# ABOUT CARBIDES-MADE NANOCERAMICS FISSION TARGET FOR RIB PRODUCTION

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*Abstract*

Intensities of RIBs can be increased with improvement of release efficiency of fission targets. One of factor, which limits release efficiency of targets, is efficiency of release of isotopes from target material. This paper presents investigation of dependence of release efficiency from ceramics target on its grain size and inter-grains pores, as well shows some efficiency limits and ways to improve it. Simulations were performed for uniform target material made from powder of uranium carbide. Inter-grain spaces are taken relative to grain sizes, as another parameter to optimize is high density of target material. Results show that optimal grain size is in the range of hundreds - thousands nanometers, while recent target materials utilize one order more sizes of grains. In addition, key points of production of such ceramics are discussed. The beam technologies allow producing the nanopowders from carbides of different metals with controlled grain size. Exact methods also give to us possibilities to obtain ceramics with optimal ratio between grain and pores sizes. Possible problems and preliminary program of experiments and tests are discussed.

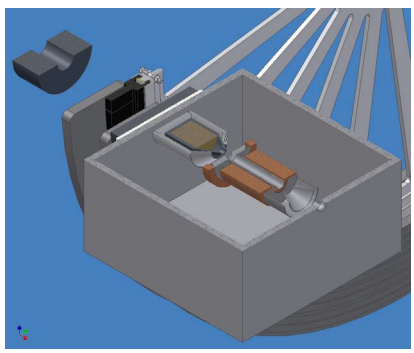

Figure 1. Layout of the SPES target system. Left to right: protecting collimator, neutron converter inside the cooling panels, fission target, ion source.

## INTRODUCTION

In the framework of the European program, to define a second generation Radioactive Ion Beam (RIB) facility, the Legnaro National Laboratories (LNL) are proposing the construction of a specialized national facility for RIB originated by fission fragments produced by fast neutrons (SPES) during the ensuing years [1]. Protons/deuterons of 40 MeV and 150 kW will produce in converter (see fig.1) about $10^{14}$ neutrons per second centered at around 14 MeV that will induce fission in a suitable fissile target, with the purpose of $10^{13}$ fission per second production at least.

Projects purpose is to increase recent beam intensities by 2 - 3 orders. Such increase is planned to achieve by increase of isotopes production rate with keeping of isotopes release efficiency at the same level as of recent targets. At the same time, sufficient yield of very short-lived isotopes will be produced with increase of total yield, in such a way the production of very exotic beams will be possible. Although some methods were proposed to maintain high effusion efficiencies for short-lived isotopes from large targets [2], there is another factor which limits release efficiency of targets, - efficiency of release of isotopes from target material. It was shown experimentally that even for recent targets the release efficiency of elements with small sticking time, e.g. Fr, is limited by diffusion from grain efficiency while effusion efficiency does small influence on yields of isotopes. [3] In such a way, optimization of target material by selecting of powder grain size can sufficiently raise yields of some isotopes from recent targets as well as open possibilities of production of very exotic beams on new RIB facilities.

## CALCULATION OF RELEASE EFFICIENCIES

Release of isotopes from UCx pill with thickness of 1 mm and diameter 11 mm was simulated for different grain sizes of target material. The material is represented as uniform porous structure with 100% open porosity. Release process is represented as consequent steps of diffusion of isotope from powder grain and following inter-grain effusion from target material. The inter-grain effusion is taken as random walk of isotope, in such a way the number of collisions can be estimated as proportional to $FP^{-2}$ and total length of flight path out of target material is proportional to $FP^{-1}$, where FP is average flight path between collisions which we assume proportional to average diameter of grains. Release simulations for different flight path values were performed by RIBO code [4] and analytically fitted.

Standard model of release process from powder targets is used in calculations. [5] Release efficiency is presented as multiplication of efficiency of diffusion from grain and inter-grain diffusion from pill of target material. Diffusion and sticking times are taken for standard UCx material.

Comparison of efficiencies of releases from UCx pill was performed for different grain sizes of target material. It was shown that optimal grain size is in the range of 1 – 10 μm for sticky elements and below 1 μm for elements with zero or very small sticking time. From the results it is clear that recently used material with 20 μm grain size is not optimal for short-lived isotopes from release efficiency point of view and efficiencies can be sufficiently improved by reduce of grain size.

It is significant to note that at ~100 μm grain sizes, isotope output from a grain may not be described by diffusion model. To make the calculations more exact the modeling by means of molecular dynamics will be required.

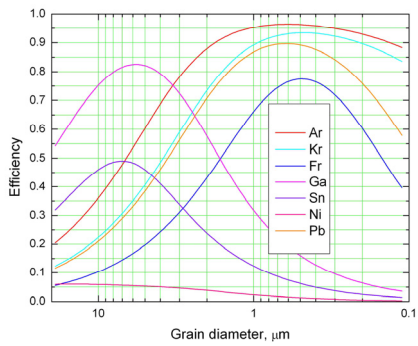


Figure 2. Efficiencies of release from UCx pill for isotopes of listed elements with 100 ms half-life.

