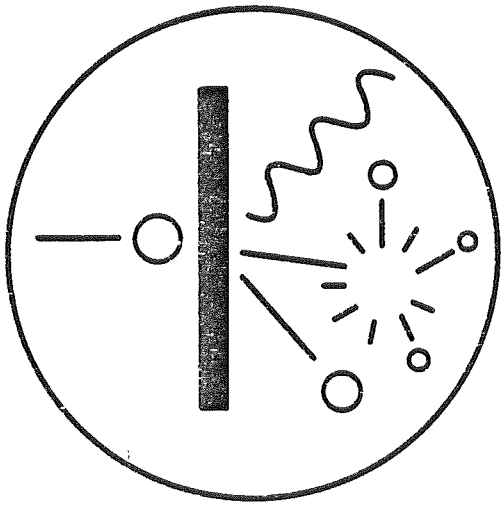
# INTERNATIONAL NUCLEAR

# TARGET DEVELOPMENT SOCIETY

# NEWSLETTER



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# Editorial

Dear Colleagues,

We are approaching the 13th World Conference of the International Nuclear Target Development Society (17 - 19 September 1986) and we know that Jo Gallant and Peter Dmytrenko are sparing no effort to make it a succesfull meeting.

This 13th Conference will again be an opportunity not only to exchange technical know-how but especially to strengthen old and new friendships and I believe that this is one of the most important things in live.

I hope to meet you all in Chalk River.

J. VAN AUDENHOVE
President

*Progress Report*

*Centre de Recherches Nucléaires, Groupe PNPA*
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*A. Meens*

During the past year we prepared by rolling :

- $^{100}Mo$ of 1 mg/cm$^2$
- $^{110}Pd$ and $^{107}Ag$ of 500 µg/cm$^2$
- a few rare earths and their isotopes including Nd, Sm, Gd, Tb, My, Ho and Er of 300 to 400 µg/cm$^2$
- $^{24}Mg$ of 200 µg/cm$^2$.

In order to prepare 0.3 mg to 2 mg/cm$^2$ thick targets on thick backings, we used the following technique : A few microns of the backing material were evaporated at the same time on the self-supported target and on the backing. The two granular evaporated layers were then put together and passed through the rolling mill in a stainless steel envelope. This method produces a very good sticking. With it, we have made :

- $^{64}Zn$, $^{66}Zn$, $^{74}Ge$, $^{146}Nd$, $^{145}Sm$, $^{160}Gd$, $^{164}Dy$, $^{176}Yb$ on Pb,
- $^{66}Zn$, $^{110}Pd$ on Au,
- $^{66}Zn$ on Ta.

Targets of $^{40}Ca$, $^{42}Ca$, $^{44}Ca$, $^{88}Sr$, $^{126}Te$, $^{128}Te$, $^{130}Te$, $^{140}Ce$ $^{39}KI$, and $^{41}KI$ were prepared by simple evaporation on Pb.

Self-supported 1 mg/cm$^2$ Ca targets have been prepared and conserved individually in Ar without any deterioration in sealed glass ampoules.

Re of 300 µg/cm$^2$ has been evaporated on Al of 100 µg/cm$^2$.

More routinely we prepared :

- by evaporation, self-supporting Ta, W, Ir, Pt, Au, Pb, Bi of 100 to 300 $\mu g/cm^2$ or on C backings
- multi-layers with Fe and Gd ferromagnetic films
- 500 cracked, slacked C strippers
- $Fe_3C^{13}$, $AgS^{34}$, $Ni^{68}$, $Ge^{74}$ sputter targets for the MP source.

For $\alpha$-particle measurements, thin layers of minerals, or mineral solutions, were prepared on mylar or stainless steel by centrifuging, electrospray, electroplating and evaporation.

This text is a translation of my contribution to our 1985 Annual Report.

# MATERIALS RESEARCH, DEVELOPMENT, AND PRODUCTION BY THE ISOTOPE RESEARCH MATERIALS LABORATORY AT THE OAK RIDGE NATIONAL LABORATORY*

W. S. Aaron

During the past few months, the Isotope Research Materials Laboratory (IRML) has completed the following research, development, and production efforts.

1. Fabricated a large quantity of calcium metal.
2. Fabricated plutonium standards for ORNL's Contact-Handled Transuranium Waste Drum Assay Facility (CH-TWDAF).
3. Developed improved process for recovery of $^{14}C$ from AlN pellets.
4. Developed procedure for preparing $Pb^{34}S$.

