Session P: Poster session

P 1.09 *Usage of magnetron pulse DC power supplies for various vacuum technological processes.*

Viktor Kozlov, Edmund Machevskis,
Sidrabe Inc., Latvia

Abstract

New pulse DC power supplies for magnetron sputtering devices give ample opportunities in realization of vacuum technological processes.

In work application of pulsing power supplies for activation of a surface before coating deposition is considered. Comparison of DC, AC and pulse DC power supplies on adhesion of coating is done. It is shown that power density in glow discharge powered with pulse DC power supply can be increased 3-5 times.

Application of pulse DC power supplies at reactive processes of oxide coating deposition with usage of ceramic targets and materials with low conductivity is considered.

SIDRABE

ICCG 8

1. Introduction

Occurrence of new power supplies for coating deposition technology in vacuum promotes development of this technology. Pulse DC power supplies can significantly improve such vacuum technological processes as plasma pretreatment and reactive sputtering. The purpose of the given work was to study opportunities of the pulse power supply for preliminary treatment of polymeric film in glow discharge plasma and for coating deposition by magnetron sputtering.

2. Experimental

Work was done on roll to roll laboratory vacuum machine UV80. As a substrate 125 microns thick PET film and 50 microns thick PI film were used. Width of PET and PI films was 620 mm. Winding speed of the films was adjusted in an interval 0.3 - 10.0 m/min.

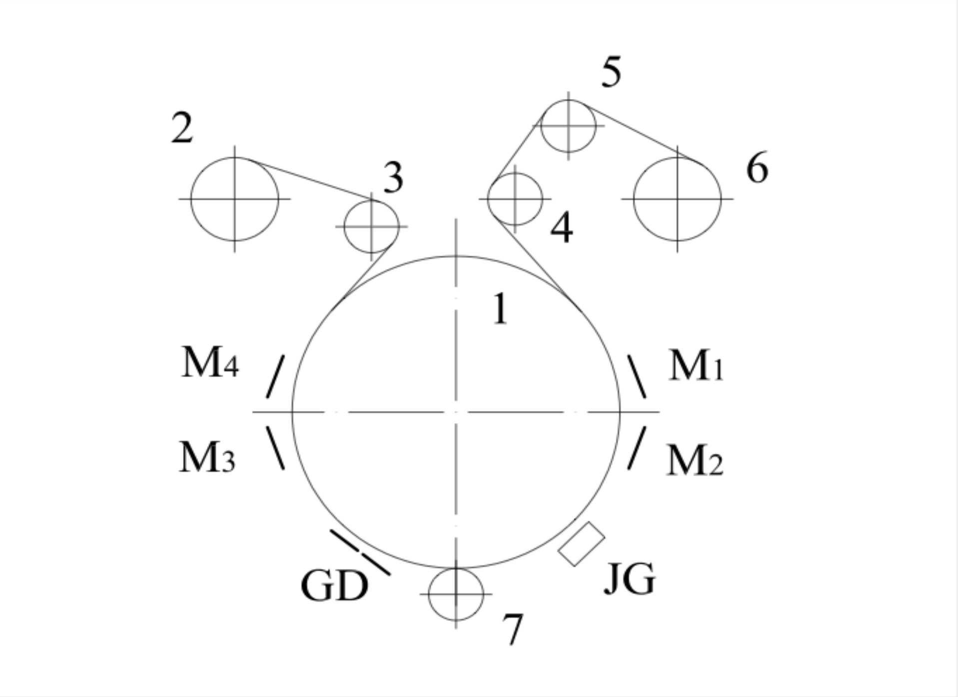
In work pulse DC power supply Pinnacle Plus+ 10kW, 325 - 800 Vdc by Advanced Energy, output frequency 0 - 5 - 350 kHz, reverse time 0,4 - 5,0 ms was used. This power supply was used for activation of a surface before coating deposition and for deposition of SiO_2 *by magnetron reactive sputtering.*

