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Using porcelain insulation for glow discharge plasma of the DC planar reactor

Confecção de isolantes elétricos de porcelanas dos eletrodos na geração de plasma DC luminescente

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ABSTRACT

The confection of electric insulation by porcelain ceramics can be more acceptable than using pieces of alumina ceramics since the porcelain can be built in a more flexible manner. The goal this project was to use electric insulation with porcelain ceramics to encapsulate the electrodes of the planar reactor to generate a normal electrical DC glow discharge. The idea is to study the influence of impurities porcelain generates in such contact with plasma. The raw material of porcelain has composition of 40% of kaolin, 25% of quartz, 25% of feldspar and 10% of clay. During luminescent plasma discharges was possible to identify the electron column and the positive column regions. During experiment was analyzed the stability of plasma evaluating sensible parameters conditions such as the gas argon pressure and also the breakdown voltage. The measurement of a pressure range versus electric tension permits to plot the Paschen's Curves with a minimum sparking potential. Our results have indicated that low value of the product $(pd)_{min}$, where p is a pressure of gas and d is the gap between the electrodes, than the minimal electric voltage doesn't following theoretical Paschen' curve and it can possibly be related with impurities on the composition of porcelain.

Keywords: Glow; Discharge; Cathode; Paschen; Breakdown; Electron.

RESUMO

A confecção de porcelanas com finalidade para isolação elétrica tem sido mais acessível do que as peças obtidas de cerâmica de alumina pelo fato das peças de porcelanas terem um processo de produção mais flexível. O objetivo neste projeto do reator planar a plasma foi empregar isolantes elétricos construídos de porcelana para encapsular os eletrodos e gerar um plasma luminescente entre o cátodo e o o ânodo submetido a uma tensão DC. A idéia é estudar a quantidade de impurezas que compromete a sua utilização como isolante elétrico. A matéria prima da porcelana tem em sua composição 40% de caulim, 25% de quartzo, 25% de feldspato e 10% de argila que são submetidas à dosagem rigorosa e maleabilidade obtida com adição de água. Durante a descarga de plasma luminescente foi possível identificar a região da coluna dos elétrons e dos íons e analisar a estabilidade de plasma em função da pressão de gás argônio e da voltagem de ruptura. Com intenção de testar exaustivamente esta alternativa de isolação elétrica efetuamos o levantamento da Curva de Paschen estudando a condição de equilíbrio de plasma conhecida como o *Mínimo de Paschen*. O mínimo de Paschen corresponde a uma tensão mínima V_b para manter uma descarga elétrica com um máximo de ionização num ponto $(pd)_{min}$, do produto da pressão do gás residual pela distância de separação entre o cátodo e o ânodo, dado em Pa cm. Os resultados experimentais indicaram que para os valores do produto pd abaixos do pd mínimo não seguem a curva de Paschen devido possivelmente às impurezas vindas da porcelana.

Palavras-chave: Luminescente; Descarga; Cátodo; Paschen; Ruptura; elétron.

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INTRODUCTION

The breakdown voltage DC V_b of rupture of a gas of a parallel plate reactor depends on the product *pd*, where *p* is a pressure of gas, given in *Pa*, and *d* is the gap between the electrodes given in cm. Then, this expression is yielded by[1],

$$V_b = \frac{Cpd}{\ln\left[\frac{Apd}{\ln(1+1/\gamma_{SE})}\right]} \quad (1)$$

where *A* and *C* are constants which depends on of gas and γ_{SE} is the secondary electron emission coefficient that depends on the gas and on the cathode material.

The point of minimum breakdown voltage of the Paschen's curve indicates a stability of a normal glow discharge with the maximum ionization. For instance, decreasing the pressure of argon gas to obtain the product *pd* under the minimum point, $(pd)_{min}$, in which indicates the neutral atoms of gas argon is not enough to yield an ionization and the reactor necessity for high voltages to promotes glows discharges. For the product *pd* above of the minimum point, $(pd)_{min}$, the high density remove kinetic energy of electrons and the reactor needs more voltage to promote breakdowns with less mean free path. Therefore, the Paschen's curve decreases in asymptotic way to values of the products, *pd*, under minimum value, and this values increases in linear way to values above of this minimum, respectively[1,2,3].

