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A SURFACE-IONIZATION ION SOURCE DESIGNED FOR IN-BEAM OPERATION WITH THE BEMS-2 ISOTOPE SEPARATOR

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A SURFACE-IONIZATION ION SOURCE DESIGNED FOR IN-BEAM OPERATION WITH THE BEMS-2 ISOTOPE SEPARATOR

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Ионный источник с поверхностной ионизацией для БЭМС-2 - масс-сепаратора на пучке тяжелых ионов

Описан ионный источник с поверхностной ионизацией для масс-сепаратора на пучке тяжелых ионов. Измерены характеристики источника для редкоземельных элементов. Эффективность сепарации диспрозия равна (20±5)% при температуре 2600°К. Быстродействие источника для редких земель при T = 2500 ÷ 2700°К составляет 5 ÷ 10 сек.

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A Surface-Ionization Ion Source Designed for In-Beam Operation with the BEMS-2 Isotope Separator

A surface-ionization ion source designed to operate in combination with the BEMS-2 isotope separator in a heavy ion beam is described. The ion source is adjusted for the separation of rare-earth elements. The separation efficiency for ^{150}Dy is determined to be equal to about 20% at the ionizer temperature of 2600°K. The hold-up times for praseodymium, promethium and dysprosium in the ion source range from 5 to 10 sec at the ionizer temperature of 2500-2700°K.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

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The present paper deals with the description of the BEMS-2 surface-ionization ion source. This device, operated in a beam from the U-300 heavy ion cyclotron, is designed for investigations of radioactive isotopes far from the β-stability line. Short lifetimes and small production cross sections of these isotopes impose on this type of device the main requirements such as a high efficiency, high separation rate and reliable continuous in-beam operation. The modifications made in the previous design [1] were aimed at increasing the reliability of the ion source operation at high temperatures to provide efficient ionization of rare-earth elements.

The ion source is shown schematically in *fig. 1*. The tungsten ionizer has the form of a hollow cylinder (1) open from the side of the cyclotron beam. The cylinder internal diameter, length and wall thickness are 19 *mm*, 20 *mm* and 1 *mm*, respectively. The size of the ionizer "entrance window" was chosen taking into account the actual dimensions of the recoil beam. The ionizer bottom is a cone with a vertex angle of 135°, which is designed to shape the paraxial beam of ions extracted through an exit orifice 1.5 *mm* in diam. From the side of the target, the ionizer is closed with a thin, 1 μm, tungsten foil (4), which is transmissive for recoil nuclei knocked out by the beam from the target. The foil is put between binding rings made of tungsten foil (50 μm) and pressed against the ionizer by a thin-wall (0.3 *mm*) tantalum cylinder (6). A tantalum recoil catcher (2) is placed

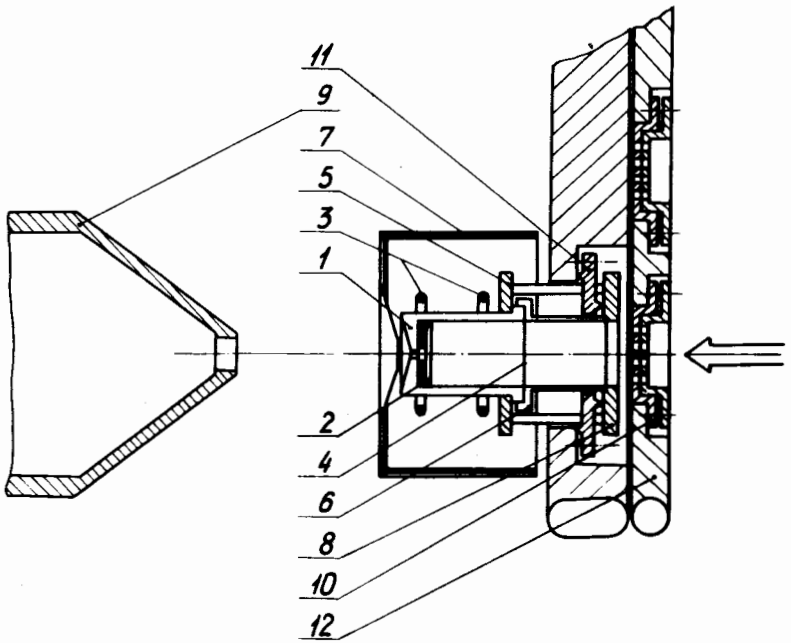

Fig. 1. Schematic ion source: (1) ionizer, (2) tantalum catcher, (3) tungsten filaments, (4) tungsten foil, (5) and (8) tantalum rings, (6) tantalum cylinder to press the tungsten foil, (7) thermal shield, (9) extracting electrode, (10) target cassette, (11) titanium insert, (12) copper target holder.

inside the ionizer. The ionizer, together with the tantalum cylinder (6), is held in the operating position by means of tantalum rings (5) and (8). In order to reduce heat transfer, these rings are fastened by a titanium insert with sharp teeth onto a bulky water-cooled copper holder. On the other side of the holder, a copper target cassette (10) is mounted.

