Use of Actinide Targets at the HRIBF

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At the Holifield Radioactive Ion Beam Facility (HRIBF), radioactive nuclei on the neutron-rich side of the valley of stability are produced via proton-induced fission in a uranium carbide (UC) target. These targets are operated at temperatures in excess of 2300 K to facilitate transport of the radioactive atoms to an ion source where an ion beam is produced. Ions with the mass of interest are selected and transported to a particle accelerator to be boosted up to energies useful for nuclear physics research. In 1998, a series of tests was initiated using low-intensity, low-energy proton beams (up to 10 nA at 40 MeV) irradiating a low-density UC target (about 1 g/cm^3). In 2000, the first nuclear physics experiment using an ion beam of radioactive nuclei produced in a UC target was conducted at the HRIBF.

Prior to 2006, UC targets for use at the HRIBF were produced by applying a thin coating of uranium dicarbide onto the fibers of a robust and highly-porous carbon matrix consisting of reticulated vitreous carbon fibers (RVCF). This target geometry (see Fig. 1) seems ideal given the thin layers of UC material, the open structure of the matrix and the ability to withstand high temperatures [1]. However, the fabrication process is complex resulting in high costs and inconsistent quality, which negatively affected the quality of the radioactive beams.

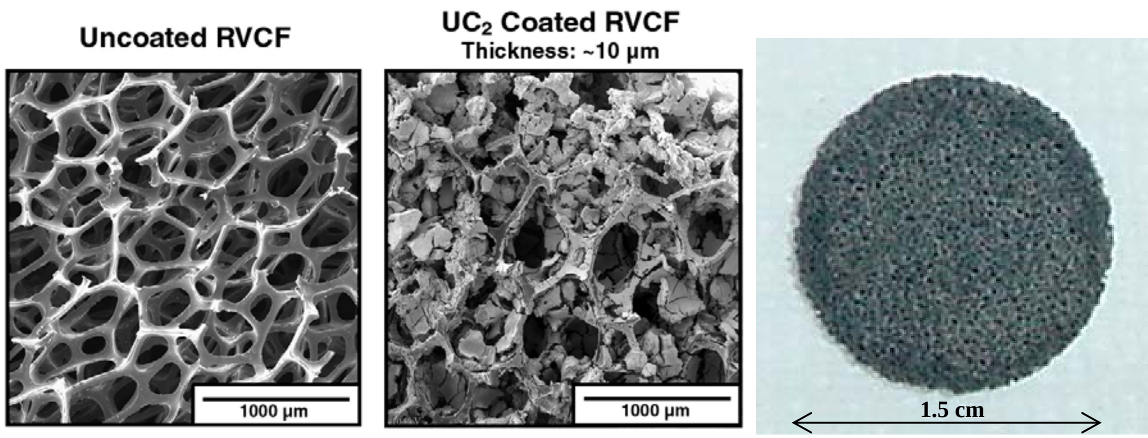

Fig. 1. SEM images of the uncoated carbon matrix (left) and the UC-coated matrix (middle). A UC/RVCF disk (about 2 mm thick) is shown in the photograph on the right.

Since the middle of 2006, UC targets used at the HRIBF have been produced using a pressed-powder technique developed in collaboration with ORNL staff from the field of nuclear fuel processing. These radioactive ion beam (RIB) production targets consist of a mixture of UC_2 powder having an average particulate diameter of 1-2 μm and selected graphite powders. This mixture is then pressed to form a relatively low density disk. The process is relatively fast and inexpensive, resulting in disks with consistent physical properties and on-line performance. The RIB intensities extracted from these targets have been consistently high, with yields that are higher than or equal to the yields achieved when the UC/RVCF targets were used, with one notable exception that is discussed below. The neutron-rich beams and intensities that are achievable using these UC targets at the HRIBF are shown in Fig. 2 below.

