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ION GENERATION BY TUNGSTEN FILAMENT FOR PYROELECTRIC PULSED ACCELERATOR

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The article is devoted to investigation of ion generation by tungsten filament in vacuum. Electron and ion currents from tungsten filament at different residual air gas pressures are measured and compared. Dependencies of ion and electron currents from tungsten filament on its supply voltage are measured. Production of ions in the vicinity of the filament is discussed. Prospects of tungsten filament's application in pyroelectric and piezoelectric pulsed accelerators are discussed.

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INTRODUCTION

In work [1], we experimentally demonstrated the possibility of X-ray generation at the operation of a pyroelectric accelerator in a pulsed mode in a vacuum. The implementation of pulsed generation became possible due to the use of a tungsten filament as an emitter of electrons. The flux of electrons from the filament was accelerated towards the positively charged surface of the pyroelectric crystal. Accelerated electrons produced intense X-ray generation for several seconds after turning on of the filament. To date a pulse X-ray generation is the most effective operation mode of pyroelectric accelerator [2]. In work [3] devoted to the investigation of properties of piezoelectric accelerator [4], the filament was used to increase the intensity of X-ray radiation. In our works [5, 6], we experimentally demonstrated the possibility of X-ray generation at the operation of ceramic piezoelectric transformer with filament in a vacuum. In these experiments, the tungsten filament emitted electrons and provided negative sinusoidal voltage on the high-voltage electrode of the piezoelectric transformer. However, back in 1901 in [7] E. Rutherford observed an ion current when a metal wire was heated at low air pressure (see also [8]). To clarify the possible role of ion generation by a filament in pyroelectric and piezoelectric accelerators, the experiment on the observation of the ion current from the filament and comparison the ion current with the electron current in the opposite accelerating field was carried out.

1. EXPERIMENT

Fig. 1 shows a diagram of the experimental setup. A tungsten filament (1) from a flashlight bulb with a glass bulb removed was located in the vacuum chamber (6). The filament (1) was supplied by the controlled DC current source (4). An isolated from the ground copper electrode (2) was installed against the tungsten filament, connected to the positive (see Fig. 1,a) or negative (see Fig. 1,b) pole of block of 9-volt batteries (5). This design of the power supply (5) was used in order to minimize leakage currents. A picoammeter (3) was connected sequentially to the electrical circuit of the copper electrode (2) to measure the current of charged particles from the tungsten filament.

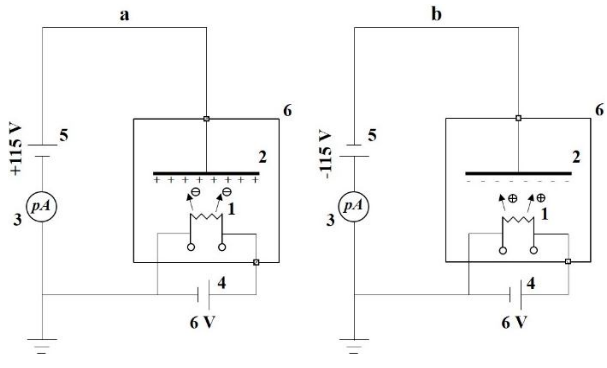

Fig. 1. Schematic diagram of the experimental setup: a – measurement of electron current; b – measurement of ion current from tungsten filament

At the first phase of experiment, we measured the dependence of the electron and ion current on the residual gas pressure during the operation of a tungsten filament in a vacuum chamber. Initially, measurements of the electron current were carried out at various pressures of the residual gas. A positive potential +115 V was applied to the copper electrode. A voltage 6 V was applied to the filament that lead to electron emission from the filament. The electrons were accelerated in an electric field between the filament and the copper electrode. The arrival of accelerated electrons to positively charged electrode provided a current in the electrical circuit. In this case, the pico-ammeter measured a negative current value.

When the negative potential -115 V was applied to the copper electrode and the same voltage 6 V was applied to the filament, the pico-ammeter measured positive current. This means that positively charged ions are produced in the vicinity of the filament. Theses ions accelerate in the electric field toward the copper electrode and provide the current in the circle, as well as described in [7, 8]. The results of both measurements are shown in Fig. 2.

At the second phase of the experiment, the dependence of the currents of electrons and ions on the supply voltage (in the range from 0.5 to 6 V with a step of 0.5 V) of the tungsten filament was measured at fixed residual gas pressure in the vacuum chamber of 5 mTorr. The results of the measurements are shown in Fig. 3.

2. RESULTS AND DISCUSSION

From Fig. 2 one can see, that maximum value of the electron current of 26 μA, generated during the operation of a tungsten filament in a vacuum, is observed at a residual gas pressure of $2 \cdot 10^{-6}$ Torr. At increasing of pressure to 8 mTorr, a decrease in the electron current to 6 μA is observed.