The ionizer is heated by bombardment with an electron beam emitted by two tungsten filaments (3), which have independent power supplies. The ionizer and filaments are covered by a three-layer thermal shield (7) manufactured of 0.1 *mm* tantalum sheets.

Other changes in the design of the ion source, as compared with the version described in ref. /1/, concern the target assembly. For some experiments, where a fast replacement of targets is needed, we have designed and manufactured a water-cooled movable frame (12) to hold two targets simultaneously. The shift of the frame, i.e., the replacement of a target, is performed by an electric motor without violating the vacuum. In addition, a thermal shield of thin graphite film (50-100 $\mu g/cm^2$) is inserted between the ionizer and the target. The film is fastened on the copper target cassette from the side of the ionizer. The matter is that, despite the intense cooling of the copper holder (12), the powerful thermal radiation of the ionizer heated to a high temperature leads to a considerable heating of the target foil. In initial experiments /2/ we used targets prepared of high-melting metal foils (Zr, Nb and Mo). The use of substance deposits on an aluminium backing as targets was practically impossible. The insertion of the graphite shielding film considerably decreased the temperature of the target and made it possible to carry out continued bombardments of cadmium oxyde deposited onto a 5 μm aluminium backing. A reliable thermal protection of the target is especially important in the case where expensive enriched isotopes are used.

Reaction products knocked out from the thin target by projectiles pass through the entrance foil to be implanted into a very hot tantalum catcher. The implanted atoms diffuse to the surface of the catcher, are then evaporated and ionized with a certain probability during collisions with the hot walls of the ionizer. Then the ions are extracted from the ionizer cavity through the exit orifice to be then accelerated by an electrostatic field.

Now we shall present some of the experimental data obtained with this ion source. *Figure 2* shows the dependence of the separation efficiency for rare-earth elements (Eu, Dy, La) as a function of the electron beam power. The measurements have been performed with the radioactive isotopes of these elements, ^{140}Eu, ^{150}Dy and ^{126}La, produced in reactions induced by 190 *MeV* ^{32}S

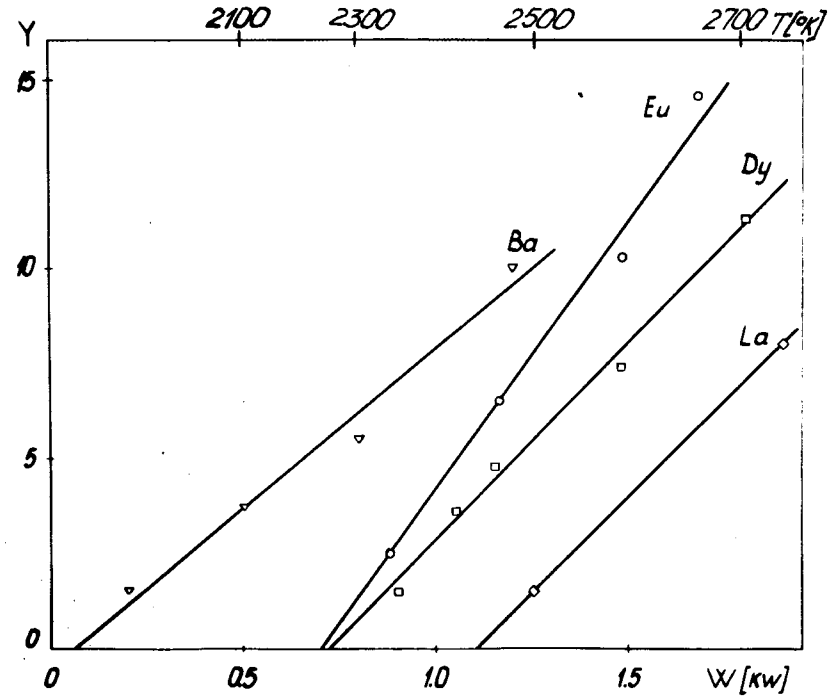

Fig. 2. The separation efficiency (in relative units) for Ba, Dy, Eu and La as a function of the electron beam power and the ionizer temperature. The curve for rare-earth elements is drawn through the points for dysprosium.

ions in ^{112}Sn, ^{124}Sn and ^{98}Ru targets, respectively. For comparison, *fig. 2* also shows the dependence of the Ba separation efficiency upon the temperature of the ionizer. The temperature was measured by an optical pyrometer in the vicinity of the exit orifice.

