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Design and implementation of a web application to estimate the surface density of implanted ions in solid substrates

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Abstract. In the present research a web application is designed and implemented allowing us to calculate the dose of implanted ions on solid substrates from experimental parameters (repetition rate and pulse duration of current, potential difference, work pressure and treatment time) and current pulses acquired during start-up and shutdown of high voltage electrical discharges at low pressures. By physical and mathematical processing, it is achieved at first estimate the value of the ionic charge, and then the areal density. This study will provide more accurate and suitable developments in relation to applications of ion implantation as an alternative technique to increase the service life of the surfaces of the materials used in various industrial sectors developments.

1. Introduction

The surface modification of a substrate involves modifying the composition and structure of materials, either by creating coatings (few microns wide) or by introducing new elements on its surface (dopant ions) in nanometric depths [1].

The three-Dimensional Ion Implantation technique (3DII) [2] performed in the JUPITER reactor [3] is a process of implanting dopant ions into metallic and nonmetallic solid substrates [1-6]. The parameters that characterize this implementation are: the ion's type, the ion's energy and the implanted dose [1,7,8]. Therefore, modify surface and sub-surface layers (without to change geometric dimensions) of solid substrates are subject of increasing interest in several sectors like energy, transport and manufacturing [9-12].

According to [13-14], the 3DII is generated from hybrid discharges of high voltage and electric arc at low pressures. This implementation makes an impact with sufficient energy (between 5 and 60 kV) ions of non-metallic species on the surface of a solid substrate. These ions penetrate a few layers (nanometric level) by changing the physical and chemical properties of the surface [13-14]. This penetration provokes a lot of collisions with the atoms composing the solid substrate, causing a set of collective processes which influence the final distribution of ions, such as the formation of defects, ions tunneling, cascade collisions, sputtering, etc. [15-19].

According to the above and considering that the final concentration of implanted ions is a very important feature of the surface modification by ion implantation [20-22], it is very important to characterize the calculation of superficial density of ions implanted in some material, moreover, there is a need to understand the complex phenomena that occur during the process. This calculation



depends mainly of time of treatment, density of ionic current, repetition frequency and pulse duration, the secondary emission ion-electron coefficient of material and the area of the cathode.

Therefore, the development of a web application and a computer simulation are both really important, especially because we can obtain information that today could not be obtained by other means. That is why it is necessary to develop computational tools that estimate more quickly, accurately and precisely the estimate the value for implanted dose on the surface of solid substrates [23].

In this paper, we introduce EDIIS - Estimation of the Surface Density of Implanted Ions in Solid Substrates, a free web application with a user-friendly interface. EDIIS was developed in a joint effort between the Software Engineering Development Research Group (GIDIS) of the Universidad Francisco de Paula Santander and the Physics and Plasma Technology and Corrosion Research Group (FITEK) of the Universidad Industrial de Santander. The web application is the result of a technological applied research, which can be used at any time, from anywhere, in different electronic devices (computers, tablets, mobile phones, etc.).

2. Methodology

The estimation of superficial implanted dose of a material using the web application is carried out according to the scheme presented in Figure 1.

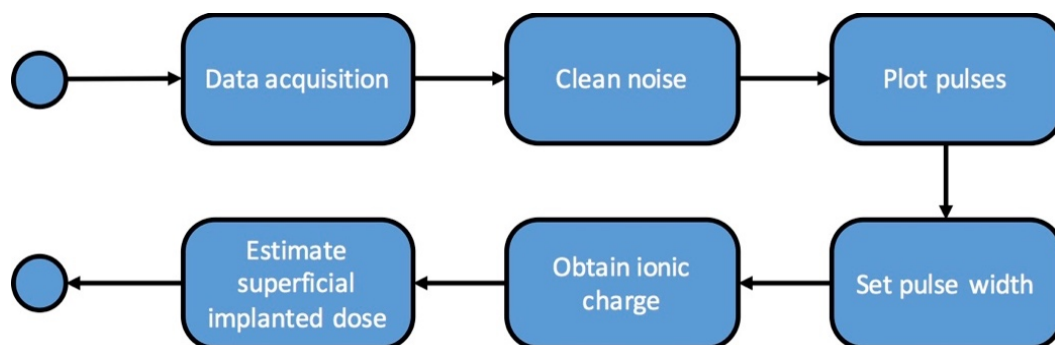


Figure 1. Methodology of estimation superficial implanted dose.