2. Experimental

Glow discharge device represented a steel plate in the size 780 x 70 x 5 mm which was connected to a minus plug of the power supply. Plus of the power supply was grounded, so the chamber was the anode. Preliminary treatment of a film was done in an interval of pressure 1×10^{-2} *-* 2×10^{-1} *Torr in mixture of argon and oxygen a parity 1:1.*

For Si and SiO_2 *deposition we used planar magnetron with target SiAl (90/10%) and Si (99,999), target size 800 x 120 mm. Sputtering power 5.0 kW, argon flow - 250 sccm, oxygen flow up to 100 sccm depending on discharge power and quality requirements. Pressure during coating deposition ~* 1×10^{-3} *Torr.*

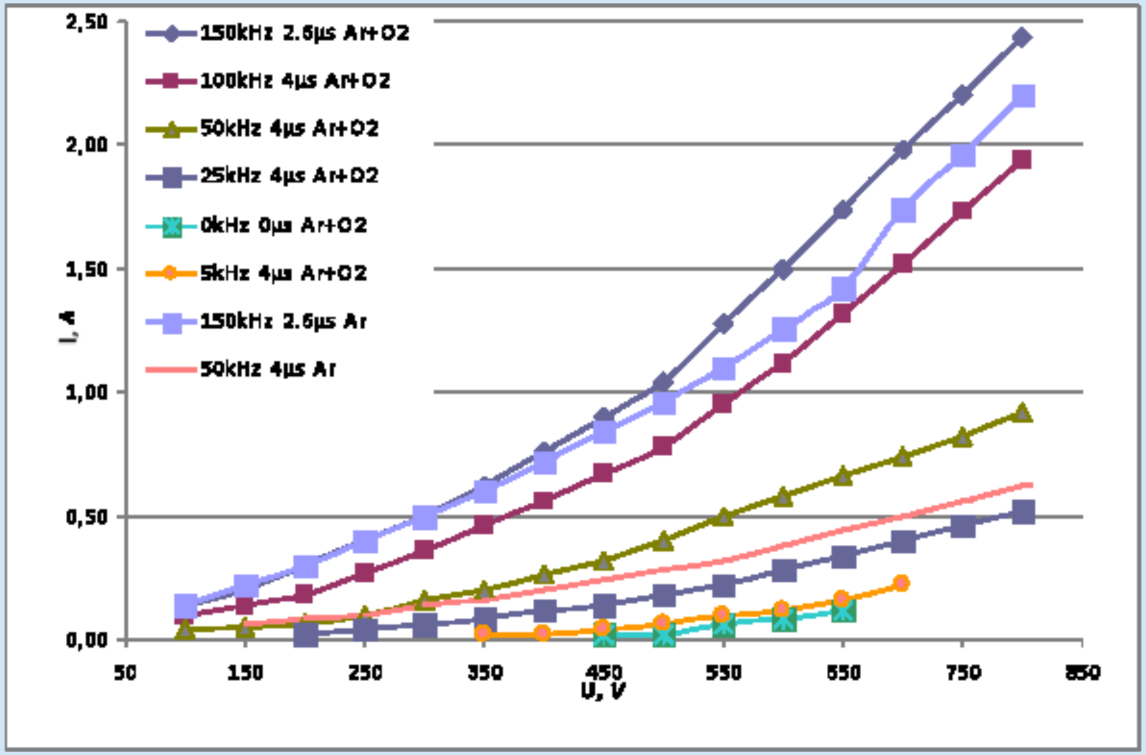
Scheme of vacuum machine



1 – drum
2-6 – rollers
7 – clamping roller
M1-M4 – magnetrons
GD – glow discharge device
IG – ion gun