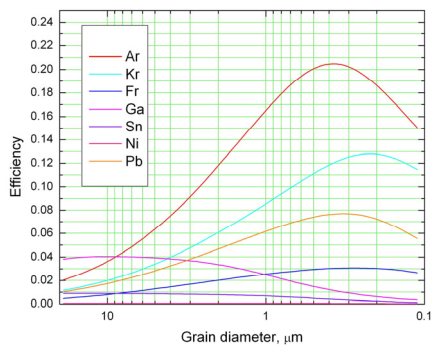


Figure 3. Efficiencies of release from UCx pill for isotopes of listed elements with 1 ms half-life.

## PRODUCTION OF NANOPOWDERS.

In BINP SIB RAS the facility for nanodisperse powders production by means of matter evaporation with the use of focused 100 kW electron beam is developed [6-8]. The feature of this method comparatively alternative ones [9] is electron beam evaporation in the atmospheric pressure medium. The beam is generated by electron industrial accelerator commercially produced in the Institute. After being extracted from accelerator tube the beams passes through extraction device into atmosphere. Evaporation chamber in which evaporant is placed (see fig.4) is attached to the extraction device. As a result of evaporant heating by the beam in the lower part of evaporator the molten pool is formed. Above the molten pool an air or inert gas flow, depending on evaporated matter type, is formed. It serves for transportation of generating aerosol containing nanopowder towards the place of its collection. Beam diameter at the level of evaporant is determined by electrons scattering with air or inert gas molecules on the way of beam passing. For transition distance of 10 cm the specific beam diameter is 1 cm. The production of hard-to-be evaporated matters powder is effectually to be produced in evaporation chamber of about 15 cm diameters.

This technology allows production of refractory materials powders with size close to tens and hundreds nanometer.

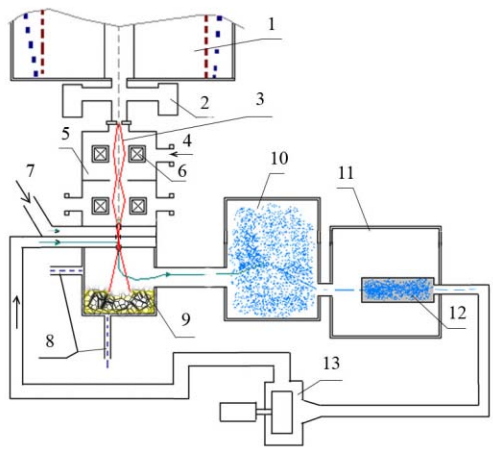


Figure 4. Facility for nanopowder production scheme. Numerated: 1 – ELV-6 industrial electron accelerator, 2 - magnetic electro-discharge pumps, beam envelope, 3 - differential pumping, 5 – focused electron beam extraction device, 6 – magnetic lens, 7 – air supply for blocking the inert gas penetration in extraction device, 8 – chamber water cooling, 9 – evaporating chamber with evaporant, 10 – intermediate nanopowder cooling chamber, 11 – powder collection chamber with hose filter 12, 13 – providing of inert gas circulation ventilator.

The facility operational principle enables to make the cycle of gas transportation to be closed inside the facility. The advantages of closed cycle are resulted in saving of inert gas and prevention of evaporated products output into environment. The last fact is important in case of toxic substance nanopowder production. Additional inert gas containing vessel (not shown in Fig. 4 to simplify it) is needed for providing of small exceeding of inert gas pressure with respect to atmospheric pressure.

To understand the possibility of heavy metal carbides production, the estimation of process was performed. As a model matter TaC was chosen. Obviously, it is a most refractory and hard-to-be-evaporated matter. The possibility of its evaporation at the facility means that there is no temperature limits for any material. Moreover, for this matter there are state functions data. Detailed calculations were presented in [10]. General results are

following:

- within the considered model, it is possible to get evaporation temperature up to 5100°C that allows evaporation of hard-to-be-evaporated refractory matters, such as heavy metals carbides at beam power P=50kW,
- experimental productivity for high temperature evaporators can be at list tens of gram per hour.

## CONCLUSION.

At present, heavy metal carbides nanopowder target fission production is seemed to be quite possible and, from another side, significantly defensible.

Beam method allows producing of refractory and chemically inert powders in the range of 10-1000 μm grains. Particularly, the powders of tungsten, tantalum, rhenium, etc., - the matters of about $3000^0$C and more fusion temperature and more than $5500^0$C boiling point – have been produced. Also, the powders of carbon fullerens, silicon, oxides of silicon, magnesium, aluminum, etc., have been produced.

Ceramic production from nanopowders is possible to be made by traditional method, i.e. by means of material compacting and its simultaneous sintering, Recently, experimental sample tungsten carbide with 600-800 μm grain was produced. The sample has about 8 gr/cm$^3$ density, it is enough strong (20 mm diameter and near 3 mm thickness tablet was not able to be broken by hand), also, it has high open porosity.

One of a problem is to develop special optimal conditions for production of different powder with different grain sizes.

From other hand, fission target resistance at high operational temperatures is a special question. The target should be in operational mode for a long time (~ 1000 hours) at 2000-$2300^0$C temperatures to provide adequate output of worked isotopes. This subject requires experimental researches.

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