Research Paper

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Radiative Heater for A Sputtering System

Engineering

KEYWORDS : thin films, sputtering and radiative heater

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ABSTRACT

The design and construction of a Radiative heater, for use in sputtering system is presented. An aluminum paraboloid mirror and a halogen lamp are used to heat the substrate, radiative heating presents as main advantage over other commercial options, low power consumption (about 90w for 300C), their relative easy to build and the ability to maintain a stable deposition temperature. The radiative heater, operating in the temperature range of 150 to 300C, and pressures between 3 and 15 mTorr, shows a minimal variation of temperature and its current consumption is less than 1.0A. The main limitation is that the heater is used with an open-loop control, which does not allow the possibility of controlling temperatures below 140C and stabilize the temperature in less than 40 min. Characterization of two halogen lamps of 300W and 150W, with which it is possible to obtain different temperature ranges is shown.

INTRODUCTION

Sputtering system can be defined as the erosion of a target of an element in the presence of reactive gases which chemically react in masse, the eroded material, with both material deposited on the surface of the substrate [1]. In the deposit of thin films using sputtering system, there are many parameters that must be controlled [1] [2]. One of this parameters is the temperature of the substrate, since slight changes in its temperature promote significant variations in the properties of the film [3]. That is why, it is necessary to be able to vary the temperature of the film deposits with a heater that allows applying different temperatures as much as in a reactive atmosphere as in vacuum. There are many types of designs of haters in the literature for deposit of films by sputtering system. The problem with resistive heaters and some cases of the radiative heaters, are short element life time heater, non-homogenous heating of the substrate, it is not possible to operate them at high pressures of erosion, they present a high power consumption and the high cost. [6] [7] [8]. It is widely known that the properties of the films deposited by sputtering system depend on the temperature of the substrate, so it is necessary to have a reliable heater that allows us to have a good control of the properties of the film deposited. [3] [8]. This work presents the development of a low-cost radiative heater to deposit thin films by sputtering system. The heater allows you to reach temperatures higher than 300C using a 150W halogen lamp. We started from the necessity of having a heater that allowed us to make deposits at different temperatures in an equipment of sputtering system, whose distance from the target to the substrate is 10cm, and where the substrate is placed above canyon erosion, upside down, in a stainless steel substrate holder, without modifying the previous working conditions. The construction and performance of the heater as well as the control used to set the desire temperature are described. The low power consumption of the heater and stability in temperature that presents the heater once it has reached the temperature of the tank, are some advantages of this design over other commercial options that use electric heaters.

DESIGN AND CONSTRUCTION OF THE HEATER

The heater is composed of an aluminum paraboloid mirror (figure 1), which concentrates the radiation of a halogen lamp, on a surface of 43cm2. The mirror is polished mechanically using a lathe at 2000 rpm. Heat dissipation was incremented, increasing the effective area of the outer surface of the aluminum mirror, this was done in order to reduce the time of cooling of the heater after stopping heating, reducing the wearing out of the system in general by heat stress.

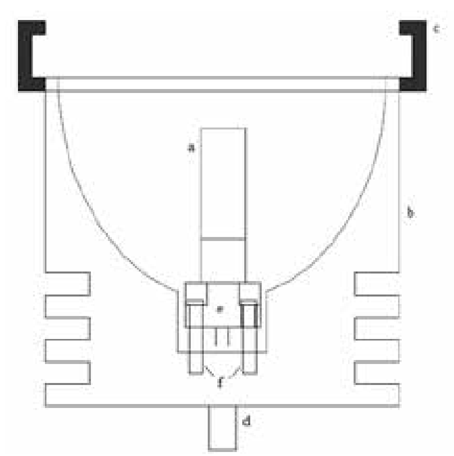

Figure 1: Design of the heater, heater showing transverse view: a- halogen lamp, b- paraboloid of aluminum, c- base for the substrate holder, d- lock bolt to chamber tank, e- base for halogen lamp, f- fixing screws of the base of the lamp to the paraboloid.

The holder base of substrate is stainless steel threaded to the aluminum mirror, it was opted for stainless steel, as the substrate holder is of that same material, and being of the same material reduces the wearing out of the base. The heater was implemented without changing the distance from the target to the substrate in the sputtering system (mod. INTERCOVAMEX v1) and with a minimum impact on the charging the substrate to the deposit chamber. The design allows the use of the type 64612FNS 300W halogen lamps, as well as the type DB23X23X68 150W halogen lamps, but their dimensions enables the use of lamps of similar design, with intermediate powers between 150W and 300W. The holder substrate is a stainless steel tray on which substrates up to 5cm in diameter are placed, fastened by a few steel jaws, as shown in figure 2.

