RADIOACTIVE ION BEAM DEVELOPMENT AT HRIBF*

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At the Holifield Radioactive Ion Beam Facility the hardware to produce and deliver the RIB's for nuclear physics and nuclear astrophysics experiments is in the initial stage of operation. The ^{69}As and ^{17}F have been delivered for the first experiments. Presently intense research is in progress to improve the intensity of As and F beams. The ^{63,64}Ga beams and the ^{56}Ni beam in batch mode are in development plans.

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Holifield Radioactive Ion Beam Facility (HRIBF) [1] is based on two existing accelerators: the Oak Ridge K=100 Isochronous Cyclotron (ORIC), and the 25 MV tandem accelerator. Extensive experience exists in the Laboratory in ion sources and electro magnetic separation. Primary light particle beams, protons (up to 50MeV, 50 μA), deutrons, ^{3}He, and ^{4}He bombard a thick target in the Ion Source (IS) located on the 200kV RIB Injector Platform (Fig. 1). Reaction products diffused out from the target material are ionized in IS After mass selection, optional charge exchange (when

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‡ Substituted talk was presented by K. Rykaczewski[3].

positive IS is used), and isobar separation the radioactive ions are injected into Tandem and accelerated. Charge exchange (interaction with Cs vapors $\approx 10^{-2}$ torr, other gases will be examined also) is based on a 3 step process: dissociation (if the reaction product is extracted from IS as a molecule), neutralization, and electron pick up.

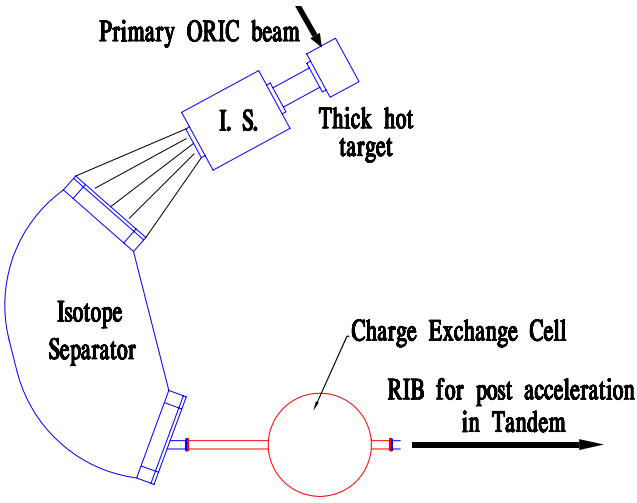

Fig. 1. 200 kV Injector platform conceptual view.

The ability to produce the Radioactive Ion Beams (RIB) by means of the Isotope Separation On-line (ISOL) technique is predominantly the challenge of high efficiency target/IS research and technology. The success in RIB production with the intensities satisfying the need of experiments depends on the applied IS and targets. The main limitations are related to proper selection and performance of target materials since target temperature in some cases exceed 2000°C. The target material properties such as thermal conductivity, changes of structure with temperature, impurities, diffusion coefficient, release time, and interaction with reaction products on the target surface, determine the efficiency of extraction of reaction products from the target. Further, the adsorption of atoms and ions on inside surfaces, and ionization efficiency determine the overall IS performance. Up to certain limits, depending on the above parameters, the efficiency of an IS improves with increasing of target and IS temperature. In practice each RIB beam needs to be an individual separate project.

At HRIBF the performance of selected IS are studied with the ion separator on-line (UNISOR) using low intensity beams (protons 40MeV, 25 pnA), and deutrons from the tandem accelerator. Also, intensive program of calculations related to an IS design and target properties is carried out [2]. The

flux of extracted radioactive ions is measured using the standard on-line nuclear spectroscopy technique, where samples are collected and transported on a moving tape to a position in front of a Ge detector. Presently two types of IS are under examination, the Electron Beam Plasma (EBP) positive IS [3] (Fig. 2) based on the CERN/ISOLDE design [4] and the Kinetic Ejection Negative Surface Ionization IS [5] (Fig.3).

