ISBN: 978-3-95450-226-4 ISSN: 2222-5692 doi:10.18429/JACoW-ECRIS2020-WEXZO05

PRODUCTION OF METAL ION BEAMS FROM ECR ION SOURCE

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Abstract

The paper describes the production of metal ion beams from ECR ion sources by the MIVOC (Metal Ions from Volatile Compounds) method. The method is based on the use of volatile metal compounds having high vapor pressure at room temperature: for example, $Cr(C_5H_5)_2$, $(CH_3)_5C_5Ti(CH_3)_3$ and several others. Using this method, intense beams of chromium, titanium, iron, and other ions were obtained at the U-400 FLNR JINR and DC-60 cyclotrons (Astana branch of the INP, Alma-Ata, Kazakhstan Republic).

PRODUCTION OF METAL IONS FROM ECR ION SOURCE USING THE MIVOC METHOD

This method is based on the use of organometallic compounds having a relatively high vapor pressure (10^{-3} Torr) at room temperature. Such a vapor pressure is sufficient for the operation of the ECR ion source with corresponding conductivity of the feed line [1].

The necessary preparation of the substance is performed depending on the chemical properties of each compound. For example, titanium and nickel compounds are prepared in an argon box under a red light, both substances are afraid of air, humidity and light. Whereas, the iron compound can be placed into container in air. After preparation all containers with compounds are pumped to the forevacuum, and connected to the ECR ion source through a mechanical or automatic valve for supplying substances [2].

THE CYCLOTRON U-400 OF FLEROV LABORATORY NUCLEAR REACTION (JINR, RUSSIA)

The cyclotron U-400 is designed for production of accelerated ion beams of atomic mass in the range A=4 ÷ 209 and energy 3 ÷ 29 MeV/nuclon. U-400 isochronous cyclotron has been in operation since 1978 [1]. Cyclotron is 4 m in diameter, D=4 m, with K=650 energy factor. Charge exchange technique is used for beam extraction. Axial injection channel with external ion source has been in operation at U-400 since 1996. An ECR ion source ECR-4M is installed at the U-400 cyclotron [3]. Ion source ECR-4M was modernized to improve its performance: higher magnetic field in the injection region; new hexapole; the increase of the discharge chamber from 64 to 74 mm; direct UHF injection.

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BEAMS OF METAL IONS FROM ECR-4M ION SOURCE AT THE CYCLOTRON U-400

At the U-400 cyclotron, stable beams of metal ions were produced by the MIVOC method for various research areas:

- ^{52}Cr, ^{56}Fe – study of fusion-fission processes, quasi-fission and multi-nucleon transfer reactions
- ^{54}Cr, ^{50}Ti – alpha, beta and gamma spectroscopy of isotopes of heavy and super heavy elements
- ^{56}Fe – study of reactions with beams of stable and radioactive nuclides leading to the formation of exotic nuclei

Figures 1-4 show the spectra of chromium, titanium and iron ions at the U-400 cyclotron.

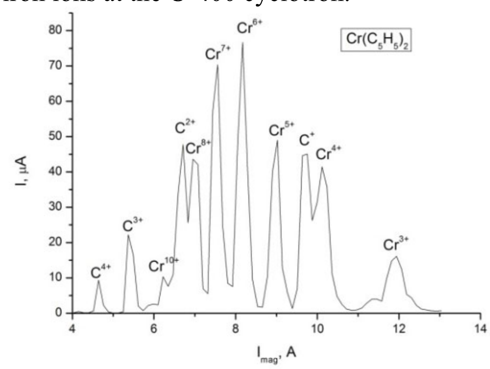

Figure 1: The spectrum of ^{52}Cr ions, the source settings are optimized for $^{52}Cr^{6+}$ – 74 µA. UHF power – 49 W.

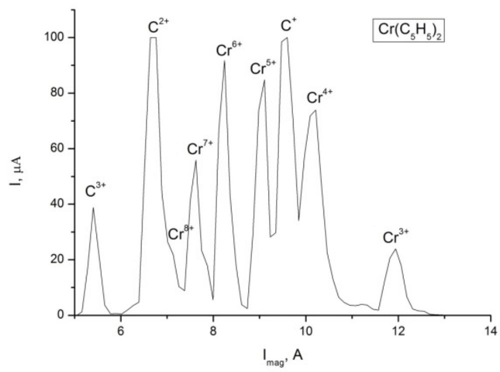

Figure 2: The spectrum of ^{54}Cr ions, the source settings are optimized for $^{54}Cr^{6+}$ – 95 µA. UHF power – 58 W.

