INVESTIGATIONS OF THERMO-IONIC EMITTERS OF HEAVY ALKALI METALS FOR DIAGNOSTIC INJECTOR OF "URAGAN-2M" STELLARATOR

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The results of solid-state thermo-ionic emitters of Cs^+ and Tl^+ ions investigations are presented. These emitters are planned to use in heavy ion beam diagnostic system for "Uragan-2M" stellarator. According to estimations for HIBP diagnostic system operations it is necessary to have primary beam current up to 0.5 mA. The aim of these investigations was determination of emission rate, mass-spectrum of ion beam during the beam extraction time and heavy ion beam current stability in area of 0.5 mA.

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1. INTRODUCTION

The HIBP diagnostic system for "Uragan-2M" has been developed in 2009[1]. Numerical modeling of trajectories of passage of a probing beam has shown that for installation with parameters "Uragan-2M" it is necessary to use primary beam Cs^+ or Tl^+ with an ion current to 0.5 mA. The purpose of the spent researches is determination of emission rate and a mass spectrum of an ion beam, stability of its parameters at a ion current to 0.5 mA.

2. EXPERIMENTAL SET-UP

The investigations were carried out at the emitter manufacturing and testing device [2]. Beam energy was up to 6 keV, ion current up to 1 mA. The device permits to measure the ion beam current and mass-spectrum. Emitters were manufactured from following materials – doped sodium zeolite for thallium emitters and natural mineral pollux or mixture based on $CsNO_3$ for cesium emitters. Fig. 1 shows a general view of cesium emitters. Emitter were baked on tantalum base with 0.2…0.3 mm thickness. The base has a diameter of 8 mm and allow baking 150 mg of emitter material. A power of emitter heater is up to 250 W.

*Fig. 1. Cesium ion emitters: Left up – pollux emitter after preparation, right bottom – emitter after 1.5 mA*hour operation*

3. EXPERIMENTAL RESULTS

A. Cesium emitters

Investigations of an emission rate was carried out with extracting voltage up to 6 kV and emitter – extractor gap 10…15 mm. Emitter was placed inside of Pierce electrode (60^0 cone with 13 mm aperture), extractor electrode was also conical (45^0 with 22 mm aperture). Emitter heating power was up to 140 W. Fig. 2 illustrated cesium ion current depending on heating filament current. Emitter was manufactured from mineral pollux [5]. One can see current saturation areas for different extracting voltage from 2 to 4 kV with heating power more than 100 W.

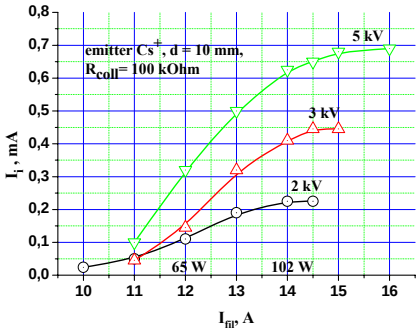


Fig. 2. Ion current value in saturation area limited by Chaild-Langmuir law

It was applied time-of-flight method for investigations of ion flux mass-spectrum. We use the generator G5-63 with pulse amplitude of 60 V and duration of 50 μs. This voltage was applied to extractor electrode, emitter potential varied from 100 to 600 V. Fig. 3 illustrated the beam mass-spectrum with emitter heating power 65 and 85 W. It was registered up to 20% of impurities (sodium and potassium ions due to time of flight) for low heating power. Sodium and potassium impurities placed in natural pollux. A pollux may has these alkali metals up to 30% in its structure.