The reduction-distillation of three large batches of calcium totaling 277.54 g was completed in January 1986. The calcium batch size was considerably larger than what the existing setup could handle; thus, a scaled-up reduction-distillation system was used. The vacuum system used was an oil-diffusion pumped "box coater" that measured 32 in. on each side. The chamber was pumped by a 10-in. oil-diffusion pump that contains a water-cooled baffle. The vacuum system typically operated in the $10^{-7}$-torr pressure range during the distillation and at times dropped in the $10^{-8}$-torr range.

The starting material was large pieces of $CaCO_3$. This was converted to CaO by placing the material in a platinum dish, heating to approximately 1100°C for 3 h, and then cooling the material in a desiccator.

The calcium metal was prepared by a reduction-distillation process that involved high-temperature reduction of the CaO using zirconium as the reductant. The CaO and zirconium reductant were pressed into pellets at 5000 psi to provide contact between the zirconium reductant metal and the CaO. A 30% stoichiometric excess of zirconium metal was present in each 3.5-cm-diam by 2.4-cm-high pressed pellet. Each pellet contained 19.5 g of CaO (13.92 g of calcium) plus 20.6 g of zirconium metal. Five pellets were used for each reduction.

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*Research sponsored by the Division of Basic Energy Sciences and Division of Nuclear Sciences, U.S. Department of Energy, under contract DE-AC05-84OR21400 with the Martin Marietta Energy Systems, Inc.

The pellets were placed in a tantalum-metal reduction-distillation column, and this column was placed in a vacuum chamber. Temperatures necessary for the reduction reaction and the distillation of the product were achieved by radiofrequency induction heating. The reduction reaction for calcium started at approximately 1000°C; the temperature was slowly raised to 1250°C over a period of 14 h. The collection efficiency was approximately 83%.

A method to produce plutonium standards for the CH-TWDAF was developed, and 45 standards were prepared containing 0.1 to 10 mCi of plutonium (94% $^{239}Pu$, 6% $^{240}Pu$). The sources consisted of a porous alumina substrate 16.5 cm in diameter by 18.7 cm tall into which the desired quantity of plutonium was loaded as an aqueous solution. The plutonium was then precipitated in place, and the water was removed in a drying furnace. The loaded, dry substrate was bagged out of the glove box in heavy plastic and placed in an aluminum can 16.8 cm in diameter and 22.8 cm tall. The can was sealed with epoxy. These sealed sources can now be used in any desired combination to standardize the assaying equipment for the quantity and general configuration of waste drums being analyzed.

An improved process for the recovery of $^{14}C$ from AlN pellets irradiated in the High Flux Isotope Reactor (HFIR) was developed. Hot perchloric acid was used to decompose the AlN pellets by the following reaction:

$$AlN + HClO_4 \rightarrow Al(ClO_4)_3 + NH_4ClO_4$$

In the process, the entrapped $^{14}C$ is expected to be swept from the hot solution by an inert gas ($N_2$) in the form of $CH_4$, CO, or $CO_2$. Several bench-top experiments were carried out using the perchloric acid process, and the following conclusions were reached.

1. The reaction is faster than the process previously used and can be completed in one working day.
2. The process temperature must be above 130°C.
3. Whole pellets can be processed (no need to break them up).
4. Tantalum (one of the materials of construction in the reactor vessel) is unaffected in the process.

A procedure for the preparation of $Pb^{34}S$ was developed and tested on normal material. The powdered lead and sulfur were mixed in a quartz ampoule,

sealed under vacuum, heated to 1000°C overnight, and cooled. After successfully forming PbS, the procedure was repeated with 800 mg of $^{34}S$ which was then loaded into tantalum cups and melted at >1200°C to yield two targets for the ORNL Physics Division.

# Stress Relief in the Production of Thick Carbon Foils

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The maximum thickness of carbon foils produced by evaporation from a vacuum arc is typically limited by their compressive stress. This stress causes such foils in the thickness range about 15-50 micrograms per square centimeter to be sensitive to the effects of water vapor, in that foils on parting agents stored in the laboratory environment develop a matte appearance as they separate slightly from their substrates, and innumerable tiny bubbles appear. Macroscopic areas of foils often separate from their substrates during evaporation when surface densities in the range 60-90 micrograms per square centimeter are reached. Further thickening then results in the development of large bubble-like formations that subsequently break into fragments.

