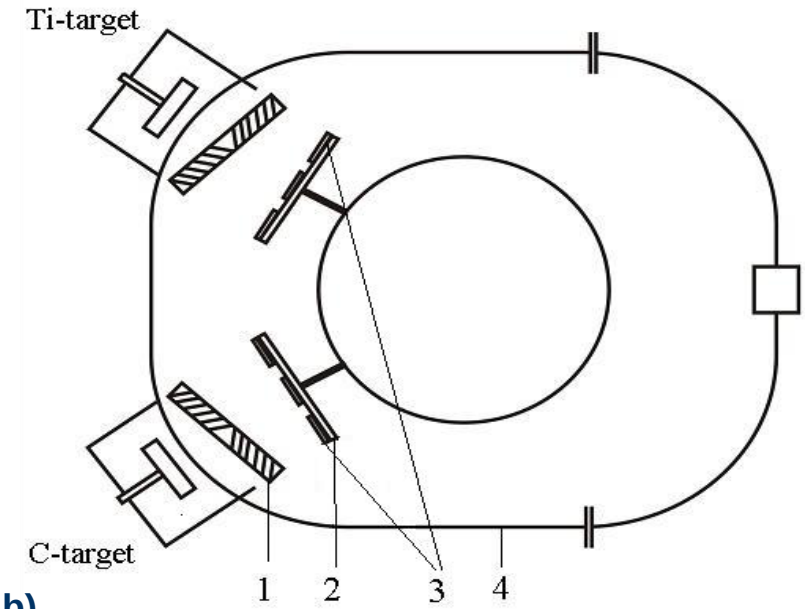
20mm

- Three versions of the linear Venetian blind filter [1] were manufactured and investigated. Distances between the lamellae and their tilt angles were selected in each version so that there was no line of sight between the cathode and the substrate. Another structural feature of the developed constructions is the possibility to change the position of the filters. Fixings of the filters are located on two perpendicular sides, what allows to install a filter either with vertical or horizontal position of the lamellae. Moreover it is possible to apply in the experiments 1 to 3 filters with combined positions of lamellae (zigzag, twisted, etc.).

# 2. EXPERIMENTAL TECHNIQUES



a)




b)

- *Fig. 1. Experimental setting in the C55CT device: a) view of the chamber interior, b) pictorial scheme;1-electrostatic filter, 2-ion current collector,3-investigated samples, 4-vacuum chamber*

The measurement of the ion current was carried out using CIE CA60 mA clamp-meter (OBIAT Pty Ltd Australia). In the current measuring range of up to 60 A AC/DC clamp-meter allows one to connect to any multimeter. Number of microdroplets deposited on the substrates was measured using metallographic microscope ECLIPSE MA20 (Nikon Japan), the magnification of 500× was applied, and the area of microdroplets analysis was 22728 μm2 for all samples. The Taguchi method of experiment design was applied [2], and the orthogonal tables L9 of the size: P = 4 (number of parameters), L = 3 (number of parameter values) were used for both titanium (Table 1) and carbon (Table 2). The experimental results were processed according to the Taguchi's procedure using the program "STATISTICA" (StatSoft Polska).

*Table 1. Experimental parameters for Ti*

| № | Optimized parameter | Parameter values | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1 | Arc frequency $f_{ARC}$ [Hz] | 0 | 50 | 100 |
| 2 | Argon pressure $p_{Ar}$ [Pa] | 0,001 | 0,4 | 1 |
| 3 | Lamella distance L [mm] | 10 | 15 | 20 |
| 4 | Current of filter $I_{separ.}$ [A] | 0 | 10 | 20 |

*Table 2. Experimental parameters for C*

| № | Optimized parameter | Parameter values | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1 | Arc frequency $f_{ARC}$ [Hz] | 0 | 50 | 100 |
| 2 | Argon pressure $p_{Ar}$ [Pa] | 0,01 | 0,1 | 1 |
| 3 | Lamella distance L [mm] | 10 | 15 | 20 |
| 4 | Current of filter $I_{separ.}$ [A] | 0 | 10 | 20 |