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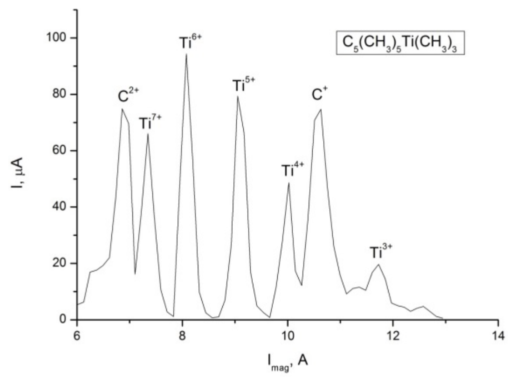

Figure 3: The spectrum of ^{50}Ti ions, the source settings are optimized for $^{50}Ti^{5+}$ – 78 μA. UHF power – 51 W.

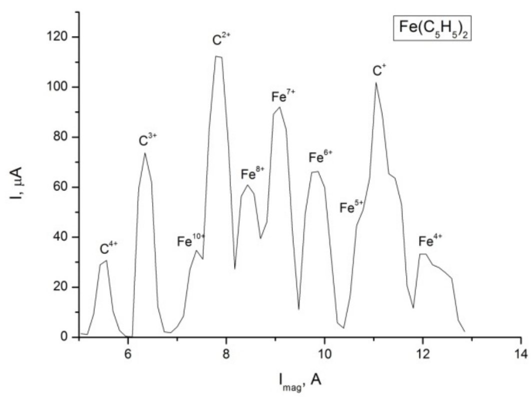

Figure 4: The spectrum of ^{56}Fe ions, the source settings are optimized for $^{56}Fe^{7+}$ – 90 μA. UHF power – 65 W.

THE ACCELERATOR COMPLEX DC-60 OF ASTANA BRANCH OF THE INP (ALMA-ATA, KAZAKHSTAN REPUBLIC)

The cyclotron DC-60 is designed for production of accelerated ion beams of atomic mass in the range A=4 ÷ 132 and energy 0,35 ÷ 1,7 MeV/nuclon [4]. Main objectives: scientific research; education; production of track membranes with special properties; creation of micro and nano structures; surface modification of standard materials, creation of new materials with required properties. The cyclotron is equipped with the ECR ion source DECRIS-3 [5].

Beams of ions of titanium ($(CH_3)_5C_5Ti(CH_3)_3$), chromium ($Cr(C_5H_5)_2$), cobalt ($Co(C_5H_5)_2$), nickel ($Ni(C_5H_5)_2$), iron ($Fe(C_5H_5)_2$), germanium ($Ge(CH_3)_4$) and hafnium ($(C\text{-}_5H_5)_2Hf(CH_3)_2$) after preliminary preparation were produced by the MIVOC method of the DECRIS-3 ion source at the DC-60 cyclotron shown in Figs. 5-11.

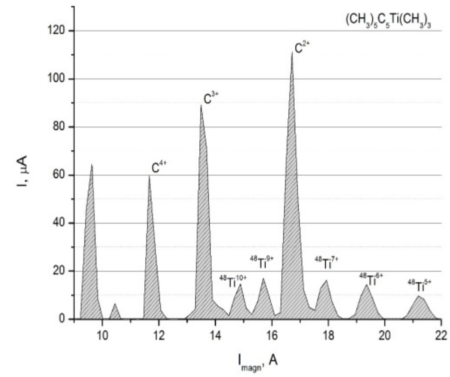

Figure 5: The spectrum of Ti ions, the source settings are optimized for $^{48}Ti^{9+}$ - 18 μA. UHF power – 156 W.

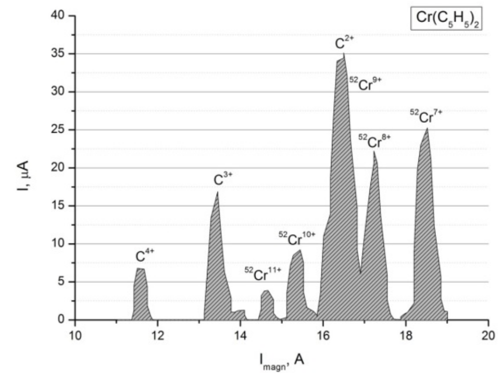

Figure 6: The spectrum of Cr ions, the source settings are optimized for $^{52}Cr^{10+}$ - 9 μA. UHF power – 72 W.