Stresses cause other unfortunate effects. The substrate may be deformed by the stress in the overlying film (Röll,1976). Gradients in the stress often cause foils to curl into tightly wound unusable tubes when the foils are removed from their substrates. Foils may part from their substrates spontaneously during storage, so that the experimenter finds them later as only a pile of scraps.

These stresses have been known for many years and are not limited to arc-evaporated foils; cracked ethylene foils show similar stresses that limit their thicknesses to typically 1-2 micrometers (Enke, 1985).

Baking freshly-produced foils at 80 degrees Celsius for several hours sometimes improves their usability, presumably because the parting agent becomes sufficiently plastic that it flows to reduce the stresses in the carbon foil. However some detergents, when used as parting agents, become insoluble under such heating and the foils become unremovable.

Although the stresses persist for many weeks or months when a foil is deposited onto a clean hard substrate, they usually relax (at least in part) at room temperature within a few days when they are deposited onto a soaped and polished substrate. A foil can then be built up to several hundred micrograms per square centimeter by successive evaporations spaced at time intervals of a few days.

There are disadvantages to this procedure: The thickness is difficult to monitor when successive evaporations are carried out at long intervals. The foils pick up impurities from the atmosphere each time they are removed from the vacuum system; hence such foils may have impurity levels of several atomic percent of oxygen and hydrogen. The necesssary relaxation does not always occur. When thick foils are made, many of them may still be lost during production and storage because of residual stresses.

We noted many years ago that occasionally a foil would be made with unusual characteristics: instead of developing the matte appearance that typically occurs at surface densities above about 20 micrograms per square centimeter, some foils stayed mirror-smooth to much greater surface density, even in the laboratory environment. This suggested that the stresses were avoidable.

To check whether the angle at which the carbon atoms struck the substrate was an important factor, we constructed the test rig shown in Fig. 1. The geometry was such that the thickness of carbon was expected to be the same at every point around the circle if the emission of carbon from the arc was proportional to the cosine of the angle between the emission direction and the plane of the arc. We had already established that such proportionality was followed by our arc (Olivas et al.,1977).

We made a series of evaporations onto glass slides previously coated with a detergent [Creme Cote (TM), manufactured by James Varley and Sons, St. Louis, MO] and polished thoroughly, and determined that the angle of incidence was indeed an important parameter. At angles of incidence greater tnan 40 degrees the stresses were noticeably reduced, so that coatings could be made much thicker than at normal incidence. The coatings stayed shiny for long periods of time and showed little inclination to break away from their substrates. They also floated off somewhat more slowly than foils evaporated at normal incidence.

Such coatings have their own disadvantages: They are less uniform in thickness than coatings deposited at nearly normal incidence. It requires a longer time to deposit them; mounting them in an evaporator and monitoring their thicknesses during evaporation is more difficult. For applications in which extreme smoothness is important, however, the method provides foils that are significantly improved over conventional foils.

Parts of this work were supported by Department of Energy SBIR Contract #DE-AC03-83ER80070, Mod. A002.

