PRODUCTION OF INTENSE METAL ION BEAMS FROM ECR ION SOURCES USING THE MIVOC METHOD

A. E. Bondarchenko, S. L. Bogomolov, K.I. Kuzmenkov, V.N. Loginov, V.Ya. Lebedev,
JINR, Dubna, Moscow Region, Russia
Z. Asfari, B. JP. Gall, IPHC, Strasbourg Cedex 2, France

Abstract

The production of metal ion beams by electron cyclotron resonance (ECR) ion sources using the MIVOC (Metal Ions from Volatile Compounds) method [1] is described. The method is based on the use of metal compounds which have high vapor pressure at room temperature, e.g., $C_2B_{10}H_{12}$, $Fe(C_5H_5)_2$, etc. Intense ion beams of B and Fe were produced using this method at the FLNR JINR cyclotrons. Experiments on the production of cobalt, chromium, vanadium, germanium, and hafnium ion beams were performed at the test bench of ECR ion sources.

Main efforts were put into production and acceleration of ^{50}Ti ion beams at the U-400 cyclotron. The experiments on the production of Ti ion beams were performed at the test bench using natural and enriched compounds of titanium $(CH_3)_5C_5Ti(CH_3)_3$. All these efforts allowed the production of accelerated titanium and chromium ion beams at the U-400 cyclotron.

PRODUCTION OF METAL IONS USING THE MIVOC METHOD

The experiments on the production of chromium, cobalt, vanadium, nickel, and hafnium ion beams were performed using the DECRIS-2m (Dubna ECR ion source) source [2] installed at the test bench. Natural compounds $Cr(C_5H_5)_2$, $Co(C_5H_5)_2$, $V(C_5H_5)_2$, $Ni(C_5H_5)_2$, and $(C_5H_5)_2Hf(CH_3)_2$ were used as working substances. For the production of germanium ions, two compounds were tested, i.e., tetraethylgermane $Ge(CH_2CH_3)_4$ and tetramethylgermanium $Ge(CH_3)_4$. Experiments with tetramethylgermanium yielded better results. The results obtained at the test bench are presented in Table 1.

Table 1. The intensity (eμA) of metal ion beams produced at the test bench using the MIVOC method (* - intensity optimisation)

Z	5+	6+	7+	8+	9+	10+	11+	12+	13+
Fe		43	93	125	172	145*	114	73	45
Co		57	80	86	98		82*	25	
Cr	50	70*	60	37	17	7			
V	75*	54	41	54	55.5*	43	34	19.5	
Ni		45*	43	48	53*		30	10	
Ge			43*	54		47*			
Z	13+	14+	16+	17+	18+	19+	20+		
Hf	31	45	50*	45*	36	27	17		

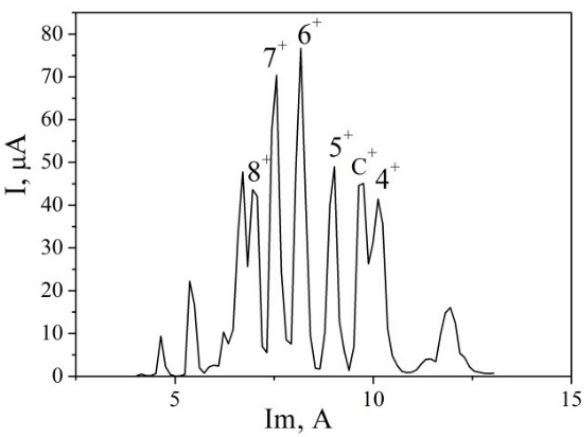

Figure 1. Charge spectrum of chromium ions produced by the ECR4M source.

After the tests ^{48}ti and ^{52}cr ions were accelerated at the u-400 cyclotron for the experiments on fission physics using the $c_5(ch_3)_5ti(ch_3)_3$ and $cr(c_5h_5)_2$ compounds as a working substances. the stable beams of ti^{5+} and cr^{6+} were produced during three weeks experiments.

Figure 1 shows charge state distribution of chromium ion beam, obtained after the bending magnet of the axial injection system of the u-400 cyclotron, source settings being optimized for the production of cr^{6+}.

ISBN 978-3-95450-181-6

PRODUCTION OF TITANIUM ION BEAMS

Major progress in the titanium-50 beam production was achieved through collaboration between IPHC (Strasbourg, France) and FLNR JINR.

Following several years of developments in chemistry carried out at IPHC, the $C_5(CH_3)_5Ti(CH_3)_3$ compound was synthesized using 92.57% enriched ^{50}Ti. Two-step chemistry was done with quite high efficiency from $TiCl_4$ to $C_5(CH_3)_5Ti(CH_3)_3$ through an intermediate $C_5(CH_3)_5TiCl_3$ organic compound.