The goal this project was develop electric insulation with porcelain ceramics to encapsulate the electrodes of the planar reactor to generate a stable electrical DC glow discharge

MATERIAL AND METHODS

Clay of Porcelain

The porcelain material is a white color, translucent and waterproof product that presents vitrification property and it has mechanical resistance and small porosity. The raw material milling of the porcelain is classified according a granulometry of the composition of 40% of kaolin, 25% of quartz, 25% of feldspar and 10% of clay which malleability of porcelain is obtained with addition of water. The kaolin is an ore composed of hydrated aluminum silicates, such as kaolinite and haloisite[4,5].

Vertical lathe machine

The body clay has to be compressed to eliminate all internal air bubbles to get a uniform consistency body. After that, the body clay can be molded approximately a circular and uniform thickness with the required dimension. The smooth finish dimension of clay is obtained using a precise knife of a homemade vertical lathe machine, which can be seen in Fig. 1, used in slow rotation.

The cylindrical shape of clay can be built using a vertical lathe machine that consist in a disc horizontal that is moved by 12 Volts DC electric engine, used in trucks, which has strong torque and slow rotation.

The state of wet of the clay promotes it well anchorage on center of the disc rotation in other to turn it diameter from edge to core region. However, it is necessary keeps over dimension of 15 % of the clay due to water evaporation during air dryness. During the dryness is important keeps the tolerance of parallelism and also of planicity of the clay as long as possible of all body. The clay is kept in dehydration process for two or three days at room temperature during in which its color changes from gray to sand.

At center of the lathe machine disc a removable pin is used to turn small cylindrical shape of the clay. The tub porcelain is used to insulate conductors wires that make power connection with anode and ground connection with cathode electrode. And finally the burning process of the clay is made inside an electric oven[5].

Figure 1: Lathe machine to mold clay of porcelains

Vitrification of the porcelain.

The vitrification process of porcelain occurs inside a oven in which the temperature rate is increased 1,5°C/min up to 300°C, and after that the temperature rate is adjusted to increase 0,5°C/min up to 1200°C. This plateau of 1200°C is maintained during 12 hours then the porcelain is cooling down inside of the oven during another 12 hours. During this process the porcelain loses all water and changes from the crystalline phase to the vitreous phase, characterized with grains welding. The vitrification process provided to porcelain a little weakly grayish texture and a large hardening because of presence of the silicates[4,5].

Encapsulation of cathode and anode electrodes with porcelain

The porcelain can be used to encapsulate electrodes to obtain it electric insulation and also confine glow discharge between cathode and anode region. Each disc electrode, cathode and anode, is build up of copper material of 100 mm of diameter by 5mm of thickness. One coaxial tube operating like a feedthrough working as ground of the cathode and allows adjust the gap distance between cathode and anode in 16,6 mm. The vacuum sealing of this coaxial disc is made by an o-ring assembled inside an bushing (Fig. 2).

The porcelain hides sharps points, edges and wires conductors avoiding generation of glow discharge plasma in other parts of the reactor. The thermal insulation of the porcelain reduces heat transfer from sputtering process of the cathode electrode to other parts of reactor. Beside these characteristics, the porcelain also defines an structural design of reactor because clay can be modeled in appropriate shapes.

The adjustment of porcelain size is made erecting their parts by diamond tips tools according of size of the cathode and the anode pieces. The cathode and anode conductor are encapsulated inside jacket porcelain with one of face appearing and their wires connectors are mounted inside tubs porcelains. The tubs and the jackets are stick by epoxy material.

Once the encapsulation of the cathode and the anode with the porcelain is finished, the next step is to plot the Paschen's curves for each values of the breakdown voltages to some selected pressure range.