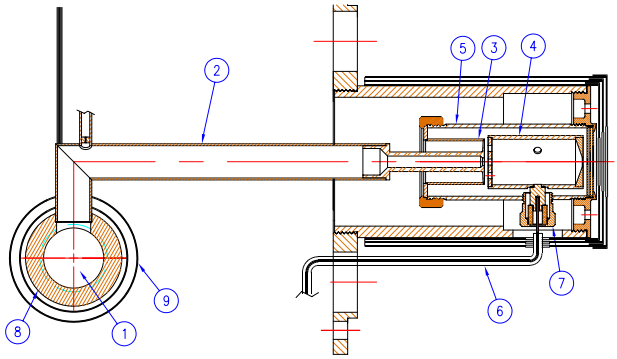

Fig. 2. Electron Beam Plasma Ion Source, 1-target, 2-transport line, 3-cathode, 4-anode, 8-target holder, 9-target heater.

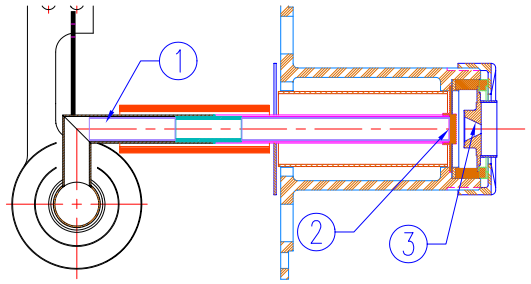

Fig. 3. Kinetic Ejection Negative Surface Ionization IS, 1-transfer line, 2-porous surface ionization matrix for Cs ionization (W), 3-conical kinetic ejection surface (Ta).

The As beam is produced in EBP IS using a liquid Ge target (^{70}Ge$(p, 2n)$ ^{69}As, $T_{1/2}$=15.1 min.). For the transfer line temperature of 1600°C the release time for As is ≈35 min. The overall efficiency of IS for ^{69}As is 0.85%, and the amount of ^{69}As, from the isotope separator, is 10^6 atoms/sec for 25 nA proton beam. Normalized to 1 μA gives $4*10^7$pps/μA. With target temperature exceeding 1400°C the yields for As decrease, and IS efficiency (measured with Xe calibrated leak) decrease as well. This effect seems to be caused by excessive target vapor (Ge) pressure poisoning the source. At

temperatures over 1600°C migration of liquid Ge on the walls toward the transport line occurs, taking all Ge out of the target holder. To control and reduce this effect we will try to make cooled barriers on the inside surfaces, to stop migration of the liquid, and a cooled needle in the center to condense the excess of Ge vapors back into the target holder. That should allow an increased target operating temperature, which should increase the As diffusion.

To produce ^{17}F (^{16}O$(d,n)^{17}$F, $T_{1/2}$=64.7 sec) the Al_2O_3 target is used. First we checked the release of radioactive ^{18}F from target material at various temperatures, measuring the target radioactivity before and after heating. From the solid Al_2O_3 the release is negligible. To enhance diffusion we use Al_2O_3 fibers with SiO_2 binder. The fiber diameter is in the range from 200 to 3 microns. That improved the release of ^{18}F significantly. For fibers the best release measured this way is about 95% at 1700°C. Checking the mass spectra for release of F from Al_2O_3 fibers in the IS, we determined that the release of atomic F is very low, and only about 2% of molecular AlF. Most probably, F, which is chemically very active, binds with Al from the target on the target surface, and is absorbed on all inner surfaces. Therefore we can produce and extract from this IS only molecular AlF. For EBP IS the maximal yield of Al^{17}F from fibers measured at low beam intensity and normalized is about 10^7 pps/μA. The yields obtained for different target materials and various fiber diameters, and the dependence of yields upon the temperature are shown in Fig. 4. With increasing target temperature, yields for Al_2O_3 increase, but start to decrease at about 1400°C. The same decrease is seen also for Xe. This may be attributable to AlF dissociation, and increased target and binder vapor pressures (Al_2O_3 fibers melting point is 2045°C). To analyze this effect we use a HfO_2 fiber target which has considerably higher melting point (2812°C). We investigated the HfO_2 fiber target up to 2100°C, and up to this temperature the yield increased (see Fig. 4). A new design of target/heater will allow higher target temperatures to check this performance. The yields of Al^{17}F from both Al_2O_3 and HfO_2 fibers, measured with 25 pnA protons, and normalized to 1 μA, are in the range of 10^7 pps/μA. The release time for fluorine, measured with ^{18}F (^{18}O$(p,n)^{18}$F), is about $T_R \approx 3.5$ min.

