THE SPES PRODUCTION TARGET*

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An extended work is in progress concerning the target development for the SPES (Selective Production of Exotic Species) project. The SPES will be an ISOL based facility (Isotope Separation On Line) in which a proton beam of 40 MeV and 0.2 mA impinges directly on a uranium carbide target. After the mass separation and re-acceleration on the experimental sites, the RIBs will have an intensity of the order of 10^9 pps (for ^{132}Sn) and an energy up to 13 MeV/u. The new idea that characterize this project is the design of its target: we propose a target configuration capable to keep high the number of fissions, low the power deposition and fast the release of the produced isotopes.

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1. Introduction

The SPES project at Laboratori di Legnaro of INFN (Italy) is concentrating on the production of neutron-rich radioactive nuclei by the Uranium fission at a rate of 10^{13} fission/s. The Radioactive Ion Beam (RIB) will be produced by ISOL technique using the proton induced fission on a Direct Target of UCx.

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The most critical element of the SPES project is the multi-foil direct target. Up to day the proposed target represents an innovation in term of capability to sustain the primary beam power. The design is carefully oriented to optimize the radiative cooling taking advantage of the high operating temperature of 2000°C. The thermal and thermo-mechanical analysis of the proposed configuration shows the capability of the thermal radiation to cool the disks with a reasonable margin below the material limiting temperature. The release from the target has been carefully studied by means of computational codes (RIBO and GEANT). The simulations show that SPES multi-foil direct target presents a good isotope extraction behavior up to intermediate masses ($80 < A < 160$).

2. The SPES facility overview

The main goal of the proposed facility is to provide an accelerator system to perform forefront research in nuclear physics by studying nuclei far from stability. In the SPES project [1] the 40 MeV proton primary beam (8 kW of power) delivered by the cyclotron hits the production target made by an UCx multi-foil target. The beam extracted from the ion source coupled to the target, will cross through a first stage of M/Q purification, which allows to trap the largest amount of radioactive contaminant. According to other facility, and to satisfy the previous constraint, we plan to use a small Wien filter, placed in the first platform just beyond the source. It will be followed by a 1/15000 isobar mass separator. To optimize the re-acceleration, a Charge Breeder will be developed to increase the charge state to +N before the injection of the exotic beam to PIAVE Superconductive RFQ (Radio Frequency Quadrupole), which represents the first re-acceleration stage before the final injection to ALPI.

The final energy of the radioactive beams on experiments will range from few MeV/u up to 10 MeV/u for $A = 130$ using the existing PIAVE-ALPI complex as RIB post-accelerator.

3. The target ion source system

The most critical element of the SPES project is the production target. Up to day the SPES target represents an innovation in term of capability to sustain the proton beam power and to produce a fission rate of 10^{13} f/s, a common goal of the 2nd generation RIB facilities [2]. In the production target of a ISOL based facility, many physical phenomena's occur, like power deposition, fission, atomic diffusion–effusion, ionization, extraction.

The target-ion source assembly should ideally exhibit the following properties: high efficiency; high temperature operation; chemical selectivity; target temperature control; long lifetime. The target ion source should, as well,

be designed for safe and fast insertion/removal from the ISOL facility to allow for both changing of the target material and source repairs as required in a high radioactive environment.

The SPES primary proton beam, is stopped in the target and the fission process produces the exotic nuclei in the intermediate mass range ($80 < A < 160$) [3]. The desired exotic species must be extracted from the target, ionized and accelerated to make a RIB. This process is time demanding and usually unsuitable for atoms having half lives lower than a few tens of ms. The SPES target design has been optimized in order to maximize the release efficiency and to exploit, at the same time, devices (basically the ion sources) developed in other laboratories. The energy deposited in the target material by the electromagnetic and nuclear interactions has to be removed, and due to the low pressure of the environment, the target can be only cooled by thermal radiation towards the container box surrounding them.

In order to optimize the heat dissipation along with the fission fragments evaporation, the SPES target consists of multiple thin disks housed in a cylindrical graphite box [4]. In this way the cooling of the target is strongly simplified: in fact, due to the vacuum environment, the heat dissipation is fully entrusted to the thermal radiation and this mechanism is directly proportional to the body surface [5]. The use of 7 thin UCx disks, 40 mm of diameter and 1.3 mm thick each, increases the total surface and allows for a better cooling as reported in Fig. 1.

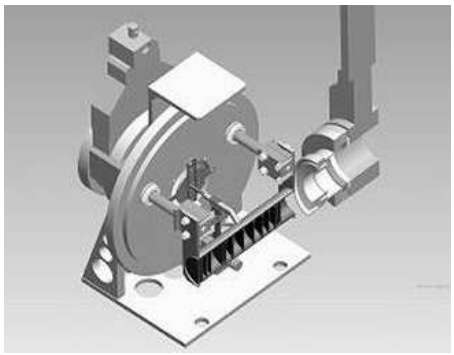


Fig. 1. The target/ion source assembly.

In this configuration only the protons with higher fission cross-section are exploited in the UCx target discs, while the outgoing lower energy, less than about 15 MeV (negligible $^{238}\mathrm{U}(p, f)$ cross-section below this value), is driven towards a passive dump.

