Electrostatic Ion Shutter with Ejecting Electrode as a Part of a Ion Mobility Spectrometer

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***Abstract* – In portable hand-held devices for trace explosive and narcotic detection the most perspective is use of a principle of ion mobility spectrometry [[1],[2]] owing to the best combination of cost, compactness, parameters of detection and a wide range of found out substances. Classical designs of a ion mobility spectrometer are represented by a set of the metal electrodes forming area with homogeneous longitudinal electric field, in a combination to an electric shutter and area of ionization to a source of ionization on the basis of a radioactive isotope. The extremely perspective problem is development of a compact not radioactive source of the ionization, allowing to generate ions both positive, and negative polarity and having low power consumption. The use pulse corona discharge as a source of ionization for a ion mobility spectrometer is represented to the most perspective. Application in a design of a pulse corona discharge ionization source allows, unlike systems with isotope ^{63}Ni ionization, to do without application of an electrostatic ion shutter which separates ionization and drift chambers. However application of an ion shutter allows to achieve the best parameters of resolution and sensitivity. In the given work the scheme of operation and results of application of an electrostatic ion shutter as a part of a ion mobility spectrometer with a pulse corona discharge ionization source will be considered.**

I. INTRODUCTION

One of basic elements of a design of a ion mobility spectrometer is the spectrometry cell consisting of two adjacent areas of ionization and drift, separated by an electrostatic ion shutter [[3]]. In a described ion mobility spectrometer the pulse (10 Hz) corona discharge ionization source has been applied. Application corona discharge allows to solve problems, characteristic for the radioactive sources of ionization most often applied in serial devices, and thus to provide good parameters on detection of substances.

II. ION MOBILITY SPECTROMETER WITH ELECTROSTATIC ION SHUTTER

Figure 1 represents the electrostatic ion shutter of Tundal type [[4]], consisting of two transparent grids from thin stainless steel, located on distance about 1 mm from each other, added with a ejecting electrode.

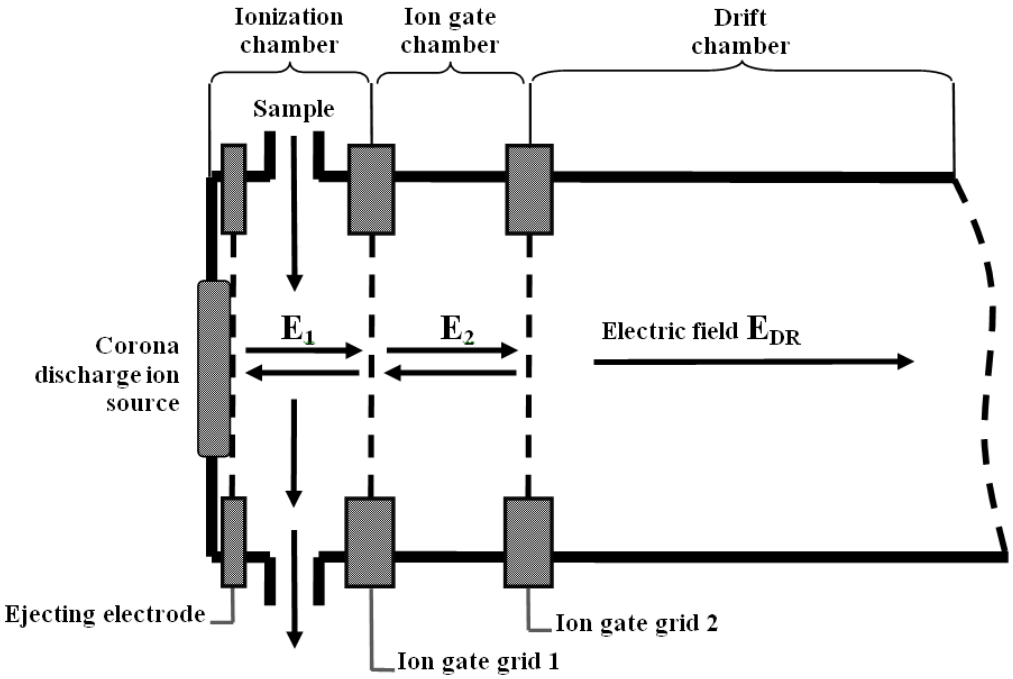

Figure 1. Eelectrostatic ion shutter with ejecting electrode.