A negative IS has the advantage over positive IS due to elimination of the charge exchange process (about 10% efficiency for ^{19}F). We investigated also the Kinetic Ejection Negative Surface Ionization IS with the same target materials and target heater. For off-line tests with a controlled leak of SF_6 gas into the IS, efficiency for ^{19}F is up to 5%, but in on-line tests it is significantly lower. For now, the best ^{17}F yield, measured for this IS is 10^6 pps/μA, which corresponds to about 0.02% efficiency, and is less than what the EBP IS can produce. Different versions of this IS, with different Cs ion-

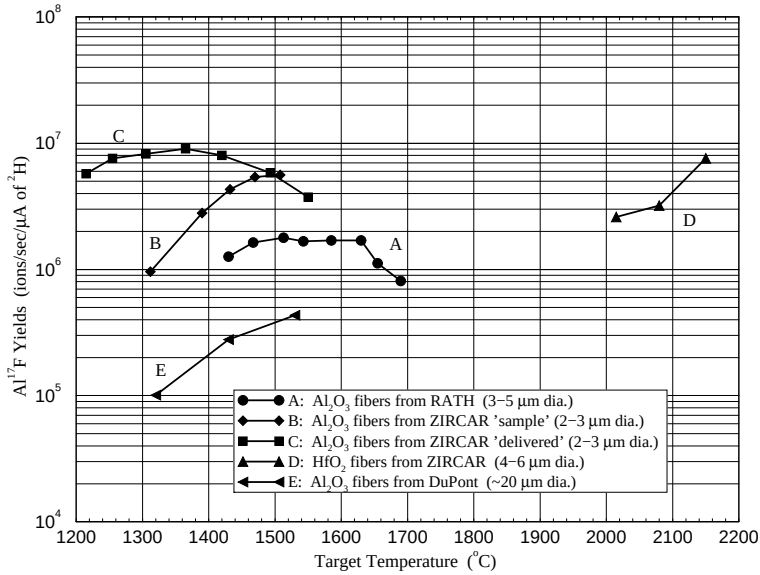

Fig. 4. Yields for molecular $Al^{17}F$, temperature dependence and maximum yields for various materials.

izers are currently under investigation. Until now the highest intensities of RIB delivered for experiments using primary proton and deutron beam are: for ^{69}As $\approx 10^6$ pps/2.6μA, and for ^{17}F from HfO_2 target $\approx 5*10^4$ pps/5.0μA. Other RIB

The results presented above for Al_2O_3 target was obtained at UNISOR with only low intensity primary beam. For higher primary beam intensities (over few μA) the beam deposit substantial amount of heat in the target material, and there are indications that such overheating may cause changes in target material structure (sintering for fibers) additionally limiting the RIB production as well for Al_2O_3 as for other targets.

Several upgrade plans for the future of HRIBF are currently under discussion and planning. The initial option was to replace ORIC by a modern proton accelerator (200 MeV, 100μA). However, the recent funding of the Spallation Neutron Source (SNS) at ORNL with its 1GeV, 1mA proton beam provide a unique oportunity to utilizing the advantage of high energy protons for producing radioactive ions. Runing SNS in a sharing mode, up to $\approx$100μA could be added to the SNS beam and then directed to the ISOL facility. The technical options for an ISOL facility in the U.S. are presently being reviewed by DOE Task Force.

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