Management of Ionization Source Based on a Pulsed Corona Discharge

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Abstract. It is developed igniting electrical circuit for pulsed corona discharge ionization to operate a source as part of an ion mobility spectrometer. The simulation circuit for forming a corona discharge allowed optimizing the parameters. The possibility of electronic switching of the primary winding and reverse polarity diodes in the high voltage part of the circuit provide operation of the corona discharge ion source for detection both positive and negative ions.

Keywords: Ion mobility spectrometry · Ionization source · Pulsed corona discharge

1 Introduction

Ion mobility spectrometers are widely used [1–5], particularly as environmental monitoring system [6–8]. Intense competition in the market for analytical equipment necessitates improving design methods. The most common sources of radioactive ionization based on 63Ni. Less popular sources of ionization by corona discharge, although they are quite stable and easy to operate [9–15]. In this article, it is developed the igniting electrical circuit for pulsed corona discharge ionization to operate a source as part of an ion mobility spectrometer.

1.1 The Circuit for Control of Ionization Source

The general structure of an ion mobility spectrometer control is shown in Fig. 1:

One of the circuits on the microcontroller generates the control signals for the ionization source, which are fed to an electrical circuit discharge formation. The discharge is produced in a mechanical structure consisting of four pairs of electrodes, the geometry of the tip edge, the ionization chamber placed in the spectrometer, which passes through the sample flow withdrawn from the subject.

In the case of usage of continually burning corona discharge it takes place problems with lifetime of source. As a result of the constant burning defects are formed needles,

B. Mandler et al. (Eds.): IoT 360° 2015, Part II, LNICST 170, pp. 260–268, 2016.
DOI: 10.1007/978-3-319-47075-7_30

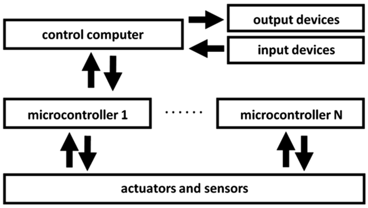

Fig. 1. The circuit of common control system architecture.

as a consequence - changing of their geometry and discharge parameters. Consequently, the ionization source should operate in a pulsed mode in order to prolong life and improve the stability characteristics. Ionization source on the basis of pulsed corona discharge must have a certain speed. It is determined by the requirements for ion mobility spectrometry. To ensure a timely response to the presence of target analyzable compounds in the sample spectrometer should hold at least 10 measurements per second. Generation and breakdown of the corona discharge must be for a period not exceeding 100 ms.

1.2 Corona Discharge Ionization Source

A development of a pulse generating circuit corona discharges includes the following tasks: the formation of the current pulse in the primary winding of the transformer, the accumulation of energy in the magnetic field of the transformer and the selection of this energy in the discharge gap. The circuit is shown in Fig. 2.

The primary winding of the transformer is connected to a power source via an electronic key Q1. A current increases and the energy accumulation is performed in a magnetic field of the transformer when applying the control pulse to the gate of the transistor in the primary winding. This energy is released in the secondary winding through a rectifier element D1 charging funded chain R1, when closing the transistor. Subsequently, tension from the chain is applied to the discharge gap. The circuit should provide a rapid accumulation of energy and it is subsequent discharge into the

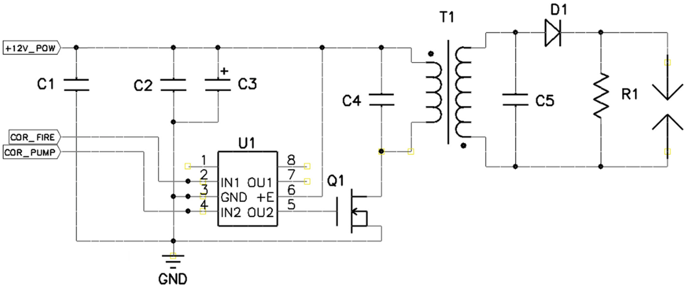

Fig. 2. The schematic diagram of pulse corona discharge ignition. The design of the ionization source, based on corona discharge.

discharge gap. The reset is performed for a time equal to the time constant. To match the signals from the low power microcontroller with the low-voltage transistor driver, high-speed MOS transistors U1is used. The circuit power is produced by capacitors C2 and C3. It is formed by a current pulse is fed to the high-voltage transformer forming T1. The parasitic capacitance elements of the discharge gap are dependent on arrangement of the needles of the connecting conductors. The geometry used for the value of the parasitic capacitance of the arrester is about 2pF. Therefore, the time constant of the RC-circuit arrester is 2mks. Experiments show that the shape of the discharge gap voltage ensures stable operation of the pulsed corona discharge.

