RESEARCH ON HOLLOW CATHODE EFFECT AND EDGE EFFECT AVOIDANCE IN PLASMA NITRIDING TREATMENT

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***Abstract**: This paper contains a description of the nitriding installation with unpolarized grid in order to avoid hollow cathode effect and edge effect. For the experimental study we have made wedge samples cut, and triangular prism-shaped samples. We also made a theoretical study on these unwanted phenomena.*

Keywords: *hollow cathode effect, edge effect, grid*

1. Introduction

Plasma technologies have been long studied in surface engineering because they provide are important regarding technical and environmental benefits over salt bath or gas treatments. Among them, the active screen technology for plasma surface engineering offers multiple advantages over conventional direct current plasma treatments, like: improved surface quality and more uniform material properties [1].

In general, for the plasma nitriding process, the components to be treated are subjected to a high cathode potential and the grounded wall while the furnace wall forms the anode. The parts are directly involved in the discharge process [2]. Conventional direct discharge plasma treatments apply considerable cathodic potentials to the components in order to reach the treatment temperature by means of bombardment with energetic ions [1].The electric voltage applied between anode and cathode during plasma nitriding is 400–700 V [2]. This makes the discharge processes sensitive to non-conductive substances, and all parts must be thoroughly cleaned to avoid severe arcing during the treatment.

The positive ions generated by glow discharge are accelerated in the cathode fall region near the cathode surface and bombard the surface of the specimen. The ion bombardment causes sputtering, transfers kinetic energy to the component and raises its temperature. Many studies have indicated that the geometry, size and ratio of the surface to mass of the component have substantial effects on the temperature distribution within the component and lead to inhomogeneous response to nitriding.[2]

Plasma characteristic, correlated with the specific geometry and shape are responsible for a number of problems:

1) Inhomogeneous batch heats not uniformly. Problems arise when the treated batch has a significantly varying surface mass ratio. If this ratio differs much from the same characteristic of a standard specimen with thermocouple, some of the parts in the batch can be overheated or unheated [3]

2) The hollow cathode effect is a special situation for the glow discharge between two closely separated cathode surfaces. This effect occurs when the dimension of the cathode fall region becomes as large as the separation distance. The loss of electrons is low due to the special geometry and because they are repelled by the negative walls of the cathode, and in fact, they oscillate between the sample and the wall (figure 1). The plasma density (that is the electron concentration) increases and reaches values as high as 1012 cm^{-3}[29]. As a consequence, the production of ions rises too, and the ion flux density on the substrate surface increases. Due to these factors, such surfaces can be heated to extremely high temperatures even at relatively low bulk substrate temperatures of 200–500 8C and the local heating can produce melting surface, which means destroying the part [4]. The effect manifests itself at a specific composition of the gas, which is

characterized by pressure p[Torr], and specific distance D [mm] between the face to face surfaces.

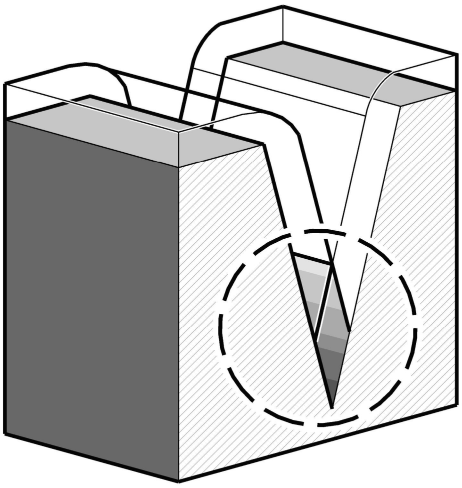


Figure. 1 *Highlighting the hollow cathode effect. Cross section through a narrow channel V shape*

3. Edge effect is the growth rate of the layer different on the edges and flat regions of the surface of a part. The elementary volume on the edges receives more energy than the elementary volume on the flat surface in the same time period [3] (Fig. 2). Due to distortions of the electric field around the corners and edges, the shape of plasma sheath, which is connected to the shape of samples, determines the ion flux distribution, which, in turn, affects the uniformity, hardness and surface phases of coating, erosion rings occur, characterized by the reduction of hardness [5].

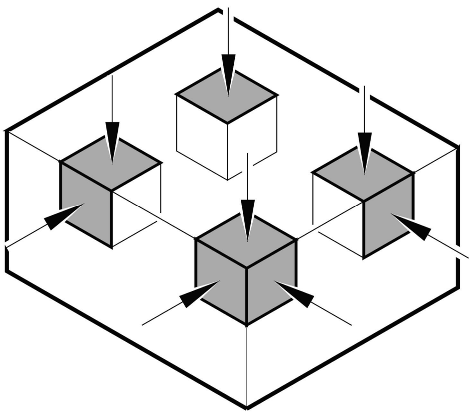


Figure 2. *Quantitative energy difference between flat, edge and corner areas, at edge effect.*

To avoid this disadvantage an experimental installation was build. This installation is equipped with an polarized screen. In such a case a glow discharge is largely “transferred” from the surface of the parts to the screen surface, and the ion bombardment of the parts becomes less intense [3]. This grid is made of stainless steel, and has the role to modify the electrical discharge field between anode and cathode, on the ionic triode principle. According to [6], the use of active screen virtually does not reduce the growth rate of the layer. Such a system is a triode.