Current pulses versus time during electric high voltage discharge at low pressures were obtained from the experimental parameters set in a process of nitrogen ion implantation into metallic solid substrates. The pulses recorded represent the total electronic charge transported. After that, the pulses (data and image) are introduced into the web application where they are scanned and digitized. Each one of these datasets corresponds to the pulses of current that can be captured on an oscilloscope during turn on of the electric high voltage discharge (in this case we use the oscilloscope Tektronix TDS 2002 B).

Graphics are displayed and then the user proceeds to set the pulse width. It depends on the region of interest. Then, the ionic charge is obtained using the difference between both pulses [24]. Finally, the superficial implanted dose in solid substrates is estimated.

3. Web application

A web application was developed using a two-tier architecture. Web application was developed with Hyper Text Markup Language (HTML), Cascading Style Sheet (CSS), Java Server Pages, Bootstrap and Google Charts. The latter help us to plot and digitize the pulse of the implementation process.

The process begins with the acquisition of data and image pulse, after the user upload the information into the web app, he has the possibility of set the pulse width and estimate the ionic charge (Q_i). After that, user provide the input data (experimental parameters of the ion implantation process) which are: frequency (f) of the discharge pulse (Hz), total time (t) of the discharge (s), total area (A) exposed (cm^2) and number of ion of the charge (Ze). The web application calculates the total

ionic charge (Q_{it}) and the dose approximate of ions implanted superficially. Equations 1 to 3 show how the process was done.

$$n = f * t \quad (1)$$

$$Q_{it} = Q_i * n \quad (2)$$

$$D = \frac{Q_{it}}{A * Z_e} \quad (3)$$

Where, n : pulses number. Q_{it} : total ionic charge transported, Q_i : ionic charge.

Figures 2 present in detail how the calculation of the ions implanted superficially through the web application is performed.

Figure 2. Section to load the image and the pulse data.

After user load the required data and clicked in Process button, the web app automatically performs a process of digitization of datasets and graphics. The screen is splitted in two sides, each one presenting the graphic along with the image of the pulses. The web app allows the user to set the maximum and minimum values to determine the pulse width necessary to calculate the area under the curve and estimate the transported load for each pulse (see Figure 3).

On top of Figure 3 is shown both pulses images obtained from Tektronix TDS 2002 B oscilloscope. Left one corresponds to the total charge transported during the electric high voltage discharge and the right one corresponds to the electric charge carried. At the bottom both pulses are graphed in different charts using our web application (the graph obtained is very similar the acquired with the oscilloscope). User can adjust the pulse width to work just with some data. In this case, user enter the required data corresponding to the X axis (Figure 4).

After that, user clicked the Next button to show both charts mixed in one chart, so the user can quickly identify the area to be calculated, corresponding to the ionic charge. Values entered in pulse width are kept in this chart. The estimated value of the ionic charge is estimated and presented (see Figure 5).

Finally, the web application proceeds to estimate the superficial implanted dose according to Equations 1 to 3 and whose value is reported at the bottom in Figure 5.



Figure 3. Images and graphics of pulses in the web application.



Figure 4. Pulse width adjusted by user.