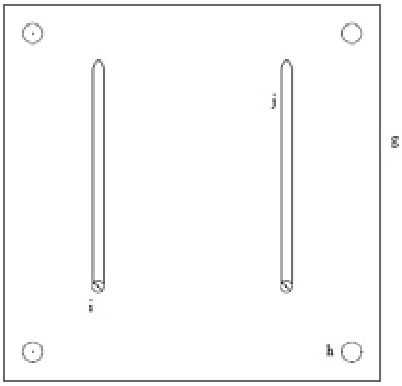

Figure 2: Substrate holder, top view: g- substrate, h- holes of fixing for the charging system of the substrate holder, i- clamp fixing screw, j- clamp.

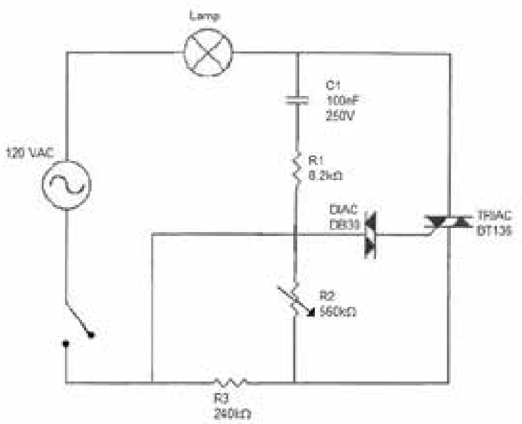

Figure 3: Electrical circuit diagram used to control the temperature of the heater, a TRIAC is used in phase delay configuration, this allows to control current that circulates in the halogen lamp, by varying the time in which the TRIAC remains on in each AC cycle, time is varied by modifying the resistance of R2.

The substrate is placed on the rear side to the one that is illuminated by the halogen lamp, the substrate heats the holder and by diffusion of heat the substrate is heated. The heater temperature control is performed by means of the current that is applied to the lamp, for this, as it is shown, in the electrical diagram in figure 3, a control that uses a very simple power circuit is used, which uses a TRIAC in a phase delay settings, using a DIAC as a triggering element, the current is set manually with the variable resistor R2, and through the current a stable temperature after 40min is obtained, according to characterization curves shown below and, this way, a close loop control is not necessary, in addition possible trajectories of tonnage are reduced by not having to insert a thermocouple permanently in the chamber.

CHARACTERIZATION OF THE HEATER

In figure 4 a picture of the heater mounted in the top of the vacuum chamber is shown, several copper wire 22 gauge stranded and ceramic insulation were used to be able to connect to the wall cross inside the chamber, since the characteristics of the deposit chamber system, require a relatively flexible cable that allows you to open the chamber (in figure 4(b)h you can see the heater operating within the chamber with the plasma on and the substrate holder placed with a sample, it important to note that the cable was placed in such way that it was far from the plasma (to avoid tonnage) and without obstructing the path of the eroded material.

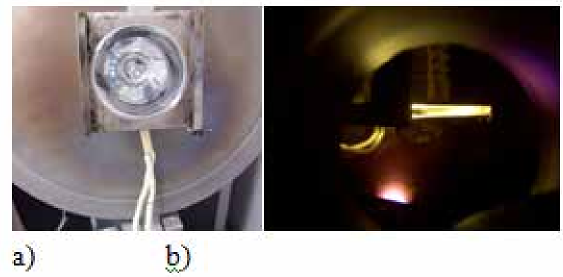

Figure 4: An image showing the heater mounted on the vacuum chamber, several copper stranded wire gauge 23 and insulating ceramic wall within the camera to connect to the passes were used, to facilitate opening the deposit system; (b) image that shows the heater operating within the camera with the plasma on.

After mounting the heater inside the sputtering system, the temperature depending on the current applied to the lamp was measured, for which a STEREN hook model MUL-095 ammeter and a thermocouple type K model TP-01 were used, the thermocouple was mounted in contact with the substrate holder, in the same position in which the substrate is placed. The current was measured taking care of placing the hook in the same position and way from the power supply cable to the lamp.

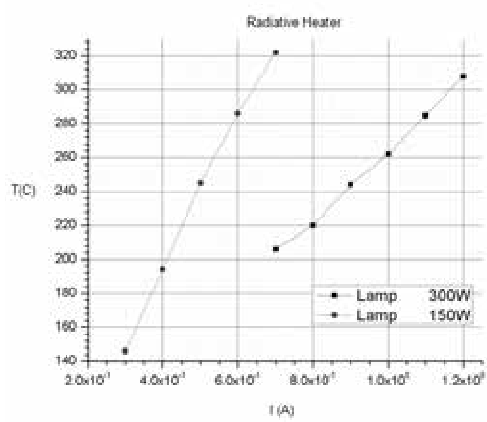

Figure 5: Graph current vs temperature of the halogen lamps of 150W and 300W. The response of both is very similar to a straight line, the temperatures of process that are intended to be reached are between 150C and 300C, so it was decided to use the lamp of 150W, since it covers the desired temperature range in stable condition.