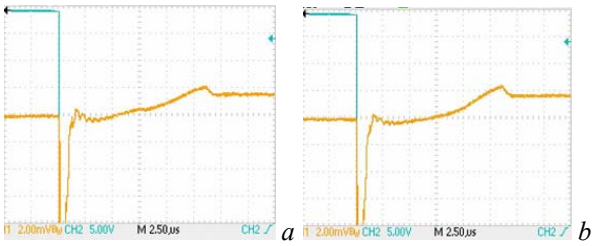


Fig. 3. The beam mass-spectrum, emitter heating power is: a) 65 W, b) 85 W; U_{extr}= 250 V, d = 15 mm

Emitter was tested for its ion resource with extracting voltage 5 kV and extracting ion current 0.5 mA. Emitter heating power was increased time to time in order to have a stable ion current during all testing time. Ion current extracting has 3 hour duration, initial heating power was 70 W, finish power – 130 W. Full extracted ion resource was 1.5 mA*hour. Further emitter exploitation in diagnostic injector will be inexpediently due to too high emitter heating power that leads to worsening of injector vacuum conditions.

It was done the work in order to manufacture a composite emitter from $CsNO_3$, Al_2O_3, SiO_2 in the frame of cesium emitters investigations. Composite emitter has better adhesion to the metal base than pollux material, 100% pure mass-spectrum and high emission rate. Fig. 4 illustrated ion current depending on extracting voltage of composite emitter after its manufacturing.

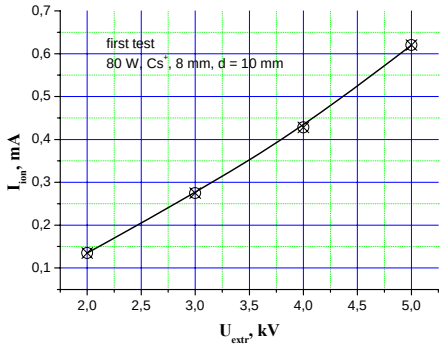


Fig. 4. Ion current depending on extracting voltage of composite emitter

This emitter resource (90 mg of initial material) was 1.1 mA*hour. Testing operations were the same as described above instead of more heating power. Initial power was 80 W, finish power – 170 W. In comparison with pollux emitter this one has less resource, needs more heating power but has 100% pure ion flux and may be manufactured from accessible components. Work on optimization of this emitter composition is not finished yet.

B. Thallium emitters.

Substituted sodium zeolite was used for thallium thermo-ion emitters manufacturing. $TlNO_3$ water solution was used for its purpose. The emitter base was manufactured from molybdenum or tantalum, the diameter of emission area was also 8 mm, initial mass of emitter material – up to 100 mg. Thallium emitters investigations were carried out in the same conditions as cesium emitters. Fig. 5, 6 illustrated thallium ion current dependences on extracting voltage: Fig. 5 – after emitter manufacturing, Fig. 6 – after extracting of 0.3 mA*hours. After extracting of 0.3 mA*hours the emission rate is decreases to 80% of initial rate with heating power conservation, after 0.6 mA*hours emission rate drops in several times. Exact estimation of emission rate decreasing – 3.5 times, was done during mass-spectrum measurements (with fixed 100 W heating power and 400 V extracting voltage).

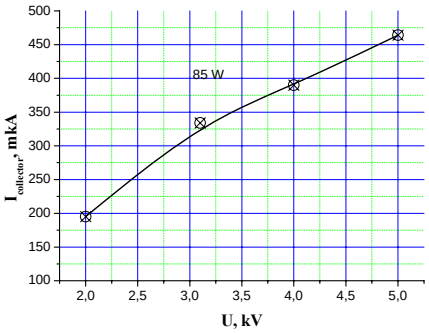


Fig. 5. Emission rate measurements after emitter manufacturing

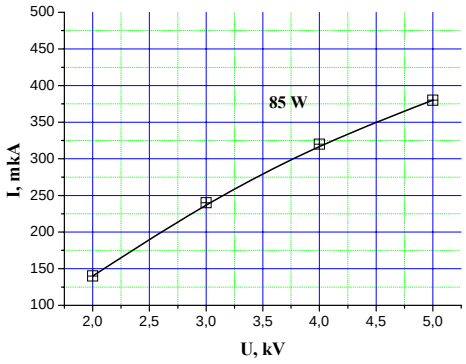
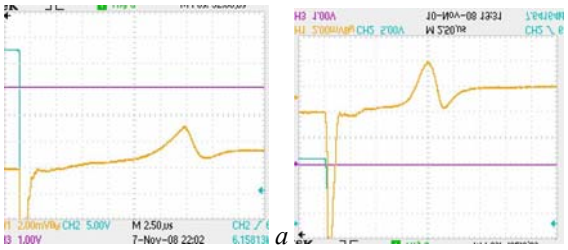