Electric potentials on a ejecting electrode and on ion gate grid 1 change on commands of operating electronics that provides regulation of duration of a cumulate of ions in the ionization chamber and in ion gate chamber. The formed

ions get from ionization chamber to ion gate chamber with a certain delay. It leads to possibility to regulate duration of ion-molecular interaction in the ionization chamber. Work of electrostatic ion shutter with ejecting electrode during one cycle of measurement is divided into 7 consecutive phases (Figure 2):

- Phase 1 – switch on of field E_1 in the ionization chamber that corresponds to preparation for the beginning of a cycle of measurement. The end of this phase corresponds to the beginning of the corona discharge impulse.
- Phase 2 – under the influence of field E_1 there is a movement of ions, formed by corona discharge, from a ejecting electrode to ion gate grid 1.
- Phase 3 – the field in the ionization chamber E_1 becomes equal to zero, ions stop. In the stopped bunch there are ion-molecular reactions between molecules of investigated substance and formed by corona discharge reactant-ions. Sensitivity of a spectrometer can be raised by means of increase in duration of this phase at the expense of fuller transfer of a charge from reactant-ions to molecules of investigated substance.
- Phase 4 – moving bunch of ions to ion gate chamber.
- Phase 5 – under the influence of field E_1 in the field of ionization and E_2 in the field of ion gate ions are injected in drift area. Thus by means of an electrostatic shutter begins possible to inject a thin bunch of ions that essentially increases the resolution of a ion mobility spectrometer.
- Phase 6 – the direction of field E_2 changes on opposite, thus the electrostatic ion gate is closed. Remained in the ionization chamber ions under the influence of field E_1 move to ion gate grid 1 and will be neutralized on it.
- Phase 7 – the initial condition of electric potentials on ejecting electrode and ion gate grid 1 is restored. The system is prepared for a following cycle of measurement.

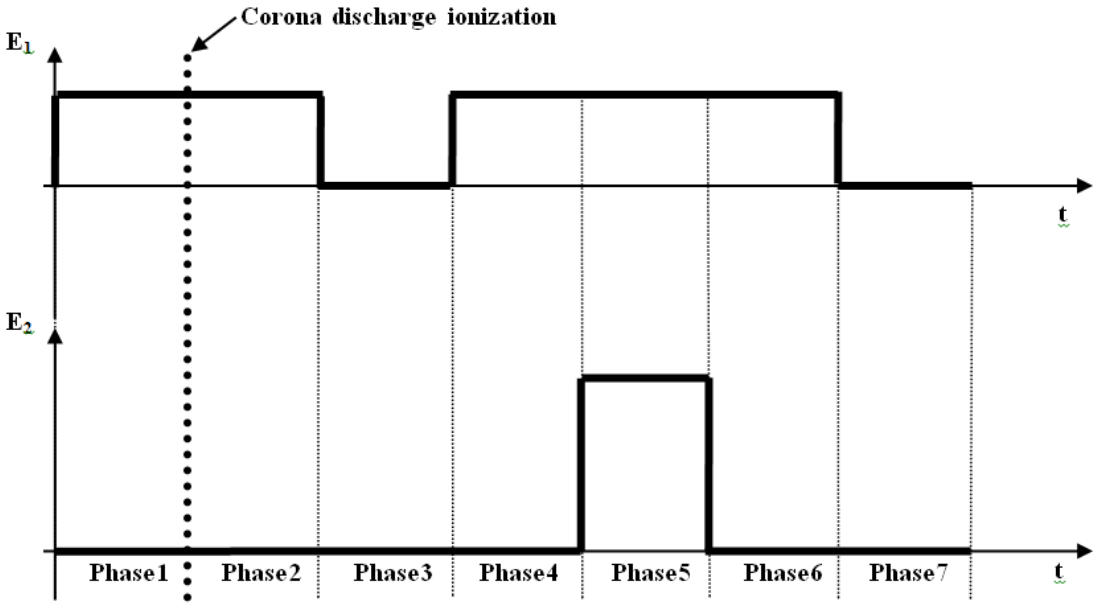

Figure 2. Distribution of fields in the ionization chamber E_1 and ion gate chamber E_2 during functioning of electrostatic shutters

In case of negative ions an increase in duration of the Phase 2 leads to a reduction of a total charge of ions. Thus the spectrum structure remains invariable. The total charge on a collector for negative ions is maximum at the minimum duration of the Phase 2. In case of positive ions at increase in duration of the Phase 2 leads to a reduction of amplitude of peaks of fast ions and increase in amplitude of peaks of slow ions. Thus, by means of an increase in duration of the Phase 2 it is possible to cut fast positive ions and to focus attention on slow ions that can be useful at detecting of ions of substances with low mobility. For positive ions the increase in size of the general charge is characteristic at increase in duration of the Phase 2 from 0 to 0,3 ms that is shown on Figure 3. Mobility of positive ions essentially below mobility negative, therefore doesn't occur falling of a charge because of neutralization of ions on the ion gate grid 1 at duration of the Phase 2 less than 0,3 ms. The increase in the common charge at this interval arises because of increase in cumulative time of injection of ions in drift chamber.

