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TARGETS PRODUCTION METHODOLOGY FOR $^{90}Zr(^{6}Li,d)^{94}Mo$ REACTION

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ABSTRACT

The thin Zr target production is essential to achieve good quality of the data in the measurements of the $^{90}Zr(^{6}Li,d)^{94}Mo$ reaction. The methodology was developed in order to minimize light nuclei contamination, as ^{12}C and ^{16}O and to improve the zirconium/contaminant ratio in the target and avoid further oxidation. Tests were performed with the EDWARDS-E12E and UNIVEX450 systems in the Target São Paulo Laboratory by the electron bombardment technique. Up to now, the most favorable test points to the production of sandwiches of thin golden films (Au+Zr+Au) using the UNIVEX450 system with a refrigerated copper crucible and a very clean and controlled environment.

1. INTRODUTION

The investigation of the α - cluster structure in ^{94}Mo through the $^{90}Zr(^{6}Li,d)^{94}Mo$ reaction [1,2] is a research subject of the Nuclear Spectroscopy with Light Ions Group at IFUSP. In the $^{90}Zr(^{6}Li,d)^{94}Mo$ reaction, the emerging deuterons are detected in the focal plane of the Enge Magnetic Spectrograph at the Pelletron Laboratory. However, due to the kinematics' reaction, the deuterons associated with the excited states of light nuclei, as those populated by $^{12}C(^{6}Li,d)$ and $^{16}O(^{6}Li,d)$, spoil parts of the spectra. Furthermore, the cross section for the reaction on ^{90}Zr is low, ~2-10 μb/sr and about thirty times lower than the respective values on ^{12}C and on ^{16}O (usually present in targets).

Figure 1 shows some predicted positions of emerging deuterons from ($^{6}Li,d$) reactions, at 32.0 MeV incident energy, on ^{90}Zr, ^{12}C and ^{16}O, according to the scattering angles. The positions are associated with the ground states and some excited positive band states of the residual nuclei. The predicted positions for ^{94}Mo presented correspond to: G.S. and 0+, 2+. 4+, 6+, (8+), (10+) and the last bound states, at excitation energies of 0.871, 1,574, 2.423, 2.956, 3.897 and 6.555 MeV, respectively. Note that the nuclear emulsion covers 50 cm along the focal plane.

Figure 2 shows a spectrum obtained in a preliminary data acquisition in São Paulo. The difficulty to analyze the peaks of interest with low cross sections in the presence of contaminant peaks can be clearly seen in both graphs.

In this context, the target production methodology is very important for the viability of the measurement and for the good quality of the data. The aim of this work is developing a methodology to obtain the thin Zr film with the EDWARDS-E12E and UNIVEX450 systems in the Target São Paulo Laboratory by the electron bombardment technique [3], minimizing light nuclei contamination, as ^{12}C and ^{16}O and improving the zirconium/contaminant ratio.

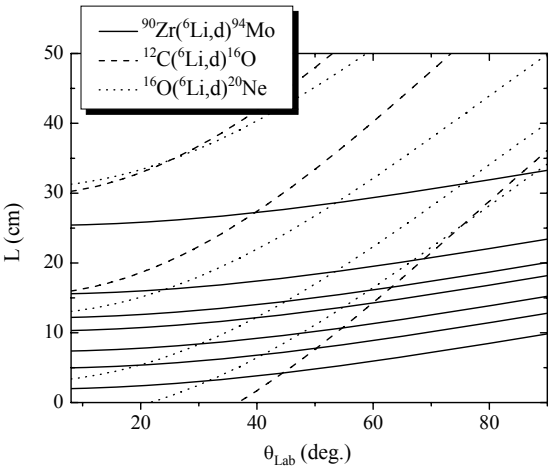

Figura 1 - Predicted positions of emerging deuterons from ($^{6}Li,d$) reactions, at 32.0 MeV incident energy, on ^{90}Zr, ^{12}C and ^{16}O.

2. EXPERIMENTAL PROCEDURE

The methodology of ^{90}Zr targets production has been developed in the Target São Paulo Laboratory by the electron bombardment technique. It is important to point out that zirconium presents a high evaporation temperature, 1740°C (at 10^{-6} Torr) and a vapor pressure of 4 10^{-6} Torr (at 1852°C) which indicate a low evaporation rate. Other important restriction is the small quantity of isotopically enriched material available, 100 mg, which was in solid and metal form.

