^{17}F BEAM DEVELOPMENT

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During this reporting period, considerable strides have been made in developing the apparatus and techniques which have allowed the generation and acceleration of scientifically meaningful intensities of ^{17}F beams. RIBs of this species have been produced by bombarding refractory oxide target materials with energetic deuterons producing ^{17}F through the ^{16}O(d,n)^{17}F reaction, and transporting the resulting nuclear reaction products to a closely coupled ion source. Our beam development effort consisted of three principle approaches: development and evaluation of very high temperature, highly porous oxide target systems; optimization of the positive ionization plus charge exchange process; and the development of a direct-negative-surface ionization source.

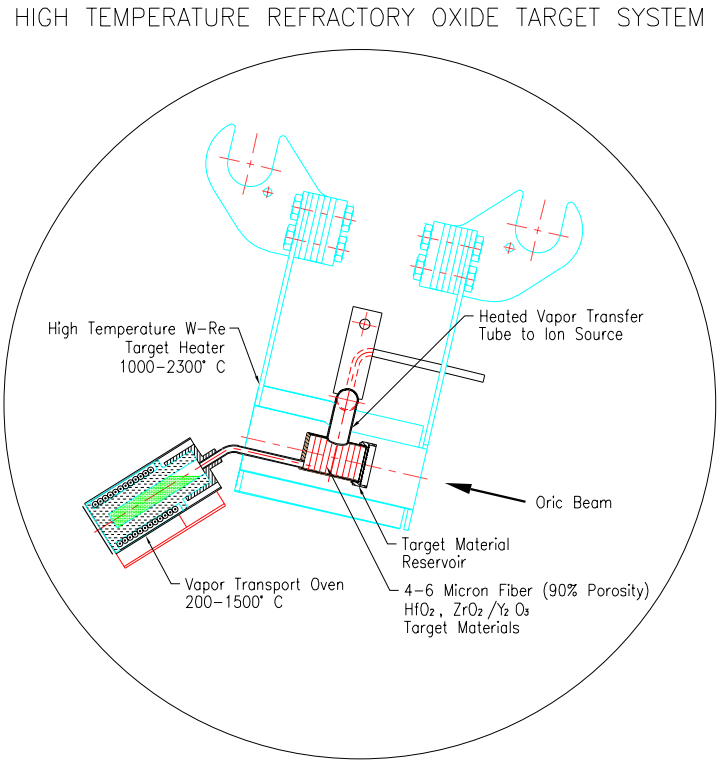
A dramatic improvement in the ionization efficiency for stable fluorine in the direct negative ionization source was realized during this period. Off-line development of this source was undertaken at the Ion Source Test Facility (ISTF) where newly developed apparatus was utilized to inject relatively inert gaseous fluoride molecules into the high temperature target/ion source (TIS). Once inside the TIS, these molecules are thermally decomposed and produce a known flux of the reactive atomic fluorine species. The gas was pulsed to prevent saturation of the inner surface of the TIS and give information on the delay-time characteristic of the ion source.[2] Implementation of this technique allowed direct and rapid evaluation of the effects of design alterations on ion source performance. This approach resulted in an improvement in the F^- ionization efficiency of several orders of magnitude during this period. The design details of this source are presented elsewhere in this progress report. A version of the source was tested at the UNISOR test facility and yielded ionization efficiencies of η=1.5% for $^{19}F^-$ (from SF_6 feed gas), η=0.5% for $^{18}F^-$ (from protons on Al_2O_3 target material) and η=0.02% for $^{17}F^-$ (from deuterons on Al_2O_3 target material). During these tests, an identical copy of the ion source was undergoing development at the ISTF. Here an accel/repel grid for Cs was added to the ion source which improved the ionization efficiency from 1.5% to ~4% for $^{19}F^-$ (from SF_6 feed gas). Another significant improvement to the overall target/ ion source efficiency was realized by utilizing the new target materials (HfO_2 or ZrO_2/ Y_2O_3) described below which yielded a factor of 10 increase to η=0.2% for $^{17}F^-$ as measured at UNISOR.

In parallel to the development of the negative ion source, the RIB injector was engaged in high intensity bombardment tests of fibrous Al_2O_3 target material coupled to a positive ionization source. Here, up to 10 μA of deuterons were delivered to the target by ORIC and positively charged RIBs were converted to negative ions with a charge exchange canal. Early in the investigation it became clear that Al_2O_3 could not operate with sufficiently intense ORIC beam currents to produce usable beams of ^{17}F. At high ORIC beam currents the vapor load on the ion source became excessive and ionization

efficiency fell off precipitously and evidence of significant target degradation was observed, even at deuteron intensities of 2 μA. The maximum flux of $^{17}F^{-}$ produced from this material was $5x10^4$ ions/s measured leaving the high voltage platform. The maximum target/ion source efficiency was 0.02% for $Al^{17}F^{+}$ which can be compared with nominal efficiencies of 0.2% measured at UNISOR under conditions of much lower intensity bombardment.

Prior to this, a detailed study of the RIB generation process revealed that significant yield improvements could be realized by selecting more refractory oxide target materials which could operate at higher temperatures than Al_2O_3 which has a vapor pressure of 10^{-4} Torr at 1550°C. Not only would this allow the application of larger production beam currents while keeping the vapor flux to the ion source sufficiently low but also had the promise of increasing the release efficiency of the target material. All of the major radioactive particle loss mechanisms which occur in the structure of the target material; diffusion, desorption and effusion, decrease exponentially with temperature and give rise to a total release efficiency which is the product of transport efficiencies of each of these steps. This strongly suggested that implementation of oxides with a more refractory character than Al_2O_3 would be fruitful. Toward this end, low density (85-95% porous) weave and felt oxide materials (4-6 μm fibers) of much more refractory materials were obtained from Zircar Co.[3] HfO_2 (2500°C); ZrO_2 (2200°C); Y_2O_3 (2000°C); CeO_2 (2310°C); ZrO_2/ Y_2O_3 (2000°C). The temperature enclosed within parentheses corresponds to a vapor pressure of 10^{-4} Torr for each material. Initial low intensity testing of the HfO_2 at UNISOR revealed comparable ^{17}F yields to that of Al_2O_3 with the vast majority of ^{17}F extracted in the form of AlF^{+} formed with trace Al present within the TIS. At this point, a design for a robust HfO_2 target system was developed which incorporated a very high temperature W-Re target heater which could operate at sustained temperatures of 2300°C to insure homogeneous heating of the target material and a variable flow-rate transport vapor oven for the Al carrier species. This configuration is shown in Figure 1. The Al atoms are forced to flow through the fibrous matrix of the HfO_2 by heating the reservoir. Initial results indicate that $^{17}F^{-}$ yields as large as $2x10^7$ ions/s with a few μA of deuterons on target could be achieved from this configuration. This system was employed in the first HRIBF astrophysical investigation using ^{17}F beams.

Fig. 1



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2. R. F. Welton, G. D. Alton, B. Cui, and S. N. Murray, RSI 69 (1998) 2892.
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