DEVELOPMENT OF THE FABRICATION METHOD OF SOME NUCLEAR TARGETS BY VACUUM EVAPORATION.

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ABSTRACT

Thin nuclear targets are usually obtained by vacuum evaporation and condensation of chemically pure or isotopically enriched material. The fabrication methods of Ba, K, Co and Si targets are described.

1. INTRODUCTION

A target laboratory is installed to supply targets for all internal and external customers of the Pelletron Accelerator(1). The carbon stripper foils used in the accelerator are also produced. The development of new methods to fabricate mechanically stable and contaminant free uniform nuclear targets has been carried out. Thin targets are usually made by vacuum evaporation on to a carbon or a plastic backing attached to a convenient target frame. The evaporation unit is a common commercially available one and described elsewhere(2).

2. THE METHOD

The vacuum evaporation of a chemically pure compound is carried out by Joule heating or by electron bombardment method(3). The boat or the crucible where the material is heated must be properly chosen to avoid the possibility that an alloy will be formed. Also, when the available power is enough to evaporate the container, the target will be contaminated by this material. If self supporting targets are needed, the material is evaporated and condensed directly on previously polished glass slides with some convenient release agent. By cutting the thin film into small pieces (on the glass) and immersing properly in water, the film pieces will release and float. Each piece is then gently fished on the target frame.

Many successful attempts are reported in the literature(4) and must be studied in advance, although sometimes it is impossible to reproduce exactly the same procedure. There is also one compilation in a diskette(5) with the main references related to the nuclear target fabrication methods which are very useful as a start point.

The choice of the appropriate release agent must be done using NaCl, CsI, RBS (detergent) or betain (sugar). The chemical characteristics of the material must be taken into account. The target may contain both separate atoms and molecules of the chemical compound used in the evaporation. If the compound is soluble in water, immersion in water must be avoided, so that the film must be deposited directly on some backing. In some cases, the evaporated chemical compound can react with some release agent. The fishing procedure may also introduce contaminants although deionized water is always used, for example, oxidation can not be avoided. If C backing is tolerated, thin carbon foils (5 to 10 mg/cm2) are used in the evaporation to receive the target material, instead of the glass slides. It is known from previous attempts that RBS release agent is affected by high temperature. If high power is needed to evaporate a material, the glass slides with RBS must be cooled using a large and cool block of Cu on it or by a water cooled system. If those attempts are not successful and the targets can not be released from the glass slide, some appropriate backing must be used.

High uniformity in the thickness of deposition is required so that beam fluctuations will not affect the precision of the data taking of nuclear reaction measurements. If the distance between evaporation source and substrate is too small, the efficiency will be high but the uniformity will be compromised. On the other hand, for large distances although the efficiency will be lower the obtained uniformity guarantees good data quality.

All the tests that must be performed in order to determine a good method are carried out using chemically pure material. When enriched isotopes are required, only in the final run the special expensive material is used. All the test runs are carried out with the same chemical compound of the enriched material.

3. RESULTS

3.1 BA TARGETS

^{136}Ba targets of 30 to 70 mg/cm^2 thickness were obtained evaporating BaF_2 by the electron bombardment method using 20 to 50 W power, Ta crucibles and target frames with 5-10 mg/cm^2 C backing. The heating process must be carried out very slowly to prevent the material to jump out. A shield is used between the vapour source and the substrates, which is open only when the power reaches ~15 W.

^{139}Ba targets of the same thickness were obtained by the same method, using $BaCO_3$. When the carbonate is heated up to ~8 W it is likely that it decomposes into $BaO+CO_2$ because the pressure inside the bell jar goes up to 10^{-3} torr. The power is maintained until the vacuum is recovered (10^{-6} torr). Once the heating process is continued, a faint characteristic green beam lines appear when the power reaches ~30 W. The lights in the laboratory must be turned off to be

able to distinguish the exact moment. The shield between the vapour source and substrates are then opened and the power raised until ~50 W is attained. The carbonate form is more difficult to evaporate because it is more hygroscopic than fluoride and tends to jump out of the Ta crucible.
Ba isotopes targets must be stored in dry N_2 or Ar otherwise the Ba film will become mechanically unstable and easy to break. It is known that Ba tends to recover the original chemical form in air.

3.2 MULTIPLE TARGETS, SI AND CO TARGETS

Multiple targets of K, Mg, NaCl, Al, Si and Co were obtained by successive evaporation of the different materials. K_2HPO_4 was evaporated by electron bombardment using Ta crucible and very high power ~150 W, but no K or P was found on the target. Ta must be a very probable contamination because of the high power. Formerly both K and P were required. To obtain K target KCl was evaporated in Ta crucibles using the electron bombardment method and very low power (~10 W) on nuclepore rings. Mg, NaCl and Al were evaporated one after the other using Joule heating.
Si and Co are evaporated by the electronic bombardment method using C crucible. Si has a very high fusion temperature and Co forms an alloy if Mo, Ta or W crucible are used, therefore C is chosen. Chemically pure Co and Si are used in the metallic form. The crucible must be previously prepared because pure carbon is porous and a large quantity of material must be used. Co or Si is absorbed during the heating procedure until saturation is reached. For Co it is possible that an alloy is formed because the fusion temperature becomes very high. It is known that Si forms an alloy with carbon. Before saturation, many sparks of fire are seen for Co. When the absorption process saturates and more material is put into the crucible it forms a metallic, glitting, uniform and compact piece. The crucible is then ready to be used as a vapour source. It can be used immediately or stored for a future use. The crucible material becomes brittle but can be used three or four times before it breaks. If a hard carbon piece is used, less material is needed until saturation is reached.
Several Si single targets and Co single targets were also fabricated on nuclepore backing just as described before without any adherence problems. The single targets must be prepared close to the use and stored in inert atmosphere.
In previous attempts it was verified that Co self supporting target can not be made on glass slides with RBS because the deposit are not uniform. If C backing is used the Co film attaches uniformly and is mechanically stable. Si has a strong affinity with glass and when evaporated on RBS it diffuses through the layer of this release agent so that it attaches to the substrate. CsI or betain must be used to get a self supporting Si target but the thin film is very brittle. Both elements attached to the multilayers target without any adherence neither breaking problems.

4. ANALYSIS

The estimated thickness of the targets is obtained by weighing the target frames with carbon backing before and after the evaporation of the target material is carried out. This procedure gives an estimate of the real thickness because other nuclei may be present and the precision of weight measurements in the analytical balance is of the order of 10 mg. The small target area reduces the total additional mass to the order of 50 mg, therefore reduces the precision of the measurement.
In some cases a thin Al foil is mounted together with the target frames in the evaporator but one has to assume that the attachment of the target material is equal to that on C substrate. Some Ba target thickness were determined using the 2 MeV a particle beam produced in the 5SDH tandem accelerator of the LAMFI* Laboratory through the Rutherford backscattering method (RBS)(6). The backscattered particles are detected in a surface barrier detector, positioned at 170o in lab-system.
The carbon backing thickness' were determined by optical transmitance through a previously calibrated home made apparatus(7).

5. CONCLUSION

Many different targets were obtained to be used in various nuclear physics measurements in pure and applied physics. The obtained targets are mechanically stable during data acquisition. The uniformity all over the target area was sufficiently good and no target evaporation was detected. The established fabrication methods is reproducible.

6. REFERENCES

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