The tests developed are divided in three parts. All tests were previously performed using a not isotopically enriched material. The first part consisted in the production of enriched targets of ^{90}Zr, using a thin aluminum film as backing, in-

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stead of the usual carbon, in the EDWARDS-E12E system (Figure 3). In this system a tungsten crucible of 3.0 mm diameter was used, under a pressure of 2 10^{-5} Torr. During the evaporation process part of the material formed an alloy with the crucible. The total amount of isotopically enriched material used was about 40 mg. Figure 2 represents the spectrum obtained in the preliminary data acquisition with this target, indicating the importance of new investments in the production of clean targets.

Sandwiches of thin gold films (Au+Zr+Au) are produced in order to avoid the oxidation of the zirconium in the second and third parts of the test. In these new tests, the UNIVEX450 system (Figure 4) with a refrigerated copper crucible, 20 mm diameter, was used in an environment at a total pressure of 1 10^{-6} Torr and a oxygen partial pressure of 3 10^{-8} Torr. The isotopically enriched material spent in this system was about 20 mg.

The second test consisted in the evaporation of zirconium on a previously produced film of gold. In sequence, without breaking the vacuum, only changing the crucible, the gold was evaporated. Most of the thin films of gold broke during the process in consequence of the high temperature.

Finally, in the third test the zirconium was evaporated on a microscope slide with a thin film of gold previously deposited. In sequence the sandwich was completed as described in the second part. The sandwich film, Au+Zr+Au, was released in hot distilled water.

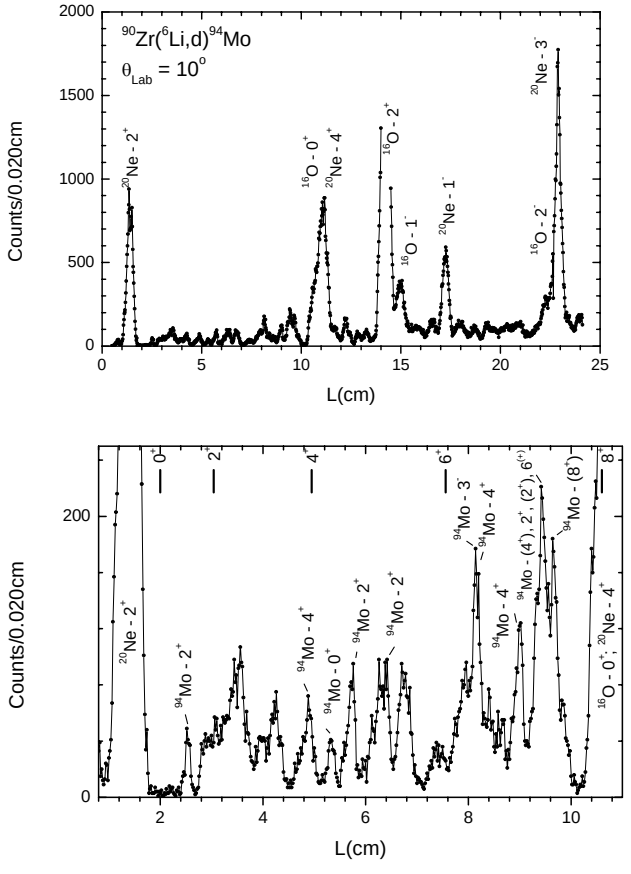

Figura 2 - Spectrum obtained in a preliminary data acquisition. The second graph is the same spectrum expanded.

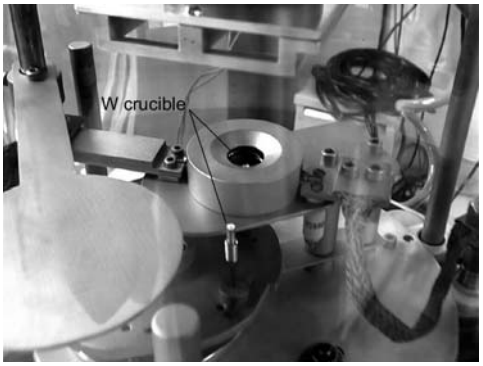

Figura 3 - The EDWARDS-E12E system.

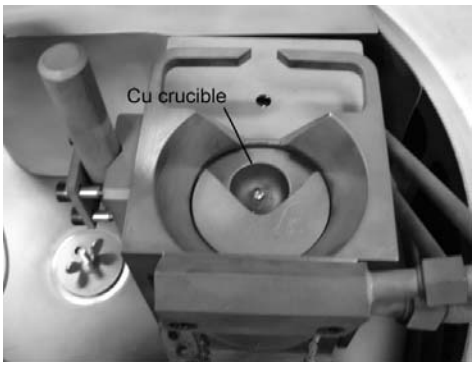

Figura 4 - The UNIVEX450 system.