*Fig. 6. Emission rate measurements after extracting of 0.3 mA*hours*

After extracting of 0.5 mA*hours resource one needs to increase the heating power to 150 W in order to have the initial level of extracting current.

Fig. 7 illustrated thallium beam mass-spectra with different extracting voltage.

Fig. 8 illustrated the mass-spectrum of Tl^+ beam for less emitter-extractor distance and corollary of higher ion current level. One can see that impurities (Na^+ and K^+) have 20…25% level.



a *b*

Fig. 7. Thallium beam mass-spectra:
a) heating power 65 W, U_{extr}= 250 V, d = 12 mm,
b) heating power 65 W, U_{extr}= 600 V, d = 12 mm

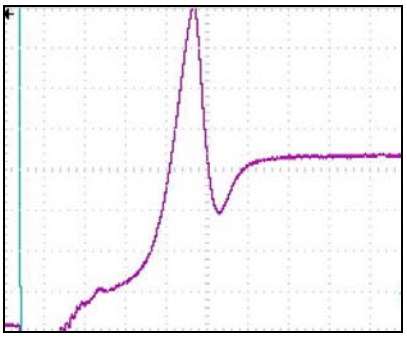


Fig. 8. Mass-spectrum with heating power 75 W, U_{extr}= 600 V, d = 5 mm

As one can see from above results that after the extraction of 0.6 mA*hours the emitter operation with 0.4…0.5 mA ion current will require heating power up to 150 W. This power will lead to serious worsening of injector vacuum conditions and expediently will be to replace the emitter.

CONCLUSIONS

The results of this work show that heavy ion thermo-emitters elaborated in NSC KIPT are suitable for operations in rated ion current mode in primary beam injector of HIBP diagnostic system at "Uragan-2M" stellarator.

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ИССЛЕДОВАНИЕ ТЕРМОИОННЫХ ЭМИТТЕРОВ ТЯЖЕЛЫХ ЩЕЛОЧНЫХ МЕТАЛЛОВ ДЛЯ ИНЖЕКТОРА ДИАГНОСТИЧЕСКОГО КОМПЛЕКСА СТЕЛЛАРАТОРА «УРАГАН-2М»

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Представлены результаты исследований твердотельных термоэмиттеров тяжелых ионов Cs^+ и Tl^+. Данный тип эмиттеров планируется использовать в диагностическом комплексе на стелларатоpе «Ураган-2М». Согласно проведенным расчетам, для работы диагностического комплекса необходима величина первичного тока ионов порядка 0.5 мА. Целью исследований было определение эмиссионной способности эмиттера, массового спектра потока ионов в процессе отбора тока и стабильности величины тока ионов тяжелых металлов в режиме 0.5 мА.

ДОСЛІДЖЕННЯ ТЕРМОІОННИХ ЕМІТЕРІВ ВАЖКИХ ЛУЖНИХ МЕТАЛІВ ДЛЯ ІНЖЕКТОРА ДІАГНОСТИЧНОГО КОМПЛЕКСУ СТЕЛЛАРАТОРА «УРАГАН-2М»

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Представлено результати досліджень твердотілих термоемітерів важких іонів Cs^+ та Tl^+. Цей тип емітерів планується використати у діагностичному комплексі на стелларатоpі «Ураган-2М». Згідно з проведеними розрахунками для роботи діагностичного комплексу на пучках важких іонів необхідна величина первинного струму біля 0.5 мА. Метою досліджень було визначення емісійної здатності емітерів, масового спектру потоку іонів у процесі відбору струму та стабільності величини струму іонів важких металів у режимі 0.5 мА.