The α-active isotope ^{150}Dy ($T_{1/2}$ = 7 *min*) was produced as a result of the reaction involving the evaporation of 6 neutrons in the bombardment of the enriched isotope ^{124}Sn by ^{32}S ions (the target was prepared by depositing a 2 *mg/cm*^{2} layer of oxyde onto a 1 μm golden foil). To detect the decay of ^{150}Dy, the device described in ref. /1/ was used in the focal plane of the isotope separator. The isotopes ^{140}Eu ($T_{1/2}$ = 1.4 *sec*) and ^{126}La ($T_{1/2}$ = 60 *sec*) were detected by β-activity in the focal plane of the isotope separator adjusted for the separation of isobars with A = 140 and 126. The dependences of the separation efficiency for these elements on the heating of the ionizer have the shape of threshold curves. This is possibly due to the intensive formation of the rare-earth oxydes at an ionizer temperature lower than the threshold one. The oxygen amount inside the ionizer at a residual pressure of 10^{-5} torr is sufficient to oxydize the atoms of the element investigated. These oxydes break down on the hot tungsten walls with a probability depending on the temperature. The thermodyna-

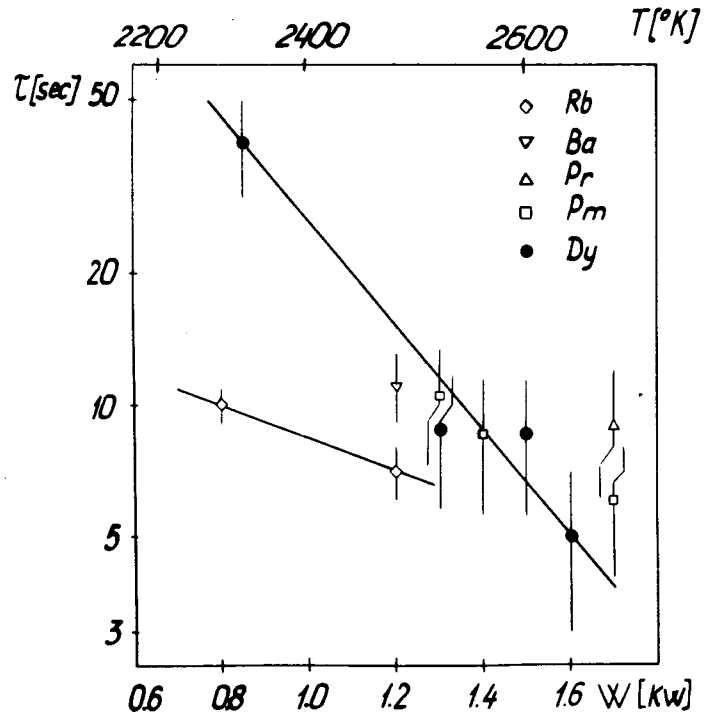

Fig. 3. Hold-up times for dysprosium, promethium, praseodymium, barium and rubidium in the ion source as a function of the intensity of the ionizer warming-up.

mic equilibrium of this process at a temperature lower than the threshold one is displaced toward the higher oxyde concentration /4/.

The absolute separation efficiency for ^{150}Dy was determined for T = 2600°K. The activity of ^{150}Dy in the focal plane was compared with the 7-min α-activity of recoil nuclei knocked out from the target. To determine the latter activity, we placed a tantalum grid between the target and the ionizer for stopping a half of the recoil nuclei. The quantity of ^{150}Dy left on this grid was determined after bombardments. As a result, the efficiency was obtained to be equal to (20 ± 5)%.

The ion-source hold-up times for dysprosium (^{150}Dy), promethium (^{134}Pm), praseodymium (^{131}Pr), barium (^{122}Ba) and rubidium (^{77}Rb) have been measured. In these experiments the projectile beam was periodically shut down and the activity build-up was measured as a function of time in the focal plane of the isotope separator. The results of these measurements are presented in *fig. 3*. The separation rate both for rubidium and for cesium /1/ is apparently determined by the diffusion of atoms from the catcher. In the case of dysprosium at T= 2300-2500°K the hold-up time is substantially longer than that for rubidium. This can be associated with the much longer adsorption time of dysprosium atoms on the ionizer walls /3/. The hold-up times measured for rare-earth elements (praseodymium, promethium and dysprosium) and barium at T = 2500-2700°K are in the range of 5 to 10 *sec*.

The experience of operating this ion source has shown that it is very reliable and convenient in operation.

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