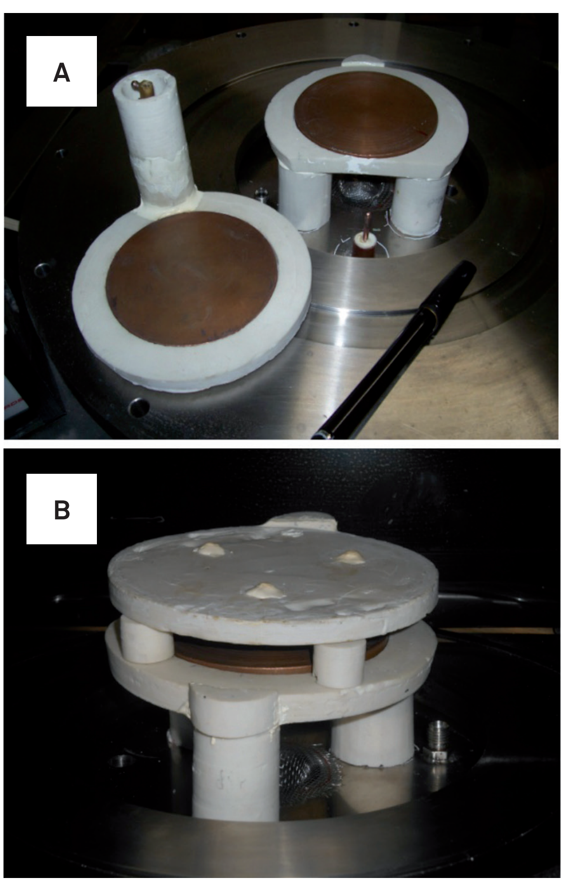

Figure 2: (a) The cathode and anode conductor are encapsulated inside jacket porcelain with their faces out, (b) the cathode and anode electrodes are assembled.

EXPERIMENTAL SETUP.

After adaptation of a fine pressure control valve of the argon gas to the parallel plate reactor, it was possible to make measurements in a range of 25 points of pressure. For each pressure of the argon gas, the electric voltage between cathode and anode was increased until generates the normal DC glow discharge of plasma starting from a dark plasma stage. The measurement choice was decreasing pressure range, starting with rate of 50 Pa from 700 Pa until 300 Pa, the rate of 20 Pa decreasing from 300Pa until 200 Pa and using a rate of 5 Pa from 200 Pa to less value. To each value, the electric voltage of a rectifier was increased by one self transformer until reach the breakdown voltage V_b. For pressure values under 20 Pa it was not possible to obtain glow discharge. The total pressure range of the values described with almost 25 points was used to plot the Paschen's curve. The induced floating voltage of the table structure and its disc of reactor stayed around 23,66 Volts. This experiment still has concerned about degassing and composition of porcelain that can be seen in other works[6].

RESULTS AND DISCUSSIONS

Using the MATLAB-r14® it was possible to plot the Paschen's curve from this 25 points data in which the first 11 points with low pressure have showed out from theoretical Paschen's curve but the others points were according straight part of the curve, as seen at Fig. 3. This two region make evident minimal breakdown of voltage of V_b=225 Volts that keeps *DC* glow discharge with maximum ionization when is kept at the minimal product of $(pd)_{min}$= 135,7 cmPa for the gap distance of d = 15,6 mm between of cathode and anode electrode. The breakdown voltage of this experiment can be compared with Lisovskiy et al.[7], with a minimal breakdown voltage V_b=257 V acting at minimal product $(pd)_{min}$= 187 cmPa. And it can also be compared with values of the undergraduate monograph of

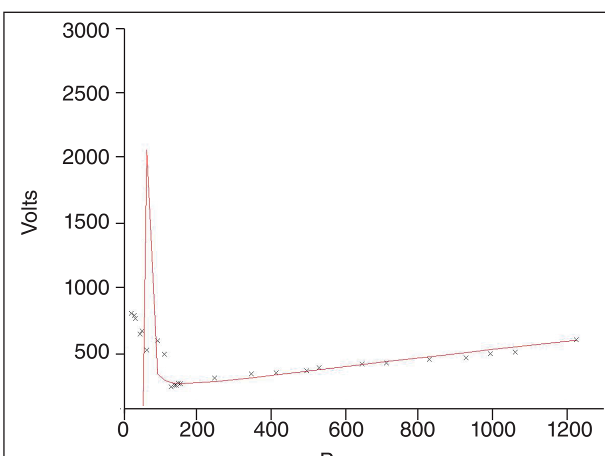

Figura 3: Paschen's curve corresponding to product *pd* of 25 pressure points data.

FATEC-SP´s student[10] that showed values of V_b=227 V and $(pd)_{min}$= 128 cmPa.