Also research of influence of time of injection of ions from ionization chamber in drift chamber (the Phase 5) has been conducted (Figure 4). During the given experiment the dynamic range of change of duration of injection of ions and influence of the given parameter on spectrograms in cases of positive and negative ions was investigated.

At work with negative ions the smooth increase in amplitude of peaks and the general charge of system is characteristic at increase in duration of injection of ions from ion gate chamber in drift chamber. Thus, the choice of duration of injection of ions in area of drift doesn't get essential influence on possibility of detecting of separate categories of the substances forming at ionization slow or fast ions, and is in a greater degree defined by resolution requirements. For this case value of saturation for fast ions of the Phase 5 equals 1,50 ms. At the further increase in the given parameter the increase in amplitude of peaks of fast ions doesn't occur, however the amplitude of peaks of slow ions considerably increases.

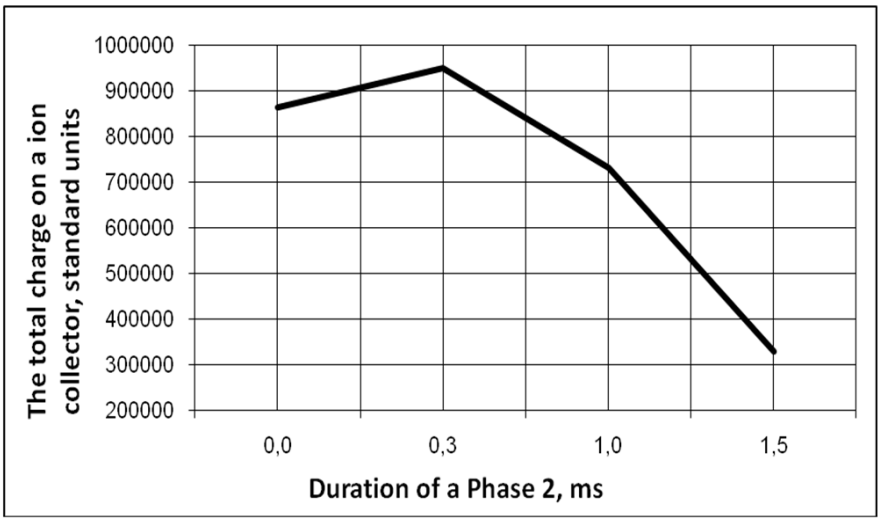

Figure 3. Dependence of a total charge on a ion collector at positive polarity depending on duration of the Phase 2 electrostatic ion shutter.

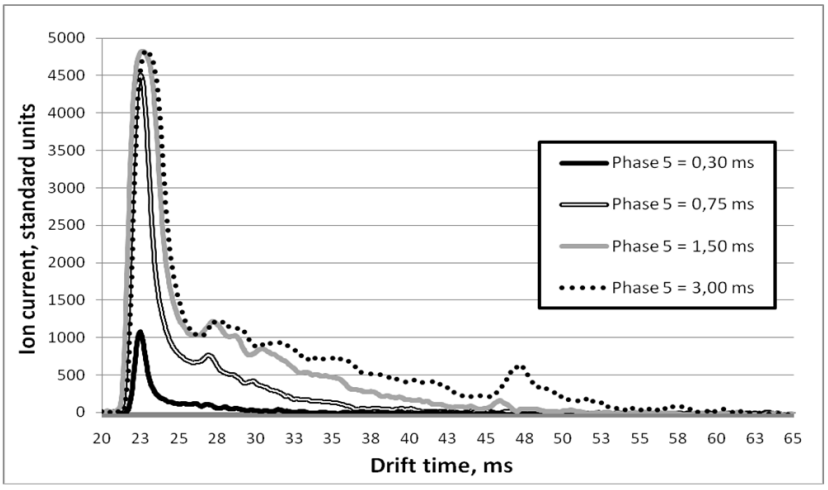

Figure 4. Comparative spectrograms of positive ions of laboratory air at change of the Phase 5 electrostatic ion shutter.

Thus, at detecting of some substances in positive polarity with the characteristic slow ions formed during ionization, the increase in duration of injection of ions from ion gate chamber in drift chamber (Phase 5) is necessary.

III. CONCLUSION

During work performance the scheme of an electrostatic ion shutter as a part of a ion mobility spectrometer with pulse corona discharge ionization source has been developed. In classical structure of an electrostatic ion shutter of Tundal type the ejecting electrode which is structurally a part of corona discharge ionization source has been added. Thus, possibility of regulation of duration of a finding of ions in ionization chamber has been entered during course of ionic-exchange reactions and time of passage of ions directly through an ionic shutter with possibility of allocation of a narrow clot of the ions getting in drift chamber. At an estimation of influence of the given structure of an electrostatic ionic shutter on detecting of ions it is shown that at detecting of positive ions it is required to establish more time of injection of ions from ion shutter area in drift area, than at detecting of negative ions.

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