EVAPORATION OF TARGET MATERIALS OF LOW VAPOR PRESSURE ON VERY THIN CARBON BACKINGS BY ELECTRON-BOMBARDMENT

P. Maier-Komor

Physics Department, Techn. Universität München, Germany

INTRODUCTION

Thin and uniform targets are needed for high-resolution spectroscopy, excpecially with heavy ions. Typical target thicknesses are of the order 5-50 $\mu g/cm^2$ which precludes the use of self-supporting foils. Therefore thin backings have to be used, mainly carbon backings. The preparation techniques are unproblematic if the isotopes can be evaporated at moderate temperatures from a boat or heated crucible. Damage to the carbon backing can be avoided by a thermic shield and by limiting the evaporation rate.

Metals with very low vapor pressures can only be evaporated by electron bombardment from a cooled crucible. Because of the large primary beam energy special precautions have to be followed in order to prevent damage to the backing material.

We have studied the influence of energy dissipation in the vapor source on the preparation procedure, especially heat conduction, convection and radiation.

EXPERIMENTAL

Using isotopes the amount of evaporation is very small. Therefore, when using commercially available electron guns only a small fraction of the emitted electrons actually impinge on the evaporant. Typically the cross section of the beam is of the order 3 x 7 mm and consequently the effective intensity is too small to evaporate metals of low vapor pressure.

We are working with a Veeco type VeB6 electron source which utilizes the Pierce principle. The electrostatic deflection angle is 40° (Fig. 1). In 7 to 13 cm distance from the source the diamter of the beam is about 3 mm. The maximum acceleration voltage is 20 kV and the maximum power is 6 kw. Since the manufacturer doesn't offer a crucible capable of withstanding the high power density produced by this source (85 kw/cm^2) we have developed a suitable water cooled crucible. The crucible is simply a flange with a spherical cavity (Fig. 1). It is bolted to the cooling water feed-through with an O-ring seal. Is is therefore very easy to replace, making feasible the use of separate crucibles for different isotopes. Use of a liner was ruled out because of the difficulties involved in controlling the contamination of the evaporant.

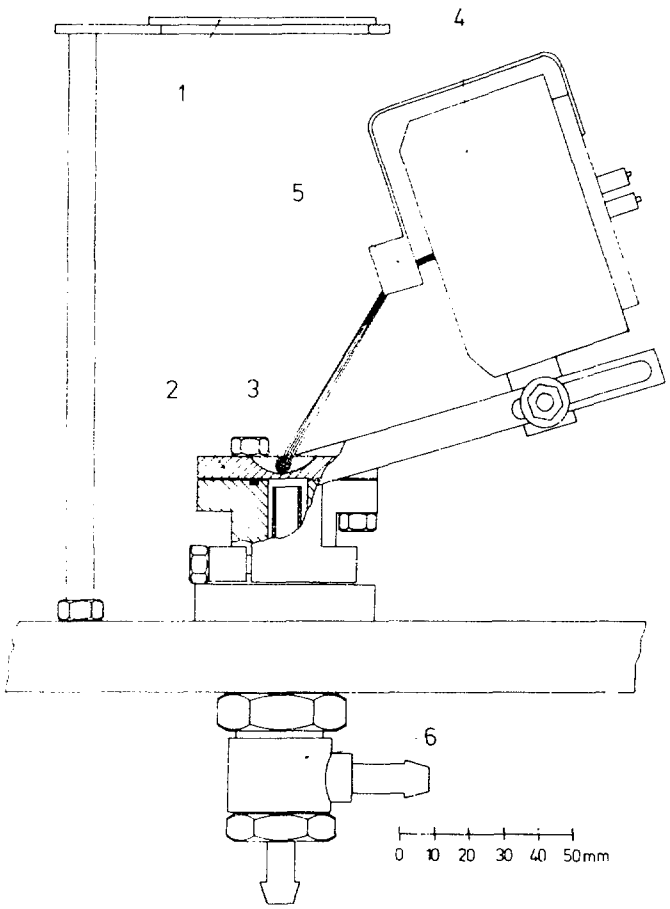

Fig.1
Constructional Details of the Electron Gun
1 Substrate Mount
2 Copper Crucible
3 Evaporant
4 Electron Source
5 Deflector
6 Water Cooling