The Paschen's curve admit theoretical expression described by a constant A = 0,10 for copper and the unit is given in ion-electron collision per Pa.cm, it also uses the other constant C = 1,4 which is given in unit of V per Pa.cm. The secondary electron emission γ_{SE}, is a dimensionless number and it can be obtained from Eq. 2.

$$(pd)_{\min} = \frac{e}{A}\ln\left(1+\frac{1}{\gamma_{SE}}\right) \tag{2}$$

that gives γ_{SE}= 6,83x10^{-3}[1].

The electron ionizes gas background with effective potential of V^* = 16,7 eV per electron-ion pair, calculated from $AV^* = C$ [1], which is large than the actual ionization potential of V_i = 15,7 eV per electron-ion pair, which gives the electron gain of $x_i = V^*/V_i = 1{,}06$. According to the Fig. 4 that shows some photos of the glow discharge, there are peculiar aspects during the changes of the voltage and the pressure of argon gas. The shots with low pressure A and B describes discharge under the minimal product $(pd)_{\min}$ where the discharge appears gradually as long as voltage is increased up to breakdown happens and the plasma always takes throughout all volume, that means, it doesn't have just time of separation with and without plasma. Otherwise, to the shots with high pressure C to G above the minimal product $(pd)_{\min}$ the discharge arises after voltage have surpassed breakdown voltage in a precise way. The shots from D up to G shows fill of the plasma partially between electrodes. The last two shots F and G indicates that the positive column of glow discharges takes a tail shape between electrodes that looks like plasmoids. Arising the voltage of the planar reactor surpassing the threshold point of the luminescent state the discharge plasma, the plasma reaches arc jet plasma states following with strong sparks and huge electric current that disarming the circuit breaker of the reactor.

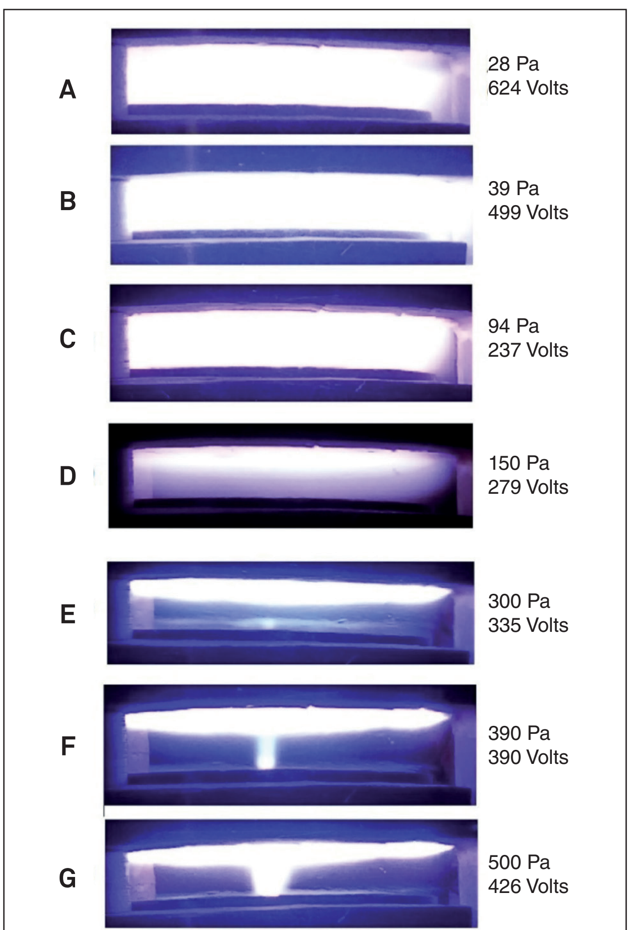

Figure 4: Evolution of *DC* glow discharge along pressure increasing.

CONCLUSION

The confection of porcelain was successful to the point it is possible turning the diameter of the clay with precision. And vitrification process gives to porcelain some quality of hardness which allows adjustments of its parts only using diamond tips tools.

Once of the electrodes was encapsulated with porcelain jackets, the glow discharge DC plasma can be generated and confined between cathode and anode region without burning of the porcelain. In spite of the porcelain appearing good symmetrical shape the glow discharge at high pressure shows the presence of plasmoids.

The range of 25 measurement of pressure and voltage of planar reactor allowed to built the Paschen's curves and it indicated the minimal sparking potential with V_b=225 Volts at correspondent minimal product $(pd)_{min}$ = 135,7 cmPa.

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