The triode ionic screen interposed between cathode and anode is polarized, so it can change the electrical field configuration. Modifying the electrical field between anode and cathode, changes the discharge conditions and also the hollow cathode effect occurrence, by adjusting the grid electric potential [3].

Constructive principle of the installation is presented in figure 3.

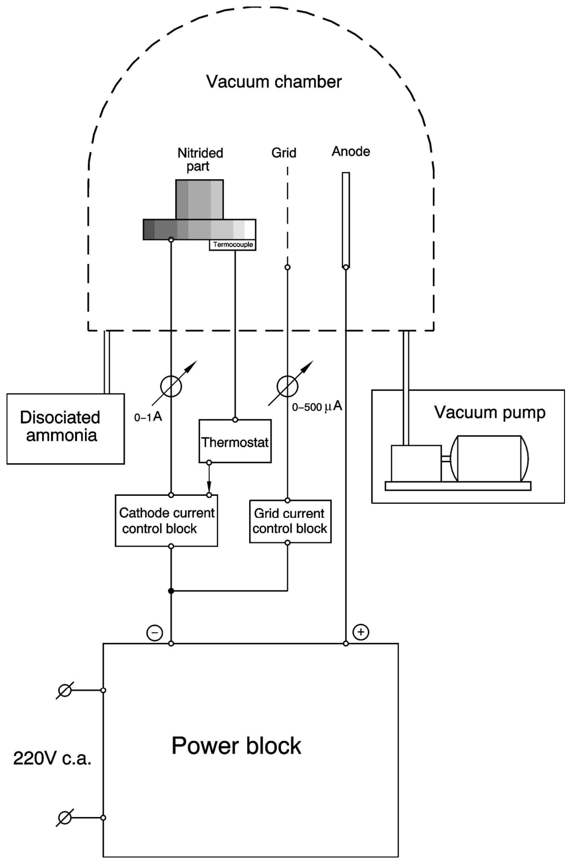


Figure 3. *Constructive principle for installation, Electrical block diagram*

In the figure 4 is presented the detailed electrical diagram. In ionic triode case the interposed grid between anode and cathode is electrically polarized, so it changes the configuration of the anode and cathode electric field.

Changing the electric field between anode and cathode changes the degeneration conditions for arc discharge, and double-cathode formation by adjusting the electrical potential of the grid.