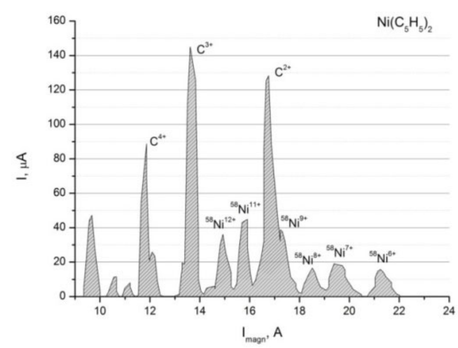

Figure 7: The spectrum of Ni ions, the source settings are optimized for $^{58}Ni^{11+}$ - 43 μA. UHF power – 260 W.

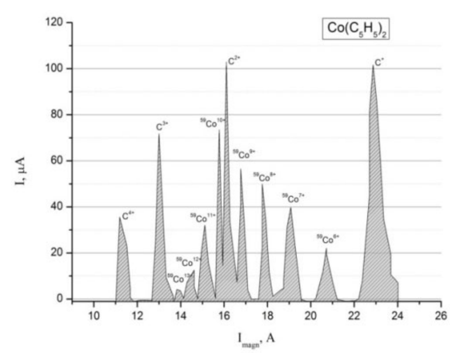

Figure 8: The spectrum of Co ions, the source settings are optimized for $^{59}Co^{12+}$ - 12 μA.

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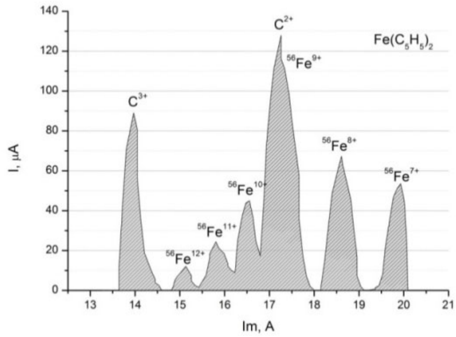

Figure 9: The spectrum of Fe ions, the source settings are optimized for $^{56}Fe^{10+}$ – 44 µA. UHF power – 120 W.

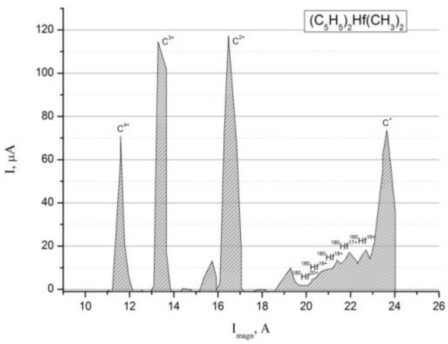

Figure 10: The spectrum of Hf ions, the source settings are optimized for $^{180}Hf^{17+}$ - 19 µA. UHF power – 230 W.

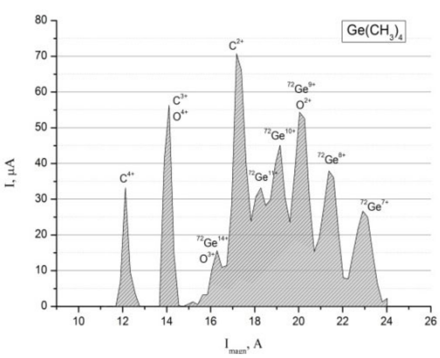

Figure 11: The spectrum of Ge ions, the source settings are optimized for $^{72}Ge^{10+}$ - 46 µA. UHF power – 270 W.

CONCLUSION

The main goal of this work was to employ the MIVOC method for production of ions of solid and extend the spectrum of accelerated ions at the FLNR cyclotrons and at the DC-60 cyclotron. With the expansion of the spectrum of accelerated elements, it becomes possible to set up new experiments in the field of experimental nuclear physics, radiation solid state physics, and various applied problems, which makes the research objective particularly relevant. As a result of the work done, for the first time at the DC-60 cyclotron, the modes of obtaining ion beams $^{48}Ti^{9+}$, $^{58}Ni^{11+}$, $^{59}Co^{12+}$ and $^{52}Cr^{10+}$ were worked out for the first time.

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