So the power deposited in the UCx is lowered considerably and at the same time the number of fission reactions is maintained high. In the choice of the beam profile a uniform distribution of the beam has been chosen in

order to flatten as much as possible the power deposition inside the disks. The ideal target material for RIB should combine different properties which sometimes cannot be fully maximized in a single material: low density, good release properties, good mechanical stability, high thermal conductivity and emissivity, and limited ageing at high temperature under intense irradiation. Such materials must operate for extended periods of time with constant performance and efficiently dissipate the incoming beam power.

The preparation of SPES UCx discs is based on the carbon-thermal reduction of UO_2 powders in excess of graphite. The powders are mixed and ground in order to obtain a homogeneous mixture (2 wt.% of phenolic resin is added as binder); these powders are uniaxially cold pressed at 75 MPa for 1 hour. Finally the heat treatment is performed in a dedicated vacuum furnace, built at LNL-INFN. The bulk density of the discs turns out to be about 3 g/cm^3, while the atomic ratio of the uranium compared to the carbon is assumed to be U:C = 1:4. In Fig. 2 SEM-micrographs of our UCx pellet is reported.

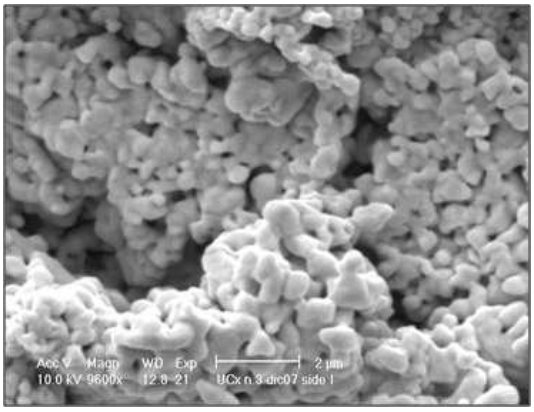


Fig. 2. SEM micrographs of a UC2+graphite sample.

The ion source assembly, incorporates many of the engineering features utilized in the ISOLDE design. The hot-cavity source was designed at the ISOLDE [6]. The source has the basic structure of the standard high temperature RIB ion sources employed for on-line operation. The ionizer cavity is a W tube (34 mm length, 3 mm inner diameter and 1 mm wall thickness) resistively heated to near 2000°C. The isotopes produced in the target diffuse in the target material and after that will effuse through the transfer tube (approximately 100 mm length) into the ionizer cavity where they undergo surface or laser ionization. The surface ionization process can occur when an atom comes into contact with a hot metal surface. In the positive surface ionization, the transfer of a valence electron from the atom to the

metal surface is energetically favorable for elements with an ionization potential lower than the work function of the metal. For alkalis and some rare earth elements, high ionization efficiencies can be achieved. The laser resonant photo-ionization, used the same hot cavity cell, will be implemented in collaboration with INFN-Pavia; the aim is to produce a beam as pure as possible (chemical selectivity) also for metal isotopes, like Sn, Ga, Ge.

Ideally that atoms should be ionized +1 then extracted and accelerated to 60 keV energy and, after that, injected in the transport system. This whole process is limited by the source ionization efficiency. Several others kinds of sources (plasma, ECR) will be used according to RIB of interest. The unit is coupled to the RIB line and to the proton driver beam by means of two quick connectors and two pumping ports which can be sealed off with valves.

Special care will be devoted to the safety and radioprotection of the system because the estimated level of radioactivity in the production target area falls around 10^{13} Bq; therefore a special devices will be designed. Furthermore, the radiation management and the control system will be integrated and redundancies will be adopted in the design.

Currently a target prototype, using seven SiC disks of 40 mm diameter, is being developed and tested in the mechanical workshop of the LNL (see Fig. 3). Temperature measurement have been performed to validate the thermal simulations of the complete target system, as carried out with the code ANSYS. For this purpose at different values of the target heater current the temperature of the last graphite dump of the multi-foil target system has been measured with a pyrometer, viewing the dump temperature through a quartz window.

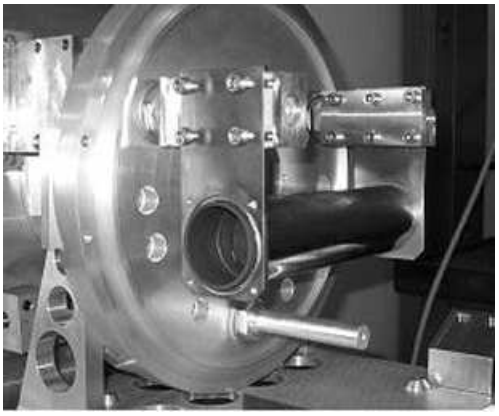


Fig. 3. The SPES SiC target prototype with 7 discs of 40 mm diameter.

4. Conclusions

A new concept target has been designed for RIBs production in the framework of the SPES project: this facility is expected to run the first exotic beam in 2014. Before starting the construction the R&D program will continue mainly for target-ion source development subsystems in order to get satisfactory answers. Uranium carbide pellets was successfully produced and a good control on production process and the final material properties were demonstrated. The tests performed so far, indicate that the SPES target configuration is a feasible solution to produce exotic ions.

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