3. Results and Discussion

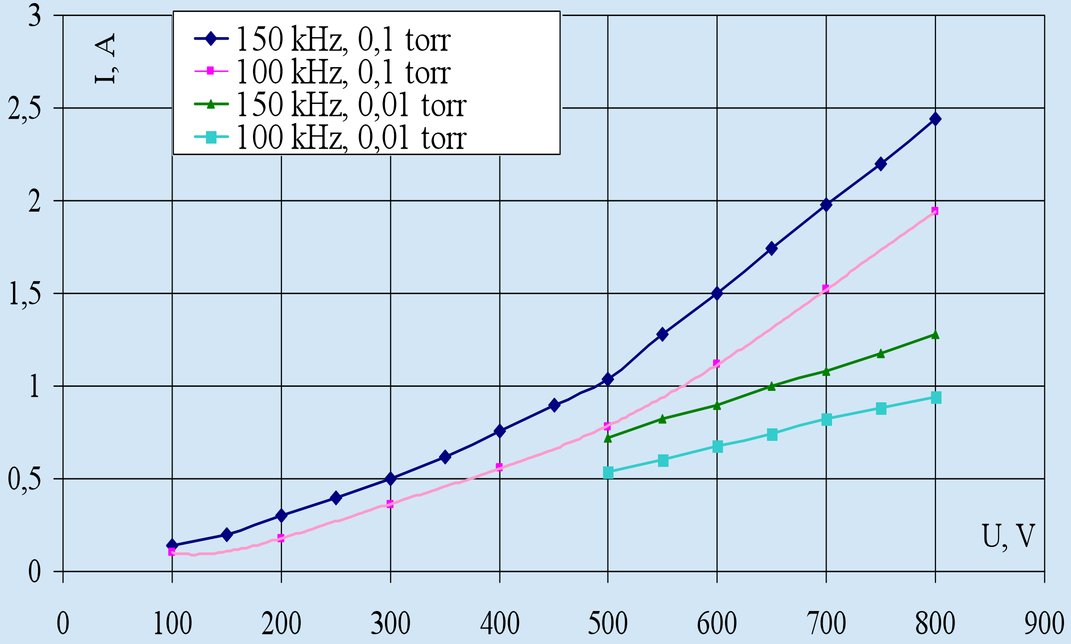
3.1. Activation of a surface of a polymeric film before coating deposition



Discharge current (and power) depends on frequency of the pulse power supply while other parameters are equal. With increase in frequency of the pulse power supply the current of the discarge (and power) grows. At reduction of frequency of the pulse power supply the discarge becomes unstable, the quantity of arcs grows. At small frequencies the current of the discharge decreases up to 0.2 - 0.4 Amps, typical for a AC power source at 50 Hz.

P 1.09 *Usage of magnetron pulse DC power supplies for various vacuum technological processes.*

Ones more feature of the pulse glow discharge is the opportunity to work at lower pressure up to 1×10^{-2} Torr, and in this case a current of the discharge in three - four times above in comparison with DC or AC 50 Hz. It allows to facilitate embedding of the glow discharge device in technological process of magnetron coating deposition.



Model

The structure of the pulse glow discharge is similar to the DC glow discharge, i.e. the cathode and the anode differ also their role in the discharge is different.

Owing to small time of formation of glow discharge (0.1 µs typical for the glow discharge) the structure of the discharge has time to be generated during each impulse (duration of impulse ~ 10 µs at frequency 100 kHz). After voltage switch off owing to final recombination speed (recombination time makes the tenth shares of second) in gas it is kept much enough electrons and ions which after voltage is switch on create an initial current and promote the further ionization. Therefore at increase in frequency the current of the discharge increases, as from the previous impulse remains more charges

Thus, the mechanism of ionization in the pulsing glow discharge includes the mechanism of ionization connected with bombardment by positive ions of an electrode (DC-discharge), and the mechanism connected with ionization in gas (RF discharge). As electrons are more mobile then ions all insulated from ground objects, including a treated film, get negative potential which depends on individual properties of objects. Positive ions bombard elements of a chamber, and a film too, being under negative floating potential, making clearing and activation. Energy and quantity of bombarding particles depend on a condition of plasma, in plasma of the pulse discharge a degree of ionization is higher.