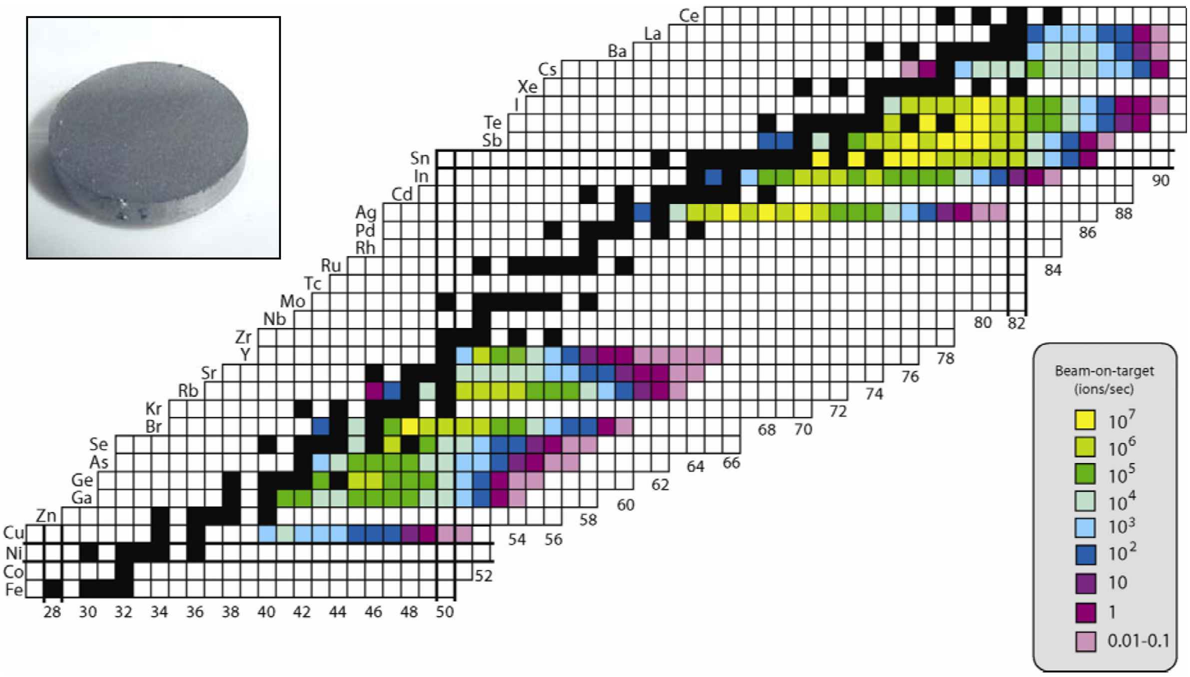

Fig. 2. Array of neutron-rich beams available at the HRIBF for nuclear physics experiments at beam energies of at least 3 MeV/nucleon. The inset shows a UC target made using the pressed-powder technique.

Analysis of the RIB intensities at the HRIBF over the last few years shows an interesting trend in the ratio of beam intensities from the two types of UC targets. These ratios depend on whether the beam is extracted from the ion source as an atomic beam or a molecular beam. In particular, beams extracted as sulfide molecular ions (Ge and Sn isotopes) tend to have higher intensities when a UC/RVCF target is used, while the beam intensities of atomic ions such as Cu, Ga, and Se isotopes tend to be higher when the pressed-powder UC targets are used. The higher yields from the pressed-powder targets are probably due to shorter diffusion paths in the UC layer and the higher fraction of graphite surface in the target matrix. In the UC/RVCF targets most of the surfaces are UC_2 and it is known that, for most elements, the release from a graphite surface is generally faster than from a UC surface [2]. At the HRIBF, sulfide molecular ions of Ge and Sn isotopes are produced by adding sulfur using a hydrogen sulfide gas feed. Investigations are on-going to try to understand why the sulfide molecule formation seems to be less efficient in the pressed-powder UC target system. Details of the fabrication processes, reproducibility of the UC target performance, and average useful lifetimes of these two types of uranium carbide targets will be discussed.

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References

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