In order to reduce heat loss due to conduction in the crucible itself we also tried crucibles made of tungsten and molybdenum. Both were turned on a lathe and had the same geometry as the copper crucible. The tungsten crucible proved to be unsatisfactory since the high temperature gradients involved tend to crack this rather brittle material. The formation of these hairline cracks is signaled by rapid deterioration of the vacuum. Molybdenum on the other hand, is very resistant to this effect. However, although the heat conduction of molybdenum is only about the third of that of copper, the measured evaporation rates were but slightly higher than those obtained with the copper crucible. Heating of the target is mainly due to two contributions:

1) heat radiated from the evaporant
2) condensation energy, i.e. heat liberated as the target builds up.

Heat absorbed due to radiation from the evaporant remains fairly constant during the evaporation process. In the beginning the carbon backing is quite transparent and absorbs little heat. As the target material builds up the heat

is reflected from the shiny surface. With ruthenium targets, for example the temperature rise is about 40°K x^{-1}

($S = \cdot\cdot\cdot (T^4 - T_o^4)$; T = 2900°K ε = 0.25, absorption coefficient = 1%)

neglecting the heat radiated by the target itself. Here the distance between the crucible and the target is about 12 cm. On the other hand the temperature increase due to the condensation energy approaches the same value (40° s^{-1}) for a condensation rate of 0.05 $\mu g/cm^2$ s. Evidently, higher condensation rates should be avoided. However for some metals (e.g. niobium) condensation rates of this order are only obtained at temperatures considerably above the melting point. With a water cooled crucible this requires a drastic increase in input power.

This becomes evident if one considers the heat losses after exceeding the melting point. Below the melting point the effective contact area between the evaporant and the crucible is very small so that the thermal resistance of the interface evaporant crucible is quite high. Above the melting point the evaporant comes into more intimate contact with the crucible. The effective contact area increases with rising temperature due to the decrease in surface tension of the molten evaporant. Consequently the heat transfer to the crucible increases over-proportionately with rising temperature. Conversely a decrease in temperature as induced for example by interrupting the electron beam, leads to a considerable increase in heat resistance to the crucible.

Above the melting point the conduction losses also increase due to convection within the molten droplet. The corresponding energy flux rapidly rises from zero at the melting point to the order of magnitude of the pure conduction loss and then seems to increase as a linear function of temperature.

In order to obtain adequate evaporation rates with a minimum of input power we have developed a control system which permits use of a pulsed electron beam. The filament current is kept constant and the beam is pulsed by switching the high-voltage. The energy impacted to the evaporant is controlled by varying the duty cycle of the pulses. The beam is interrupted as soon as the evaporant is completely molten. The intensity of the electron pulse is determined by measuring the evaporation rate with a quartz crystal thickness monitor. The upper limit is calculated in advance considering both the condensation energy[1] and the heat radiated by the evaporant[2]. As a rule of thumb, both of the contributions should not result in a temperature rise in the target exceeding 80°K s^{-1}. The beam must be switched off long enough so that the molten evaporant can solidify and that both the evaporant and the target can cool off.

With these techniques we have prepared plane, homogeneous targets of Mo, Ta, Nb, W, Re, Ru, Os, Zr, Hf, etc. on carbon backings of 3-5 $\mu g/cm^2$ [3]. Up to now thicknesses ranged up to 100 $\mu g/vm^2$, however it is possible to achieve greater thicknesses.

REFERENCES

1) R.E. Honig and D.A. Kramer, RCA Review Vol. 30, No. 2 (1969).

2) L.R. Koller, Scientific Foundations of Vacuum Technique, New York, London, John Wiley & Sons Inc. (1962).

3) P. Maier-Komor, Nucl. Instr. and Meth. 102 (1972) 485.