# 3. RESULTS AND DISCUSSION

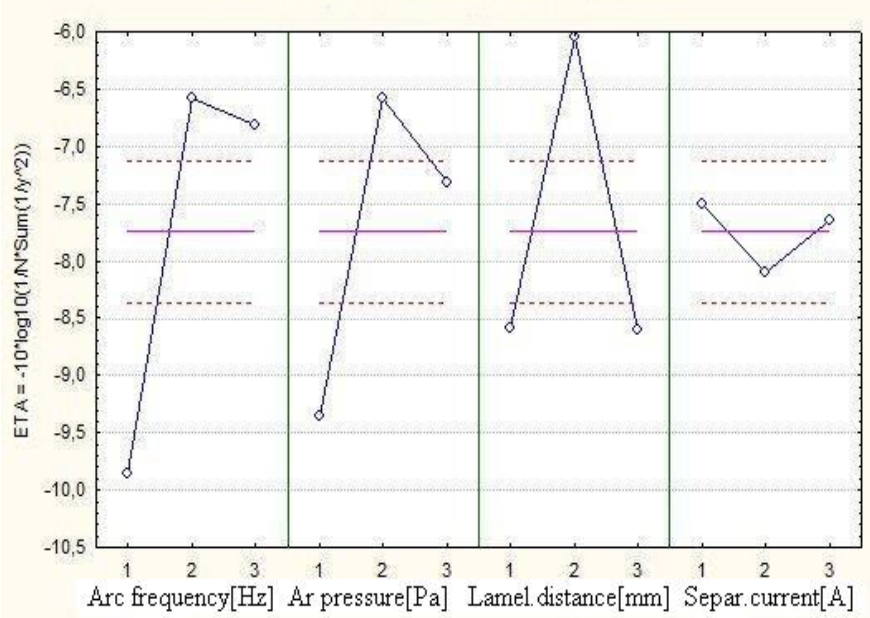



*Fig. 2. Diagrams of the dependence of the ion current for titanium cathode on process parameters*

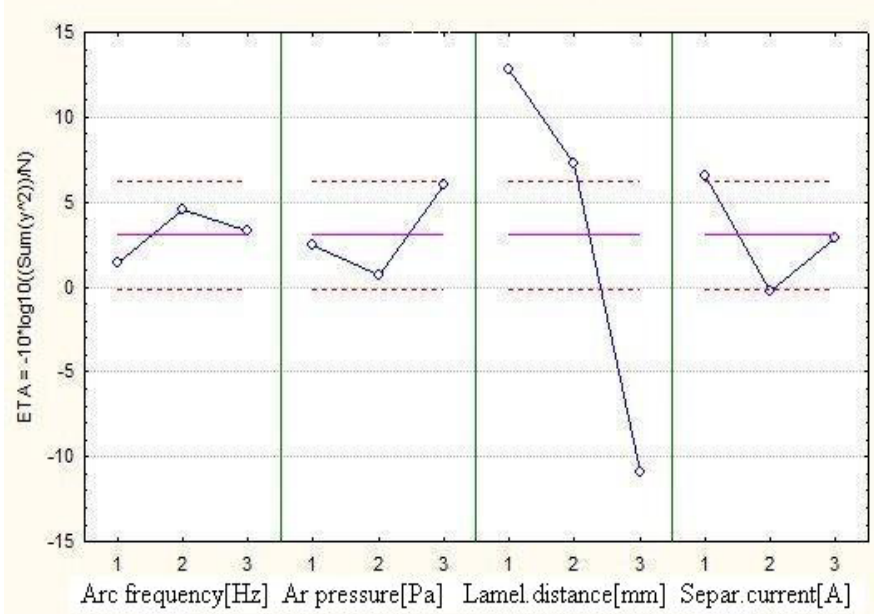



*Fig. 3. Diagrams of the dependence of the cleaning efficiency of Ti plasma on the process parameters*

The optimization criterion applied for the ion current was “the higher the better”. As it is seen from the diagrams in order to obtain maximum ion current,
the experiment should be carried out with the parameters: ƒARC = 50 Hz; pAr = 0,4 Pa; L = 15 mm; Isepar. = 0 A (floating potential)

In the calculations as the measure of cleaning efficiency the ratio of the total surface of defects to the analyzed substrate surface (22728 μm2) was applied, the optimization criterion applied was “the lower the better”. Lamella distance is the main parameter determining cleaning efficiency and for maximum efficiency the experiment should be executed at: ƒARC = 50 Hz; pAr = 1 Pa;
L = 10 mm, Isepar. = 0 A (floating potential )

