Characteristics of Pulsed Discharge of the Pate-pinholes-plate Reactor

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Abstract—The electrical discharge technologies can produce various active chemical species, which are effectively applied for many organic pollutants. Different electrode geometries were used in pulsed discharge, the metal electrode will corrode. To solve this problem, we designed a electrodeless discharge reactor (plate-pinholes-plate) and study the characteristics of pulsed discharge on the pinhole. The peak voltage, current, instantaneous power and the total power are changed with voltage and conductivity increasing.

Keywords-pulsed discharge; pinhole; active species; characteristics ;electrode

I. INTRODUCTION

Advanced oxidation processes (AOPs) which are based on the production of hydroxyl radicals have been effectively applied for many organic pollutants. Among the AOPs, the pulsed discharge is a new method applicable for decoloration of dyes from wastewater [1-6]. The ·OH radicals produced by discharge play an important role in the degradation of organic pollutants[7-9].

Up to now, different electrode geometries were used in pulsed discharge[10-12], such as point-to-plate, point-to-point, plate-to-plate], wire-to-plate, wire-to-cylinder, etc. The discharge electrode is metal, resulting in the corrosion of metal electrode and decrease the lifetime of metal electrode.We design a new discharge reactor, that is plate-pinholes-plate. In present work pulsed discharge was formed on the pinhole of an insulating plate which was inserted between two plate electrodes and the characteristics were studied.

II. EXPERIMENTAL

The schematic diagram of the experimental apparatus is shown in Figure1.

High-voltage pulses are generated using the combination of a 0-60 kV adjustable DC power supply, a storage capacitor and two rotating spark-gap switches. Two plate electrodes were stainless steel discs with 23 mm in diameter and the distance of the two plate electrodes located in the center of Plexiglas cylinder was 27 mm. Two Plexiglas cylinders with 33 mm inside diameter and 30 mm height were used, which were separated by an insulating plate with three pinholes. The thickness of the insulating plate and the diameter of the each pinhole were 2 mm and 1 mm, respectively. Gas was bubbled into the upper port of the reactor through the pinholes.The peak values of pulse voltage and current were measured with a Tektronix P6015 high-voltage probe and a Tektronix P6022 current probe, respectively. The corresponding waveforms were monitored with a Tektronix TDS3032B Digital Phosphor Oscilloscope. Sampling point reactor of discharge electrodes and grounding electrode, respectively.

$$Ep = \int_0^T u(t) \times i(t) dt$$

where u(t) is the instantaneous input voltage (kv); i(t) is the instantaneous input current; Ep is the total pulse energy (J) in a single pulse input time.

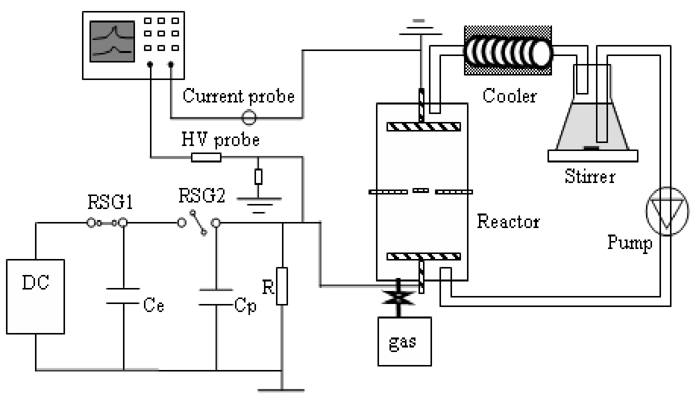

Figure 1. The schematic diagram of the experimental apparatus

III. RESULTS AND DISCUSSION

3.1 Effect of peak voltage on the pulsed discharge

The instantaneous voltage, current and the instantaneous power waveform at different initial input voltages of 16, 18 and 22 kV is shown in Figure 2, the corresponding peak voltage, current, maximum instantaneous power and single pulse total input energy are shown in Table 3. The results indicated that under the high input voltage, the instantaneous voltage, current and power is higher. The peak voltage, current, instantaneous power and the total power are increased gradually with the the increase of the input voltage. When the input voltage is 16kV, peak current, the maximum instantaneous power and the total input energy are: 7.6992A, 0.1999MW, 0.24J; when the input voltage is 16kV, peak current, the maximum instantaneous power and the total input energy are: 22.4555A, 0.7674MW, 0.61J, which is 2.92, 3.89, 2.54 times. Therefore, under the high input voltage, the useful energy of electric field may increase.