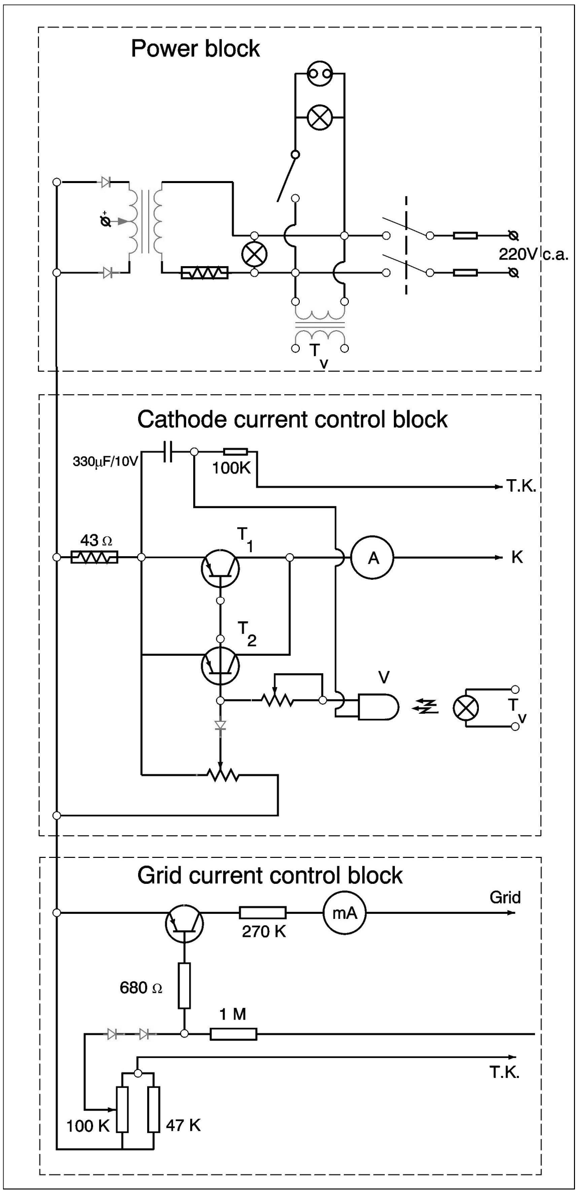


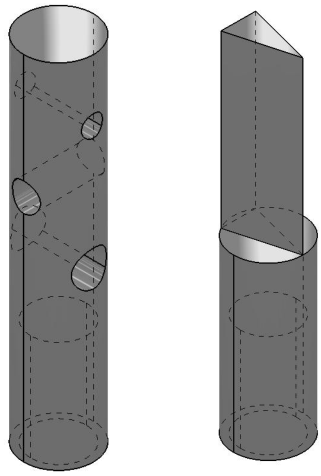
Figure 4 *Detailed electrical diagram*

The shape for the grid, or the active screen varies depending the dimensions and the part configuration. It can have the following shapes: planar grid, circular grid, cage grid. Materials for the screen: stainless steel, copper, steel sheet with different diameter holes in it [7].

The installation function with active screen represents the grid activation in a certain stage for plasma nitriding, treatment technology

After cleaning the vacuum chamber and creating the 10^{-1} vacuum value, the anodic current is connected to the installation. Then the discharge current is adjusted and proceeds to reducing vacuum level at the specific value by introducing gas. Anode current is adjusted to the desired value. Due to the discharge changing conditions the grid polarization is modified, conform to the necessary circumstances.

When the temperature is near the prescribed one automatically the anodic discharge electrical current is reduced.



a) b)

Figure 5. *Samples different shapes: a) holes different diameter, b) prismatic shape with sharp edges.*

In figure 6 is presented the plasma nitriding process and the of hollow cathode effect occurrence due to the configuration of the sample. The sample has a V shape. This shape allows us to highlight the hollow effect appearance conditions.

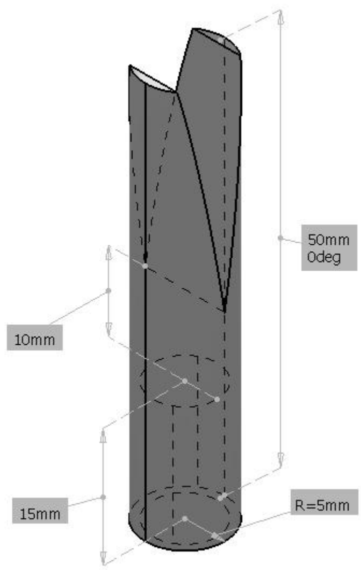


Figure 6. *V shape cut sample dimensions*

The sample has a cylindrical shape. The height is 50mm, exterior diameter is 10 mm, interior hole diameter is 8 mm, and the V shape cut has the height 25 mm, figure 6. As it is graphically explained in fig. 1 at the cathode fall intersection the electrons are caught between the two surfaces and the ionisation increases very much, also the temperature. In figure 7 is presented the hollow cathode effect during functioning.

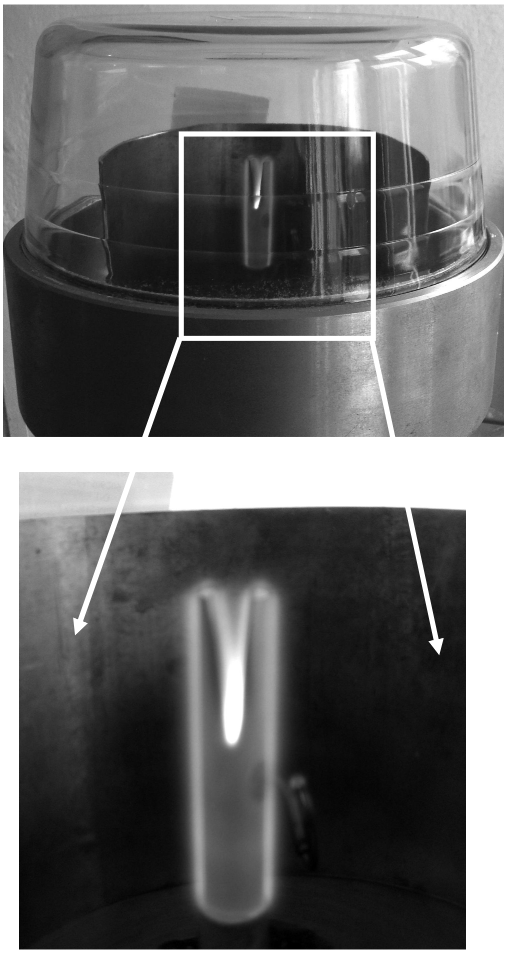


Figure 7 *Hollow cathode effect on a V shape sample during plasma nitriding process, with no active screen between anode and cathode.*

2. Conclusions

1. The installation will be used to avoid classical plasma nitriding defects by triode effect from the polarized grid.
2. The installation setings permits us to highlight the cathode effect apearance conditions.
3. Following researches on avoiding the disadvantages attached to general plasma nitriding: edge effect, hollow cathode effect, arc discharge, not uniformly deposition layers.
4. The ionic triode reduce the sputtering effect , positively influencing the surface quality, decreasing the roghness value.

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