2 Simulation of Pulse Corona Discharge Forming Circuit

To simulate the circuit it was chosen a simple case of Single negative polarity discharge. Model of corona discharge punch is based on a design of the discharge lamp. Circuit of formation of pulsed corona discharge is shown in Fig. 3. Below are presented the waveforms of the control points for different occasions. Point A is located at the output of the high voltage transformer. Point C is located on the discharger.

The Fig. 4. shows that the signal at the point C is relative to the delayed signal at the point A and has a smaller amplitude. The voltage at the Punches reaches the breakdown voltage of the discharge gap. The pulse at point C should have a larger amplitude or longer duration. This method is considering the option of increasing the amplitude of the signal at the arrester. Also the method includes increasing the amplitude of the output transformer. This method has limitations due to the technological characteristics of the components used. In forming the high-voltage pulse capacitor, C1 can quickly charge to a voltage corresponding to the breakdown of the transformer (maximum permissible voltage transformer used in the circuit is 5800 V). If the voltage reaches this value, there are technological limitations associated with the breakdown of the transformer. The breakdown will not happen in the spark gap, it will be through the element U1 in the secondary circuit, which simulates the electrical strength of the structure.

The results shown below were obtained by increasing the pulse duration to the primary winding of 15 %. Waveforms at points A and C is shown in Fig. 5.

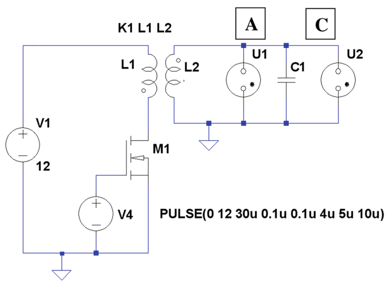

Fig. 3. The simulation of forming circuit pulse corona discharge.

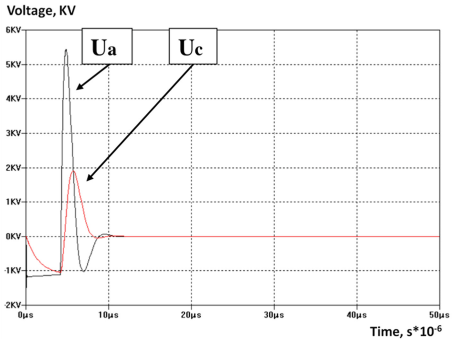

Fig. 4. The plot of voltage at the control points under conditions corresponding to the absence of discharge.

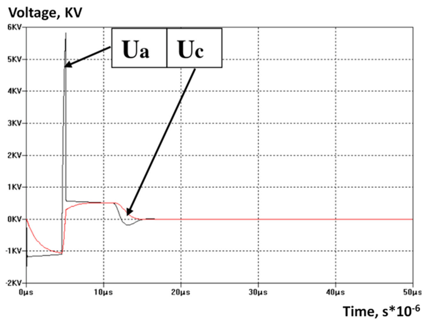

Fig. 5. The plot of voltage at the control points under conditions corresponding to the breakdown of the secondary winding of the transformer.

The voltage at point A is greater than the maximum allowed for the used transformer. Therefore breakdown occurs through the element U1. As a result, despite to the signal amplitude increase in at point A the voltage on the piercer doesn't reach the breakdown voltage of the discharge gap. Furthermore, the amplitude of the signal at the point C is reduced as compared with the case in Fig. 3. Thus, the goal is not achieved by only increasing the amplitude. This method has the technological limitations associated with the breakdown of the transformer.

Another option for solving the problem is to increase the pulse duration on piercer. Increases of the duration of pulse will lead to the fact that the amplitude of the signal exceed the voltage response of the punch (after the charge constructive capacity needles C1) and will occur electric discharge. In system added diode D1. A voltage pulse from the secondary winding charges the capacitor C2 via a diode D1. Voltage across the capacitor is held for long time, determined by the parameters of circuit C2. From this circuit a constructive capacity of needle C7 is charging, and when the discharge starts voltage breakdown and transfer of energy to the bit interval. The circuit is shown in Fig. 6.

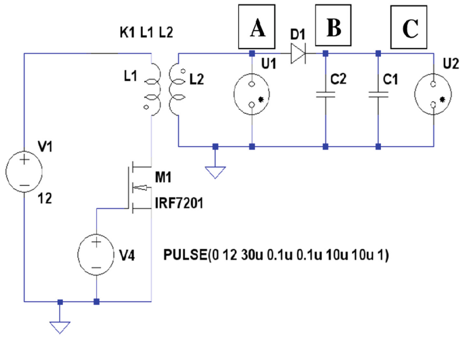

Fig. 6. The modeling circuit for forming a corona discharge with the extension of the high-voltage pulse.