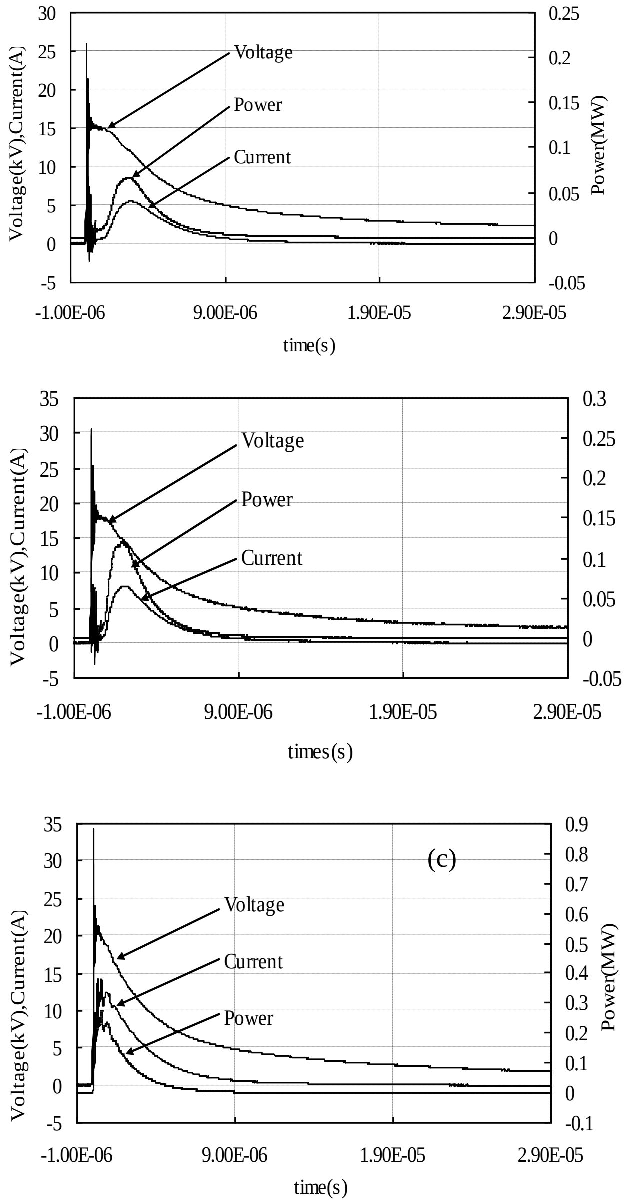

Figure 2. The waveforms of voltage, current and instantaneous energy in different voltage (a)16kV, (b)18kV, (c)22kV

[1] TABLE1 THE INPUT VOLTAGE, CURRENT, PEAK INSTANTANEOUS POWER AND TOTAL INPUT ENERGY OF ONE PULSED IN DIFFERENT VOLTAGE

voltage(kV）	16	18	22
Peak voltage(kV）	25.9578	30.4375	34.1734
Peak current (A)	7.6992	8.3977	22.4555
peak instantaneous power (MW)	0.1999	0.2556	0.7674
total input energy Ep (J)	0.24	0.34	0.61

3.2 Effect of conductivity on the pulsed discharge characteristic

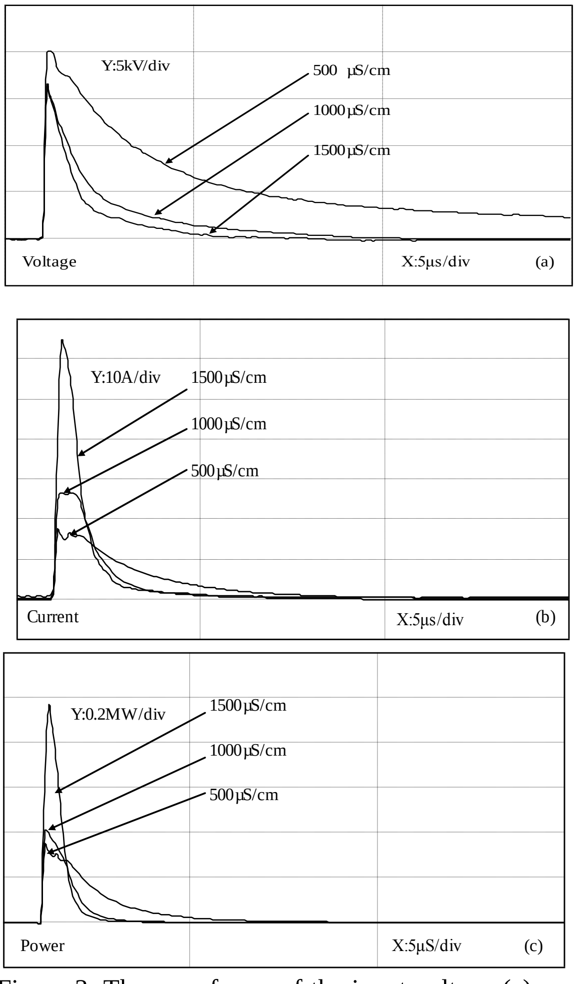

Figure 3. The waveforms of the input voltage (a), current (b) and instantaneous energy (c) in different conductivity