The opposite situation is observed with the dependence of the ion current on the residual gas pressure. Ion current increases from almost zero value to 9 nA at increasing of the residual gas pressure from about 10^{-4} Torr to 8 mTorr.

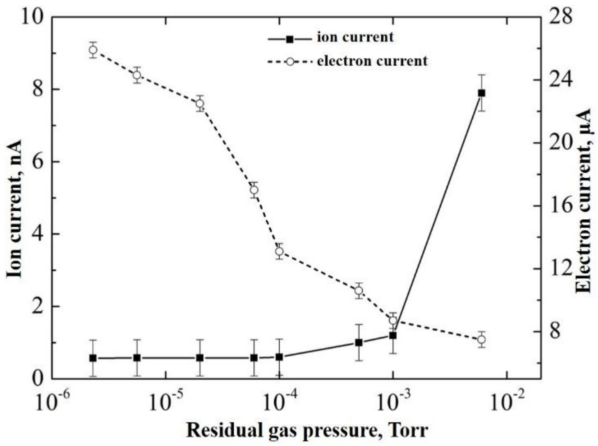

Fig. 2. Measured dependencies of electron and ion currents on residual gas pressure

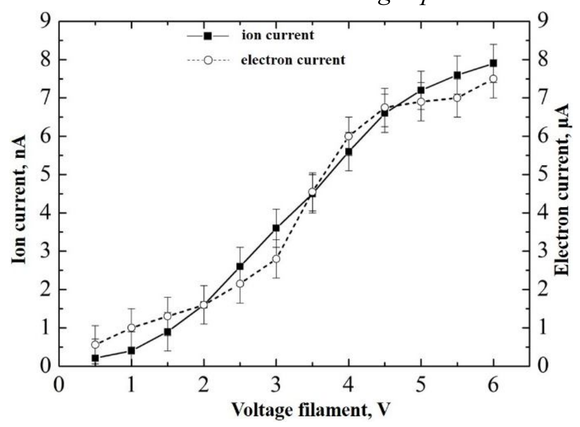

Fig. 3. Measured dependencies of electron and ion currents on filament supply voltage

From Fig. 3 one can see that almost linear increase in both currents of electrons and ions from the filament in vacuum at fixed residual gas pressure of 5 mTorr is observed with an increase in its supply voltage from 0.5 to 6 V. An increase in the supply voltage of the filament leads to an increase in its temperature. The number of ions is about 10^{-3} per electron in a wide range of supply voltage and temperatures of the filament.

CONCLUSIONS

The ion current was experimentally observed at operation of a tungsten filament in vacuum. We found, that tungsten filament produces not only electrons but also positive ions. The number of ions is about 10^{-3} per electron at the residual air gas pressure 5 mTorr and this number is practically independent of the filament temperature. The independence of this number on the filament temperature means that we observe the current of ions of the residual gas, not the tungsten ions. Probably, ions of the residual gas are produced in the vicinity of the filament by electrons emitted from the filament.

Obtained results allow us to speak about the prospects for using of the filament as a source of electrons and positive ions in piezoelectric and pyroelectric accelerators. Such sources can operate in quasi-continuous or in pulsed mode of accelerators during a cycle of thermal or mechanical action on pyroelectric or piezoelectric elements respectively in a vacuum.

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ГЕНЕРАЦИЯ ИОНОВ ВОЛЬФРАМОВОЙ НИТЬЮ ДЛЯ ПИРОЭЛЕКТРИЧЕСКОГО ИМПУЛЬСНОГО УСКОРИТЕЛЯ

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Статья посвящена исследованию генерации ионов вольфрамовой нитью накала в вакууме. Измерены и сравнены токи электронов и ионов от вольфрамовой нити накала при различных давлениях остаточного воздушного газа. Измерены зависимости ионного и электронного токов от нити накаливания и ее напряжения питания. Обсуждаются образование ионов в непосредственной близости нити накаливания. Обсуждаются перспективы применения вольфрамовой нити накала в пироэлектрическом и пьезоэлектрическом импульсных ускорителях.

ГЕНЕРАЦІЯ ІОНІВ ВОЛЬФРАМОВОЮ НИТКОЮ ДЛЯ ПІРОЕЛЕКТРИЧНОГО ІМПУЛЬСНОГО ПРИСКОРЮВАЧА

О.О. Іващук, А.В. Щагін, А.С. Кубанкін, Є.В. Болотов, В.С. Мірошнік, В.І. Волков, Ю.В. Грігорьєв

Стаття присвячена дослідженню генерації іонів вольфрамовою ниткою розжарення у вакуумі. Виміряні та порівняні струми електронів та іонів від вольфрамової нитки розжарення при різних тисках залишкового повітряного газу. Виміряні залежності іонного і електронного струмів від нитки розжарювання та її напруги живлення. Обговорюються утворення іонів у безпосередній близькості нитки розжарювання. Обговорюються перспективи застосування вольфрамової нитки розжарення в піроелектричному і п'єзоелектричному імпульсних прискорювачах.