Temperature depending on the power of two halogen lamps, 150W and greater lower 300W were characterized, as you can see in the graph of figure 5, their reactions are very similar to a straight line, measurements that were made have allowed us to know the temperature of the substrate holder depending on the current, the time in which a temperature is reached and remains stable, as well as the variation of temperature according to process pressure. Once these measures were done, using the experimental curves, shown in figure 5, temperatures were proposed and the current was adjusted according to these, obtaining a very good correspondence and repeatability.

RESULTS

The results show an almost linear relationship between current and temperature, a low variation of temperature as a function of the process pressure and temperature and temperature stabilization is relatively long (40 min), but once the temperature is reached, the temperature depending on the stability of the current stability is very high as shown in figure 6, this allows the proposed heater to be very reliable.

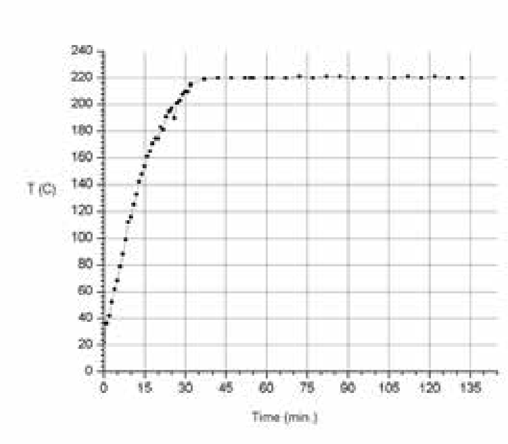

Figure 6: Graph of temperature of the substrate holder vs time, showing that the temperature stabilizes around 40 minutes, the data were collected using the 150W lamp with atmosphere of 5mTorr nitrogen pressure.

It is noteworthy that the main limitation that we have on the type of proposed circuit to feed the heater that requires a phase delay to shoot the triac, is that in the case of the lamp of 150W , currents below 260 mA, it is difficult to maintain the current stable and therefore temperature, the current varies and it is necessary to adjust it so that you can control temperature subfreezing an for the case of 300W lamp, we have this same limitation to less than 650mA currents, so it is not possible to control temperatures below 200C. This limitation can be avoided by using other power options, but we chose to keep the option proposed by its low cost and because it adapts to the experimental needs in which it is intended to be used, where we require temperatures of 150C to 300C. Tests were also conducted to determine the variation of temperature at varying the pressure and as it can be seen from table 1, in a12mTorr pressure differential temperature varied no more than 2C.

Table 1. Temperature variation depending on the pressure, as seen in the table, the temperature variation between the pressure of 3mTorr and 15mTorr is 2C.

150W Lamp		
P (mTorr)	**I (A)**	**T (C)**
3.0	0.5	245
10.0	0.5	245
15.0	0.5	247

CONCLUSION

To vary and control the temperature of the substrate in sputtering system, allows you to modify morphology, deposit reason and composition of a film deposited by this technique, so the importance of that possibility in a sputtering system. The main advantage of the heater shown in this work is low cost, the ability to be easily reproducible in a conventional machine tools workshop, its low power consumption, that allows you to reach temperatures of 300C consuming less than 90W and its high stability when reaching working temperature. Although it presents as main disadvantages, in the configuration that was used, the stabilization time of the temperature (40 min.) and that temperatures below 140C are not capable of being stabilized, it is clear that using a close loop control, it is possible to improve the performance, implying a greater cost in this category. This heater is a good choice for application in the deposit of films by the method of sputtering system at temperatures of up to 300C.

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REFERENCE

[1] I. Safi,A novel reactive magnetron sputtering technique for producing insulating oxides of metal alloys and other compound thin films, Surface and Coatings Technology 127 (2000) 203-219. | [2] S. Berg and T. Nyberg, Fundamental understanding and modeling of reactive sputtering processes, Thin Solid Films 476 (2005) 215–230 | [3] K. Choi and K. Kim,Antireflection coating of a SiO/SiN double layer on silicon fabricated by magnetron sputtering,Journal of Ceramic Processing Research 11(2010) 341. | | [4] www.pascaltechnologies.com | | [5] www.lesker.com | | [6] www.directvacuum.com | | [7] T.E. Jones, W.C. McGinnis, Rev. Sci. Instrum. 65 (1994) 977. | | [8] R. Campion, R. Ormson, Vacuum46 (1995) 195.