The waveforms at the point B (after the diode D1) and at the point C are shown in Fig. 7. From the simulation can be seen that the developed ignition circuit with high-voltage pulse extension ensures the formation of the breakdown conditions of the discharge gap and the ionization source. Simulations performed with the technological limitations of the components is used no breakdowns in the secondary circuit of the transformer.

On the resulting chart, the following stages of the circuit: the accumulation of energy in the magnetic field of the transformer, increase of the voltage breakdown and burning of pulsed corona discharge, the zero voltage recovery across the discharge gap. The total duration of the process is 50mks. This speed allows to the source to operate more than one hundred times per second, which is much higher than the number of spectrum measurements for the same period.

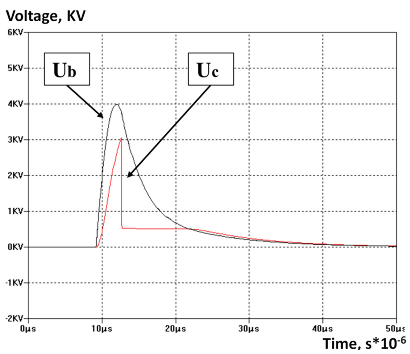

Fig. 7. Voltage at the control points under conditions corresponding to the breakdown of the discharge gap.

3 The Driving Source with Electronic Switching of Polarity

To solve the problem of functioning of the device in discoverable mode, both positive and negative ions is necessary to adapt the circuit developed by the ignition of pulse corona discharge in such a way that it allows you to create pulses of both positive and negative polarity. The previous sections described the essential work on the igniter of the pulse corona discharge, where the energy storage is carried out in a magnetic field of the transformer. The task of modifying the circuit is easier to solve in two stages: first, to change the circuit of energy storage and then design a switching circuit with the primary drive. The circuit is implemented with the possibility of mechanical switching of the primary winding and reverse polarity diodes in high-voltage part of the circuit (Fig. 8).

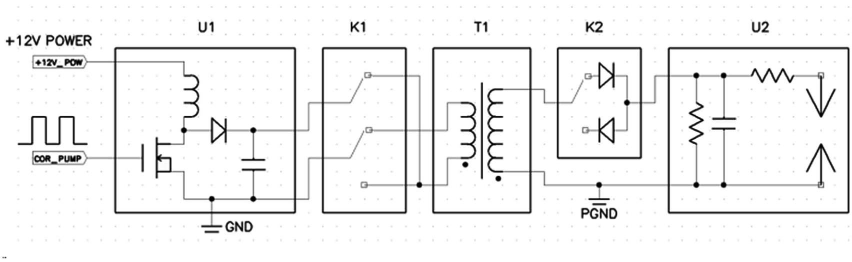

Fig. 8. The circuit of ion source with switching polarity.

The device includes a capacitive energy storage with an inductive circuit pump U1, switches K1 and K2 are input and output circuits of the pulse transformer T1, providing switching the polarity of the voltage at the arrester U2.

In the circuit the accumulation of energy is produced directly in the magnetic field of the transformer T1. The polarity switching is performed by mechanical switching of the primary winding. Simultaneously with the switching of the primary winding the diode of the high polarity part of circuit is switched.

In order to demonstrate compliance with the signal at the arrester Uc (in Fig. 6) it is simulated signal of corona discharge generating circuit with stored energy in the capacitor C3 (Fig. 9).

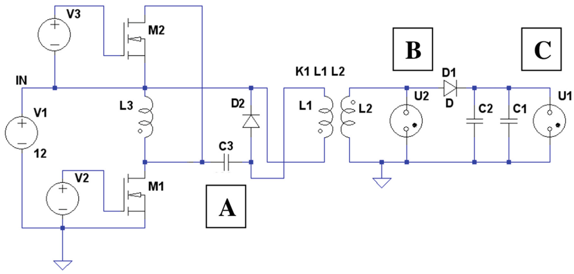

Fig. 9. The corona generating circuit is mechanically switching between modes.

Figure 10 shows the process of energy storage in the capacitor C3 and its discharge to the primary winding of transformer T1. The used circuit provides a much sharper edge of the signal on the primary winding, as compared with the case of directly accumulating energy in the magnetic field of the transformer.