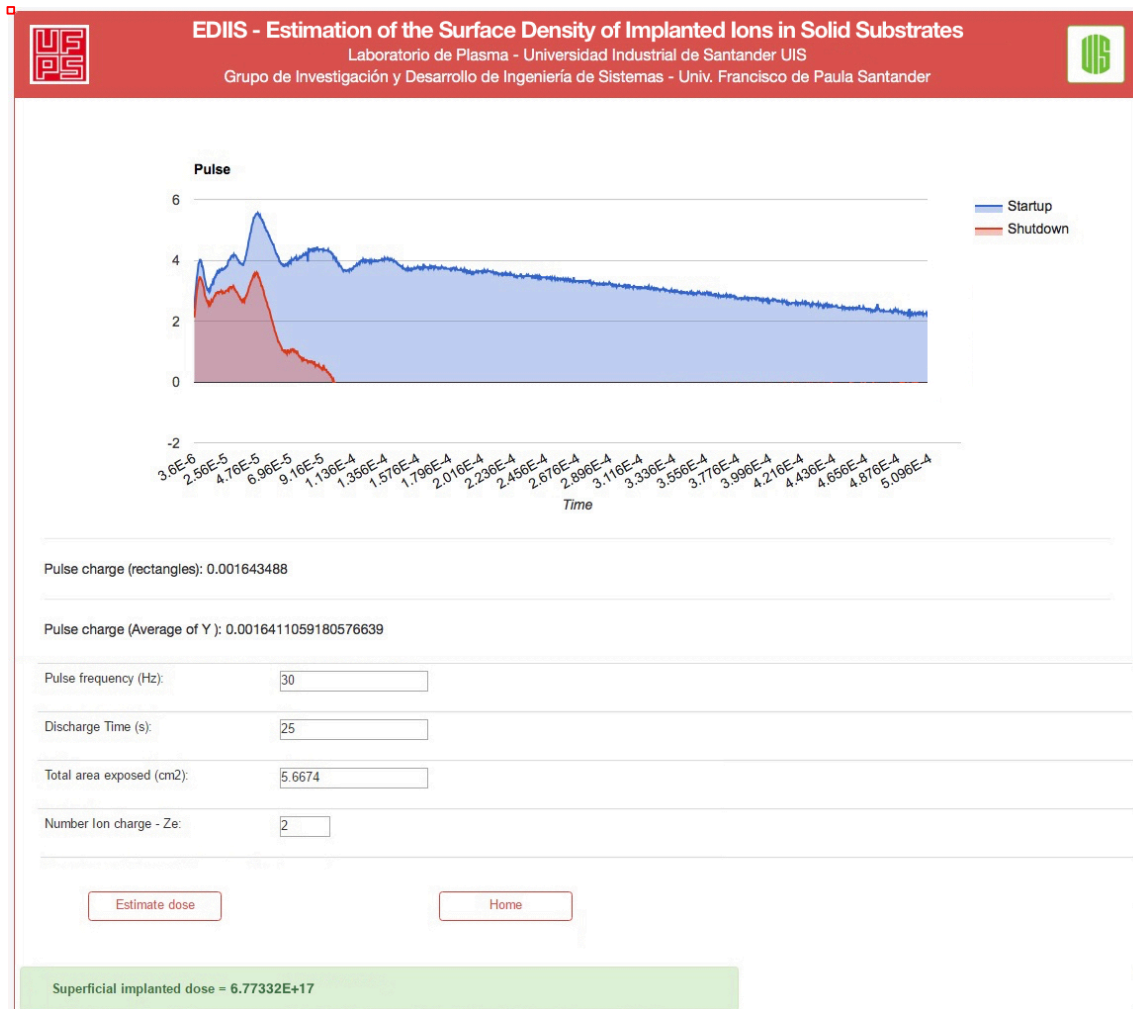


Figure 5. Experimental parameters of the ion implantation process.

4. Conclusions

A computational web tool was built to work as an aid to the estimation of the dose of ion concentration implanted in solids, bringing benefits to experimental researches in the UIS' plasma laboratory. These calculations were faster and more precise than traditional methods. Researchers can focus on the results and not spending time making complex calculations which can lead them to inaccurate and faulty implementations.

The web application developed can be used anywhere any time, only an Internet connection is required and the pulses data to be processed. The format of the data received by the system can be downloaded from the web application.

The results for the estimation of the surface dose of ions obtained from the web application were very similar to the theoretical results, ensuring that the implemented web application works correctly.

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