The stated opinion is confirmed by testing of plasma by a method of one and two probes. Estimations give us the following results. Electron temperature and electrons concentration in plasma of the pulse discharge are in 2 - 2.5 times higher in comparison with AC 50 Hz. Improved characteristics of the glow discharge allow to intensify process of preliminary treatment and to increase winding speed of film during pretreatment. Comparison of adhesion of a copper coating on PI film treated by the glow discharge was done using the pulse power supply and AC 50 Hz. Film winding speed can be increased in 3 - 5 times without decrease in adhesion at use of pulse plasma glow discharge.

Parameters of plasma

Sample	$k\cdot T/e$, eV	T_e, K	n, cm^{-3}
700 V, 50 kHz	4.6	53 400	$6.3\cdot10^{9}$
700 V, 100 kHz	3.4	39 100	$1.0\cdot10^{10}$
700 V, 150 kHz	2.6	30 600	$1.2\cdot10^{10}$
600 V, 150 kHz	3.5	40 600	$1.0\cdot10^{10}$
700 V, 150 kHz	2.6	30 600	$1.2\cdot10^{10}$
800 V, 150 kHz	2.7	31 000	$1.6\cdot10^{10}$
AC 50 Hz	1.9	22 000	$4.3\cdot10^{9}$

where,
$k\cdot T/e$ and T_e - electron temperature presented in electron-volts and Kelvins,
n – electrons concentration in plasma.

3.2. Deposition of Si and SiO2 coatings by pulse magnetron sputtering

With the pulse power supply SiO_2 coating was deposited in transition mode with stabilization of a discharge voltage at constant sputtering power. At transition from a metallic mode to a oxide mode discharge voltage decreases more, than 150 volts, therefore the mode of stabilization of power is simple in execution and yields good results. The magnetron pulse power supply provides more stable sputtering process even in comparison with MF power supply in dual magnetron sputtering.

For comparison of influence of the pulse power supply on technology of coating deposition we used value:

$$e = \frac{\delta \times \vartheta}{P/L}$$

where

$w = P/L$ *– linear density of magnetron power (dual or single),*

$\delta \times \vartheta$ *– dynamic deposition rate.*

Value e determine sputtering device efficiency for given material.

Parameters of magnetron deposition of Si and SiO_2

Magnetron, target, power supply	W, W/cm	$\delta \cdot \upsilon$, nm·m/min	e, (nm·m/min)/(W/cm)
Si - coating			
Dual, MF, Si(Al -10%), 79 cm	88	43	0,49
Single, pulse, Si(Al -10%), 79 cm	63	34	0,54
Single, pulse, Si, 99.999, 79 cm	38	20	0.53
SiO_2 - coating			
Dual, MF, PEM, Si(Al -10%), 79 cm	101	54	0,53
Single, pulse, impedance control, Si(Al -10%), 79 cm	66	45	0,68
Dual, rotatable, MF, oxide mode, Si(Al -10%), 260 cm	231	37	0,16
Single, pulse, impedance control, Si, 99,999, 79 cm	38	15	0.39

© Fraunhofer IST

At silicon sputtering efficiency of sputtering systems does not depend on the power supply and type of a target. At silicon oxide deposition in a transition mode with control at use of the pulse power supply from target SiAl (90/10%) efficiency of sputtering system is higher, than with dual magnetron in the same mode, and much more higher, than in oxide mode without control. Deposition of SiO_2 from Si monocrystal target (99,999), with the pulse power supply provides stable process, but efficiency of sputtering systems is lower.

SIDRABE

ICCG 8

4 Conclusion

4.1. Application of the pulse power supply for preliminary treatment of polymeric film by glow discharge plasma allows to increase treatment (winding) speed owing to an intensification of process.
4.2. The pulse power supply allows to lower pressure of gases in the discharge process up to $1 \cdot 10^{-2}$ Torr.
4.3 At magnetron coating deposition of Si and SiO2 with use of a pulse source efficiency of sputtering system significantly raises.