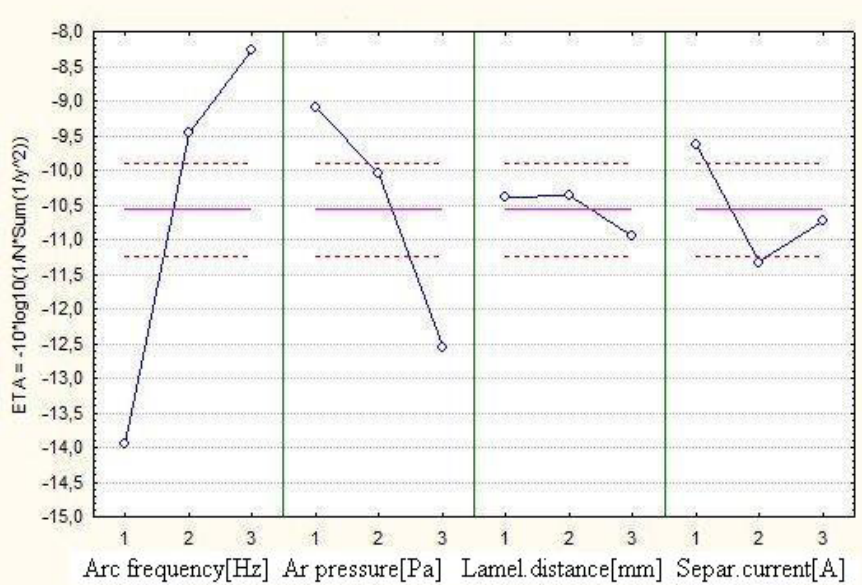



*Fig. 4. Diagrams of the dependence of the ion current for carbon cathode on process parameters*

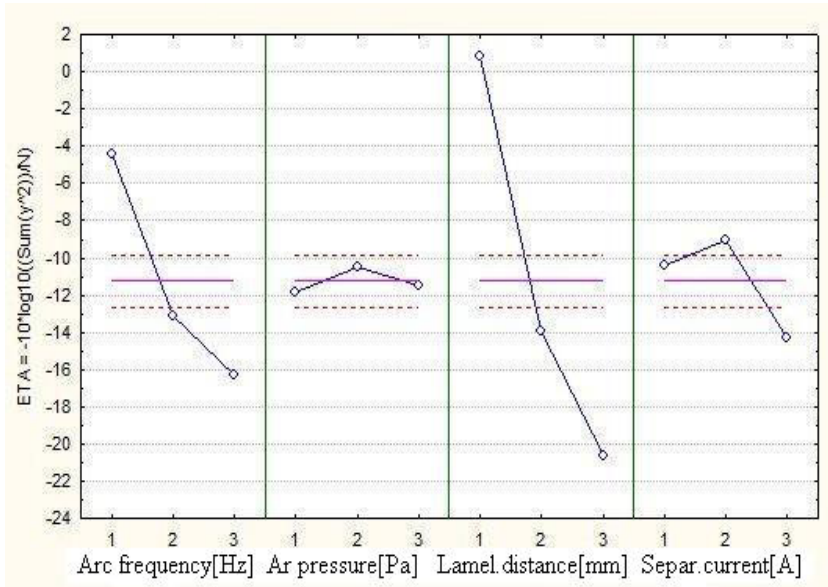



*Fig. 5. Diagrams of the dependence of the cleaning efficiency of C plasma on the process parameters*

The experimental parameters for maximization of the ion current are: *f* ARC = 100Hz, pAr = 0,01 Pa, L = 10mm, Isepar. = 0 A (floating potential), and the maximum cleaning efficiency of carbon plasma should be achieved at: *f* ARC = 0 Hz, pAr = 0,1 Pa, L = 10 mm, Isepar. = 10 A.

The parameters determined using the Taguchi method, which maximize the ion current and the cleaning efficiency were verified experimentally. Besides, the experiments were made with the optimum parameters, which were selected taking into account the overall influence of each parameter on the ion current and the cleaning efficiency (Table 3 and Table 4).