The conductivity of solution leads to the amount of the charged ions of solution, the conductivity will be changed during the pulsed discharge, the increasing conductivity will lead to the change of discharge form, namely from spark discharge to corona discharge. So, the solution conductivity is one of the main factors influencing the reactor discharge characteristics. Under different initial electrical conductivity, the peak voltage, current, the instantaneous power of the reactor waveform is shown in Figure 3, the corresponding peak voltage, current, maximum instantaneous power and single pulse total input energy are shown in Table 2. The results indicated that the peak current and instantaneous power are increased, but the total power and energy efficiency are decreased gradually with the the increase of the input voltage.

[2] TABLE 2 THE INPUT VOLTAGE, CURRENT, INSTANTANEOUS POWER AND TOTAL INPUT ENERGY OF ONE PULSED IN DIFFERENT CONDUCTIVITY

conductivity（μS/cm）	500	1000	1500
Peak voltage（kV）	20.1609	16.489	16.233
Peak current (A)	17.369	24.938	64.097
Instantaneous power (MW)	0.3450	0.4112	1.0405
total input energy Ep(J)	0.424	0.265	0.253
Energy efficiency η(%)	87.61	54.75	52.27

3.3 Effect of different electrode distance on the pulsed discharge characteristic

$$d=d_1+d_0+d_2\ ;$$

where d is the electrode distance；d_0 is the insulation thickness; d_1 is the distance between insulation plate and negative electrode; d_2 is the distance between insulation plate and positive electrode.

The electrode distance effect the discharge greatly, this is because the solution properties and the reactor is unchanged, the electric field intensity depends on the size of the electrode distance. The electric field intensity becomes stronger with less electrode distance. The discharge can occur easily around the stronger electric field. More active species generated in the field of higher energy, collision and dissociation process, so as to improve the effect of degradation of organic compounds. Under different electrode distance, the peak voltage, current, the instantaneous power of the reactor waveform is shown in Figure4, the corresponding peak voltage, current, maximum instantaneous power and single pulse total input energy are shown in Table 3. The results indicated that the peak current, instantaneous power and total input energy are increased gradually with the the decrease of the electrode distance

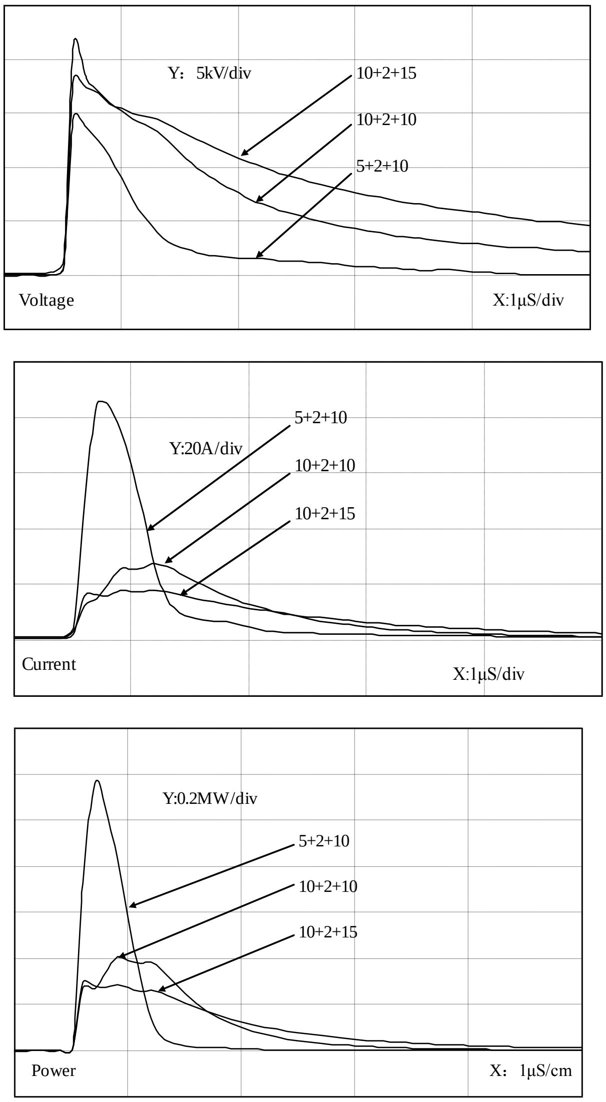

Figure 4. The waveforms of the input voltage (a), current (b) and instantaneous energy (c) in different electrode distance