3. RESULTS

The RBS technique [4] was used in order to quantify the contaminants of the films, choosing one target produced in each test. The RBS measurements were performed with a 2.2 MeV ^{4}He beam, using a silicon detector at 170° in the laboratory frame. In all acquisitions a 20μC integrated charge and a 1.4 msr solid angle were used. The spectra were analyzed through the simulations performed by the RUMP software. The energy resolution achieved was 20 keV. The results of the A, B and C targets, associated with the first, second and third tests, respectively, are represented in Table 1 and in Figure 5.

Table 1 presents the thicknesses of the principal elements in the films with an uncertainty of about 7%. It is important to note that the B and C targets are not the thickest produced, and both were chosen only to characterize each methodology. The thicknesses of the three targets are about the same (~ 45 μg/cm^2). In Figure 5 are shown the spectra measured with RBS in comparison to the model, and the discriminated elements in the analysis are indicated.

Considering the ratio between the O and Zr thicknesses, the most favorable case is the film A, although in this process there are the presence of several contaminants as seen in Figure 2. In addition, in this methodology the quantity of material spent was two times higher than in the other tests. Comparing the B and C targets, the referred ratio is almost the same. The advantage of the third process is the good efficiency of the film production. Furthermore, while in the second test the majority of the gold films broke, all films were released in the third process.

According to the number of Zr and O atoms, in B and C films this proportion is one per two, while in the A film it is two per one. This fact is essentially related with the evaporation rate and with the residual oxygen partial pressure. On one side, with the EDWARD-E12E system is possible to achieve a high evaporation rate, on the other side, the UNIVEX450 system has a very clean and controlled environment, and in addition the isotopically enriched material spent is almost the half.

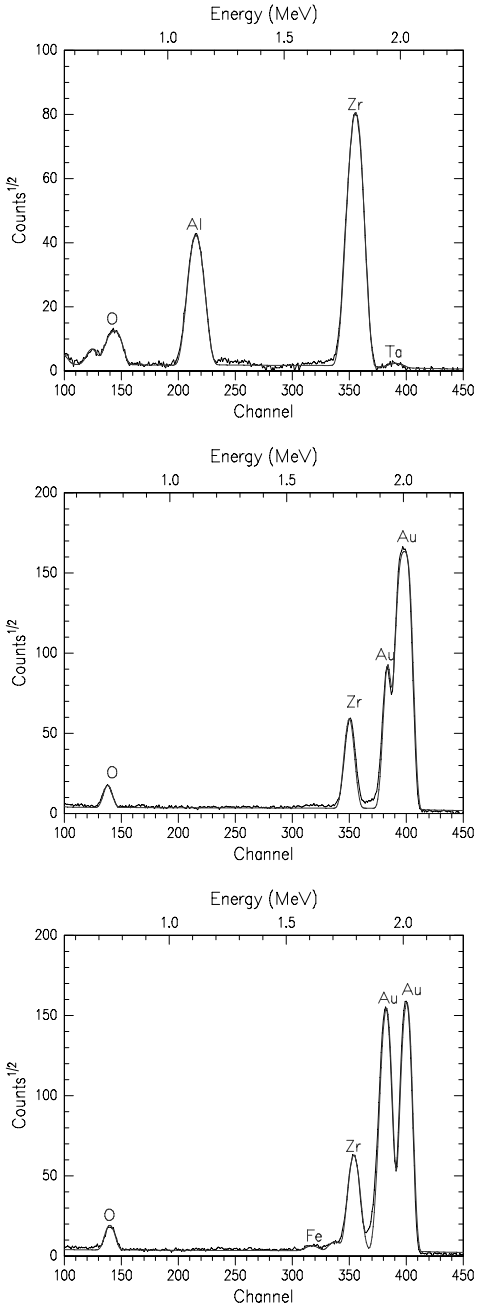

Figura 5 - Spectra of A, B and C targets obtained through the RBS technique.

Tabela 1 - Thicknesses in atoms per square centimeter with an uncertainty of about 7%, obtained for A,B and C targets through the RBS technique.

	A	B	C
		10^{15} at/cm^2	
Zr	291	94	129
O	169	206	291
Au	-	320/50	210/200
Al	750	-	-

4. CONCLUSIONS

Up to now, the most favorable test consists in the production of sandwiches of thin golden films (Au+Zr+Au) on a microscope slide using the UNIVEX450 system with a refrigerated copper crucible. The methodology presents a good efficiency in the film production in a very clean and controlled environment. Almost one half of the enriched material was spent, although, in consequence of the lower evaporation rate, the proportion of Zr and O atoms is one per two.

New efforts will be made in order to produce thicker films (~100 μg/cm^2 or ~660 10^{15} at/cm^2) and to achieve a higher evaporation rate to minimize the presence of oxygen, improving the target/contaminate ratio.

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