*Table 3. Maximizing and optimal parameters for Ti*

| Process | $f_{ARC}$ [Hz] | $p_{Ar}$ [Pa] | L [mm] | $I_{separ.}$ [A] | $I_{ion.}$ [A] | Droplets [%] |
|---|---|---|---|---|---|---|
| Max. $I_{ion}$ | 50 | 0.4 | 15 | 0 | 0,58 | 0,3 |
| Max. cleaning | 50 | 1 | 10 | 0 | 0,46 | 0,3 |
| Optimal | 50 | 1 | 15 | 0 | 0,55 | 0,2 |

*Table 4. Maximizing and optimal parameters for C*

| Process | $f_{ARC}$ [Hz] | $p_{Ar}$ [Pa] | L [mm] | $I_{separ.}$ [A] | $I_{ion.}$ [A] | Droplets [%] |
|---|---|---|---|---|---|---|
| Max. $I_{ion}$ | 100 | 0.01 | 10 | 0 | 0,4 | 1,2 |
| Max. cleaning | 0 | 0,1 | 10 | 10 | 0,15 | 0,3 |
| Optimal | 50 | 0,01 | 10 | 0 | 0,28 | 0,3 |

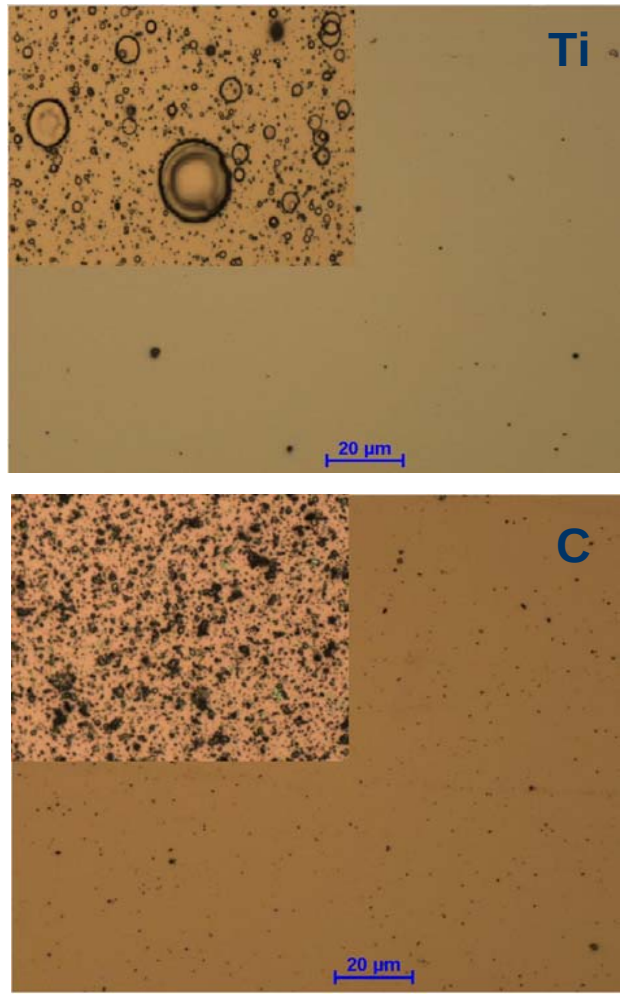



*Fig. 6. Micrographs of the surfaces of Ti and C films deposited without (inserts) and with the electrostatic filter (magn. 500×)*

## 4. CONCLUSIONS

The applied method of design of experiments – Taguchi method proved very effective for processing the experimental results and optimizing the parameters of the electrostatic filter. In the future, these findings will be very important and helpful in designing the final construction of the filter.

## ACKNOWLEDGEMENTS

This work was supported by the Operational Programme Innovative Economy POIG 2007-2013 within Developmental Project No. UDA-POIG.01.03.01-32-052/08-00: „Hybrid technologies for woodworking tools modification”.

## REFERENCES

1. O.Zimmer. Vacuum arc deposition by using a Venetian blind particle filter// *Surface and Coatings Technology*. 2005, vol. 200, p. 440-443.
2. M.Vijaya Babu et. al. Simultaneous optimization of flame spraying process parameters for high quality molybdenum coatings using Taguchi methods// *Surface and Coatings Technology*. 1996, vol. 79, p. 276-288.

# Koszalin University of Technology

## Institute of Mechatronics, Nanotechnology and Vacuum Technique

**Thank you for your attention**