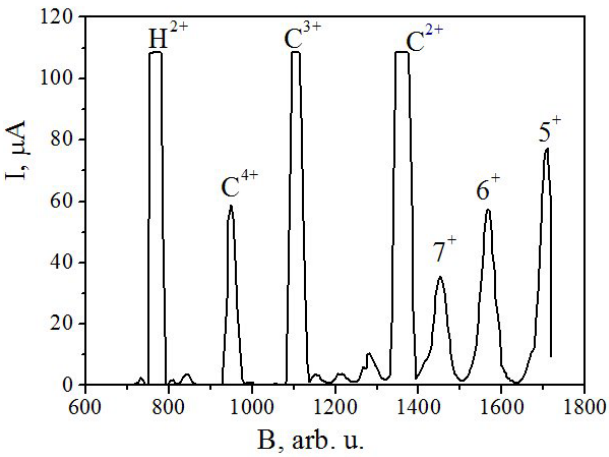

Figure 2. Charge spectrum of titanium ions produced in the ECR4M source using the MIVOC method at the microwave power of 20 W

In long-term experiments at the test bench several samples of compounds and different methods of material feeding into the source were tested. The beam currents of Ti^{5+} - 80 mkA and Ti^{11+} - 70 mkA (Fig. 2,3) were achieved at different settings of the source.

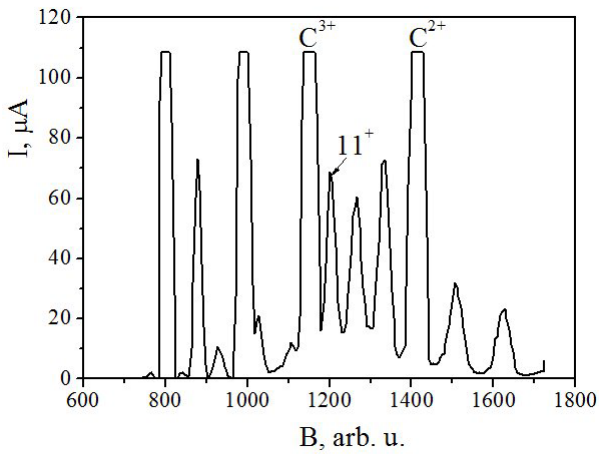

Figure 3. Charge spectrum of titanium ions produced in the ECR4M source using the MIVOC method at the microwave power of 300 W

Following successful tests, in October 2013 the first 3-week run was performed with ^{50}Ti beams at the U-400 cyclotron aimed to perform experiments on the spectroscopy of super heavy elements [3]. The intensity of the injected $^{50}Ti^{5+}$ beam was 50–60 μA. The source worked stably during experiment. The compound consumption rate was determined at about 2.4 mg/h, which corresponded to the ^{50}Ti consumption of 0.6 mg/h.

Since that, next three runs with ^{50}Ti beams were performed at the U-400 cyclotron. The durations of runs were from three to six weeks. The intensity of the ^{50}Ti beam and compound consumption were similar to those in the first run. Typically, the container with about 850 mg of compound allows the non-stop operation of the source during two weeks.

Table 2 summarizes the results of the titanium ion beam production at different laboratories using the MIVOC method (JYFL, GANIL, FLNR) and oven technique (GSI, ANL, IMP).

Table 2. The intensity (eμA) of titanium ion beams produced at different laboratories using the MIVOC[(a)] and oven[(b)] methods.

	JYFL[(a)]	GANIL[(a)]	FLNR[(a)]	GSI[(b)]	ANL[(b)]	IMP[(b)]
$^{48}Ti^{5+}$			79			
$^{48}Ti^{10+}$		20				
$^{48}Ti^{11+}$	45		68			24
$^{50}Ti^{5+}$			82			
$^{50}Ti^{8+}$				50		
$^{50}Ti^{11+}$	20					
$^{50}Ti^{12+}$					5.5	

ISBN 978-3-95450-181-6

CONCLUSION

Over the past few years, notable results and significant progress have been achieved in the production of intense multiply charged metal ion beams in ECR ion sources using the MIVOC method.

The MIVOC method was successfully used for producing and accelerating titanium-50 ion beam at the U-400 cyclotron. This method helps produce intense ion beams, provides long-term stability and is promising for experiments on synthesis of superheavy elements.

REFERENCES

[1] H. Koivisto, J. Arje, M. Nurmia, Rev. Sci. Instrum., 69, (2). 1998, p. 785–787.

[2] V.N. Loginov et al., Nukleonika 2003, Volume 48(Supplement 2), p. S853–6 S88

[3] A.V. Yeremin et al. Part. Nucl. Letters, 2015 V. 12, N1 (192), p.74 – 80.

ISBN 978-3-95450-181-6