

Development of MIVOC beams for the ECR2 ion source

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This year, the development of metal ions beams produced with the Metal Ion Volatile Compounds (MIVOC) method [1] continued. The MIVOC method consists of introducing a molecular compound containing a metal atom into the ion source and then ionizing the metal to produce beam. The advantages of MIVOC are that the metal ion beams can be produced at medium to high intensity at near room temperature without the need for an oven, and the MIVOC fixtures are easy and fast to reload, if necessary, during the course of an experiment. Another advantage is that the preparation time for the MIVOC vs. the conventional oven method is much faster. The disadvantages of MIVOC are that the compounds are difficult to prepare and transport (although many of them are available commercially) and the carbon from the molecules pollutes the ion source over time. This carbon contamination degrades the ability of the ion source to produce high charge states. Despite the disadvantages, the MIVOC method has been shown to work well for a variety of metal ion beams [1].

The MIVOC method can be used to produce many metal ion beams for the transition and rare-earth metals that would otherwise require a high-temp oven. To date, titanium beam with the compound (Trimethyl)pentamethylcyclopentadienyltitanium(IV) (Cp^*TiMe_3) and iron beam with the compound Ferrocene ($(\text{C}_5\text{H}_5)_2\text{Fe}$) have been produced at the Cyclotron Institute. Boron beam has been produced with m-Carborane. Vanadium, nickel, and chromium beams are also possible with MIVOC and may be tried here in the future.

The setup for MIVOC is as follows, as advised by Professor B. Gall. About 0.5g-2g of MIVOC compound, usually in the form of a fine powder, is placed into a glass vial. The vial is connected to a calibrated gas dosing valve, such as the Pfeiffer EVN 116. The dosing valve is then connected to a flange mounted on the side of the ECR ion sources. The glass vial is isolated from the ion source high voltage. A custom Peltier cooler and control box, also provided by Professor B. Gall and the University of Strasbourg, can be mounted to the glass vial to control the temperature and thus allows control of the vaporization rate of the material. A picture showing the setup for the MIVOC fixture on the side of ECR2 is shown in Fig 1.

To develop the MIVOC technique for metal beam production, first Ferrocene was tried. About 2g of Ferrocene from Strem Chemical [2] was introduced into the glass vial of the MIVOC fixture and mounted to the side of ECR2. After pumping the ion source overnight, first the temperature of the vial was reduced to 5° C with the Peltier cooler. Then, the EVN dosing valve was slowly opened and ECR output scans were recorded to measure the production of the ^{56}Fe charge states. At low flow rates (EVN 116 valve settings 500-600), it was possible to observe high charge states up to $^{56}\text{Fe}^{16+}$. As the flow rate increased (up to EVN 116 valve setting 775), the charge state distribution shifted toward lower charge states and became peaked around $^{56}\text{Fe}^{10+}$ and $^{56}\text{Fe}^{11+}$. It was also observed that by adjusting the temperature of the Peltier cooler between 5° C and 17° C (room temp) that the intensity and distribution of the charge states could be controlled. Lower temperatures favored higher charge states whereas higher

temperatures allowed for the maximum intensity of the lower charge states. A typical ECR2 scan, optimized for $^{56}\text{Fe}^{13+}$, is shown in Fig 2. The best results were obtained for $^{56}\text{Fe}^{13+}$ at 8° C, where about 20 μA were measured at the ion source output, and for $^{56}\text{Fe}^{10+}$ at 12° C, where about 43 μA was observed.



FIG. 1. The MIVOC fixture setup on the side of ECR2. The left picture shows the Ferrocene in the glass vial connected to the EVN 16 dosing valve, which is then connected to the ion source. The right picture shows the Peltier cooler installed, encasing the glass vial in the complete setup.

Future work with the Ferrocene includes also testing the iron beam production on ECR4 to see if similar results can be obtained.

Next, the (Trimethyl)pentamethylcyclopentadienyltitanium(IV) compound (Cp^*TiMe_3), also obtained from Strem Chemical, was tried to produce titanium beam. This compound is more difficult to work with than Ferrocene. It is heat, light, and moisture sensitive. It is best transferred into the glass vial of the MIVOC fixture under argon atmosphere in a glove box and in dim or red background lighting. Once the fixture is mounted to the ion source, it is ideally kept cool at 5° C or less until ready for use. For the test, about 1.5g of Cp^*TiMe_3 was loaded into the glass vial, the EVN 116 valve was opened to 810 (close to fully open), and the temperature was varied with the Peltier cooler from 5° C up to 17° C. A typical ECR2 scan from the test is shown in Fig. 3 with the ion source optimized for $^{48}\text{Ti}^{11+}$. With the EVN 116 valve at 810 and the temperature at about 15° C, about 18 μA of $^{48}\text{Ti}^{11+}$ was extracted from ECR2. About 2 μA of $^{48}\text{Ti}^{13+}$ was also observed.

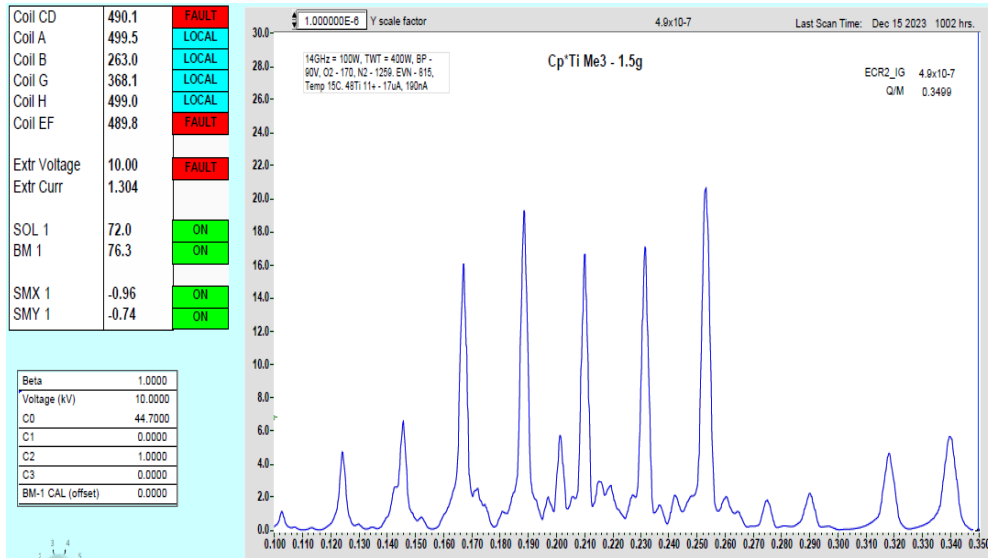


FIG. 3. An ECR2 scan for Cp^*TiMe_3 , optimized for $^{48}\text{Ti}^{11+}$. The 11+ peak is shown near $q/m=0.229$ on the X-axis.

^{48}Ti beam produced with Cp^*TiMe_3 was delivered for experiments for Professor Folden's group. Future experiments with ^{50}Ti enriched Cp^*TiMe_3 , and metal beams produced with other MIVOC compounds, are planned in the coming years.

[1] S.L. Bogomolov *et al.*, Phys. Part. and Nucl. Lett. **12**, 824 (2015).

[2] Strem Chemical, www.strem.com