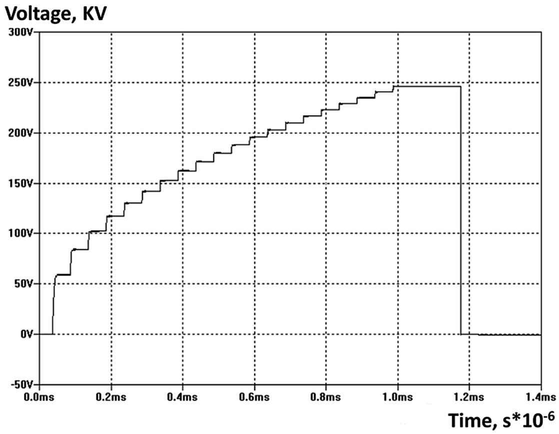

Fig. 10. The voltage at the test point A.

The signals at the control points B and C are shown in Fig. 11. The graph shows that the shape and the voltage across the discharge gap to form signals coincide in Fig. 7. Therefore, we can conclude that the correct operation of the circuit is forming a corona discharge with pre-stored energy.

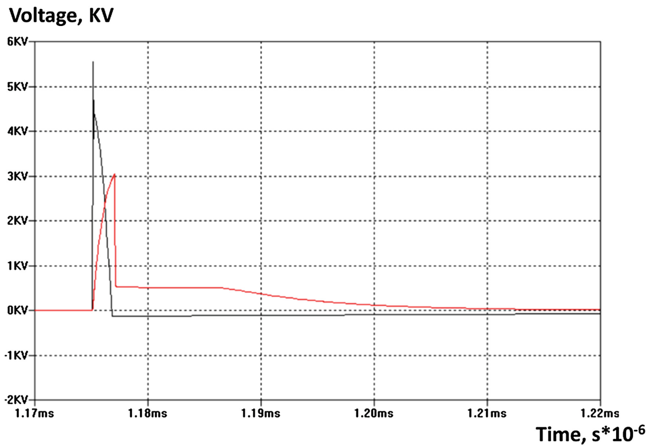

Fig. 11. Voltage at the control points B and C under conditions corresponding to the breakdown of the discharge gap.

In the practical realization of the device, it is managed to eliminate active electronic switch on the high voltage output of the pulse transformer and replace it with a diode-capacitor structure. A complexity of the structure of the corona discharge source control implemented microcontroller signals. In order to implement electronic switching polarity ionization source introduced four additional control signal. Two of them are submitted to the gates of the transistors, and allow for the accumulation of energy. Other control pulses supplied to another two gate keys, and allow to connect to a transformer capacitor corresponding to the selected polarity. The high-voltage circuit portion is modified so as to implement the passage of pulses of both polarities.

One of the criteria for the stability of the device is the stability of the current flowing through the needle when discharge corona is triggered. In the proposed circuit is made control the current flowing through a pulsed ionization source. The charge flowing through the discharge gap is transmitted across optocoupler to microcontroller for processing. Every act of tripping corona discharge leads to an equivalent change in the charge on the capacitor and the corresponding voltage.

Used diode optical pair is characterized by high speed and current coupling efficiency of about unity of the value of the input current. The photodetector type defines a linear transfer function of the optical pair. The resistor optocouplers is the most linear elements and thus suitable for use in analog devices, and then - optocouplers with foster photodiode or with a single bipolar transistor. A separate connection to bias the photodiode improves speed by several orders of magnitude compared with conventional optical pairs by reducing the capacitance of arrival at the base-collector of the input transistor.

In the proposed circuit is implemented control voltage on the storage capacitor. The signal from the divider to the input of the analog-digital converter is controlled by a microcontroller. The voltage divider is parallel connected, which reduces the signal by a coefficient of 19: 1. The signal from the divider to the input of the analog-digital converter is controlled by a microcontroller.

In the proposed circuit, when switching polarity is not required to turn off the device and mechanical switching of ionization polarity. Polarity selection is done each time the ionization source via switching control signals corresponding drives. Thus, the achieved reduction of the time required to switch between the ion mobility spectrometry modes between a few minutes (manual switching), up to one measurement cycle spectrogram, which is less than 100 ms. Given the technological limitations of the used components, the simulation circuit showed a substantial margin of the breakdown voltage in the secondary circuit of the pulse converter.

4 Conclusions

It is developed igniting electrical circuit for pulsed corona discharge ionization to operate a source as part of an ion mobility spectrometer. Modeling circuit is taking into account the technological limitations of the components used to optimize the circuit to prevent a breakdown in the secondary winding circuit of the transformer. The possibility of electronic switching of the primary winding and reverse polarity diodes in the high voltage part of the circuit provide operation of the corona discharge ion source for detection both positive and negative ions.

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