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[3] THE INPUT VOLTAGE, CURRENT, INSTANTANEOUS POWER AND TOTAL INPUT ENERGY OF ONE PULSED IN DIFFERENT ELECTRODE DISTANCE

Electrode distance（d_1+2+d_2 mm）	d_1=10 d_2=15	d_1=10 d_2=10	d_1=5 d_2=10
Peak voltage（kV）	18.3828	21.6047	14.9297
Peak current (A)	16.0984	27.4594	84.7531
Instantaneous power (MW)	0.2959	0.3846	1.1647
total input energy Ep(J)	0.3424	0.386	0.405

IV. Conclusions

1)The peak voltage, current, instantaneous power and the total power are increased gradually with the the increase of the input voltage. 2) The peak current and instantaneous power are increased, but the total power and energy efficiency are decreased gradually with the the increase of the input voltage. 3) The discharge can occur easily around the stronger electric field with smaller electrode distance. The peak current, instantaneous power and total input energy are increased gradually with the the decrease of the electrode distance.

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References

[1] M.R. Ghezzar, F. Abdelmalek, M. Belhadj, N. Benderdouche, A. Addou, Gliding arc plasma assisted photocatalytic degradation of anthraquinonic acid green 25 in solution with TiO2, Appl. Catal. B: Environ. 72 (2007) 304-313.

[2] A.T. Sugiarto, S. Ito, T. Ohshima, M. Sato, J.D. Skalny, Oxidative decoloration of dyes by pulsed discharge plasma in water, J. Electrostat. 58 (2003) 135-145.

[3] Y. Zhang, M.H. Zhou, L.C. Lei, Degradation of 4-chlorophenol in different gas–liquid electrical discharge reactors, Chemical Engineering Journal. 132 (2007) 325-333.

[4] C. Lee, Y. Lee, J. Yoon, Oxidative degradation of dimethylsulfoxide by locally concentrated hydroxyl radicals in streamer corona discharge process, Chemosphere. 65 (2006) 1163-1170.

[5] B. Sun, S. Kunitomo, C. Igarashi, Characteristics of ultraviolet light and radicals formed by pulsed discharge in water, J. Phys. D: Appl. Phys. 39 (2006) 3814-3820.

[6] B.R. Locke, M. Sato, P. Sunka, M.R. Hoffmann, J.S. Chang, Electrohydraulic discharge and nonthermal plasma for water treatment, Ind. Eng. Chem. Res. 45 (2006) 882-905.

[7] Z.Q. Gao, S.G Yang, N. Ta, C. Sun, Microwave assisted rapid and complete degradation of atrazine using TiO2 nanotube photocatalyst suspensions, J. Hazard. Mater. 145 (2007) 424-430.

[8] R.B. Zhang, C. Zhang, X. X. Cheng, L. M. Wang, Y. Wu, Z.C. Guan, Kinetics of decolorization of azo dye by bipolar pulsed barrier discharge in a three-phase discharge plasma reactor, J. Hazard. Mater. 142 (2007) 105-110.

[9] B. Yang, M.H. Zhou, L.C. Lei. Synergistic effects of liquid and gas phase discharges using pulsed high voltage for dyes degradation in the presence of oxygen, Chemosphere. 60 (2005) 405-411.

[10] M. Sato, D. Kon-no, T. Ohshima, A.T. Sugiarto, Decoloration of organic dye in water by pulsed discharge plasma generated simultaneously in gas and liquid media, J. Adv. Oxid. Technol. 8 (2005) 198-204.

[11] J. Li, M.Sato, T.Ohshima, Degradation of phenol in water using a gas-liquid phase pulsed discharge plasma reactor, Thin Solid Film. 515 (2007) 4283-4288.

[12] E. Njatawidjaja, A.T. Sugiarto, T. Ohshima, M. Sato, Decoloration of electrostatically atomized organic dye by the pulsed streamer corona discharge, J. Electrostat. 63 (2005) 353-359.