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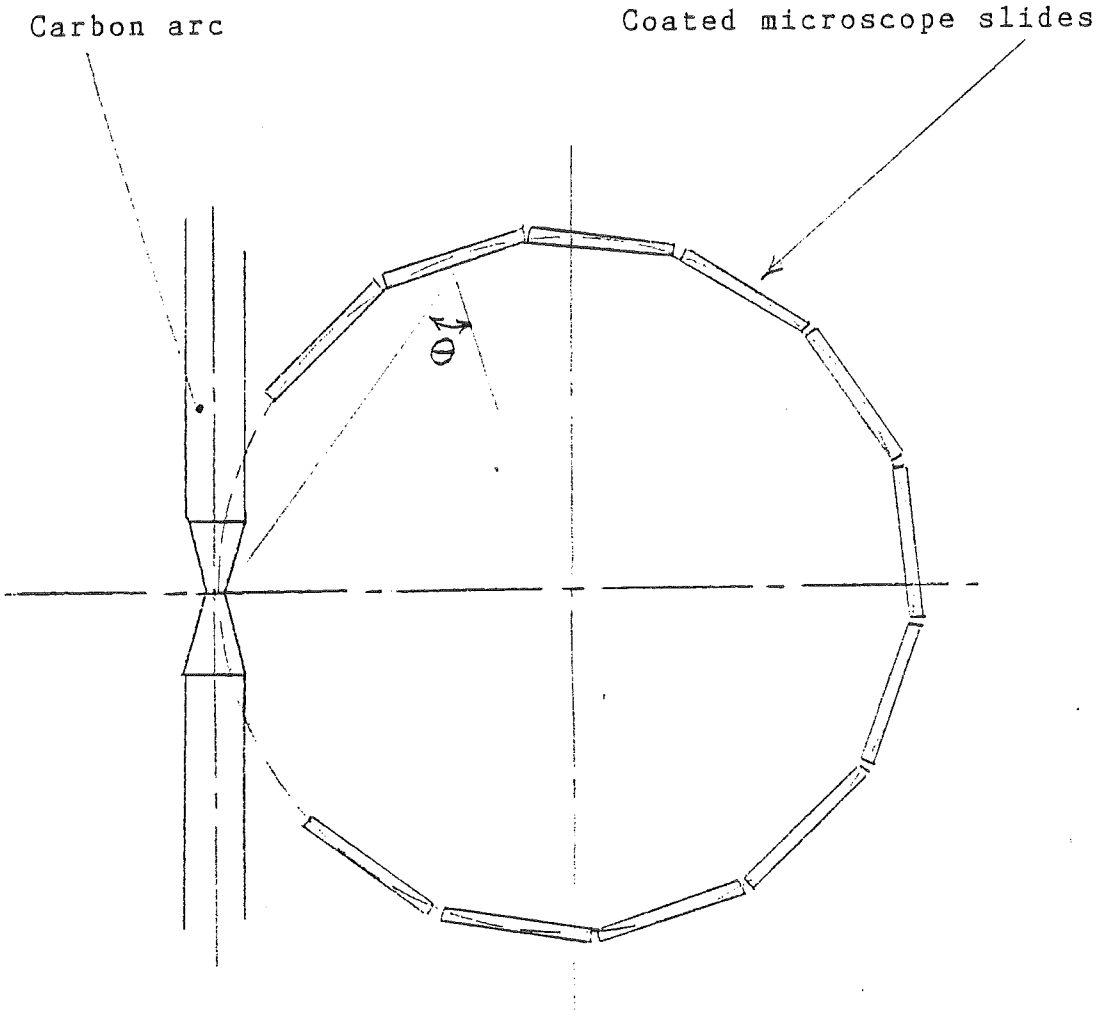


Figure 1 Schematic diagram, not to scale, of the apparatus used to coat simultaneously several substrates with evaporated carbon films having nominally the same thickness but different angles of incidence (θ).

# The preparation of Carbon pellets

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During the I.N.T.D.S. Conference in Antwerp, the preparation of carbon pellets from powders was discussed. Since attempts to prepare pellets from pure carbon had failed so far, it was suggested to mix the carbon powder with sugar before compressing it. This method, however, is only suitable, when the purity of the carbon pellets is not a critical factor.

Since reasonable pellets have been made with the Utrecht powder press for many elements and compounds, it seemed worthwhile to apply the same technique to powders of natural carbon, $^{12}C$ and $^{13}C$.

## Procedure

The powder press used for these tests is shown in fig. 1. The die consists of a Widia cylinder (no. 3 in the figure) and two Widia rods (no's 4) with diameter 4 mm which fit tightly in the cylinder. The lower rod is fixed in the cylinder, whereas the upper rod compresses the sample as pressure is exerted on the top of the press. The upper and lower halves of the press come apart to allow the cylinder to be filled with powder. The pellets can be taken out of the apparatus by disconnecting the removable collar (no. 9) and forcing the two plungers (no.'s 4 through 8) downward with respect to the housing.

The carbon powders were compressed at a pressure of $32 \times 10^8$ Pascal for one minute. In this way a pellet of 1 mm thickness was obtained. Unsuccesful attempts were made to prepare thicker pellets by first packing the powder in the cylinder with a glass rod. After exerting a pressure of $32 \times 10^8$ Pascal a few carbon pieces were produced, but never a coherent pellet. Repeated application of pressure did not improve this situation. Therefore, when thicknesses greater than 1 mm are required, one must stack

several 1 mm pellets together.

The 1 mm pellets thus obtained are used in the beam-stop crucible of our sputtering unit, type Sletten and Knudsen (1), to prepare isotopically pure $^{12}C$ and $^{13}C$ targets.

Pellets of other materials

Many pellets of other materials have been prepared with the same powder press. The various pieces were cleaned between operations by wiping away the powder residue with optical lens tissues and then emersing them in an ultrasonic bath filled with freon for five minutes. It is possible to get 4 mm thick pellets of almost all other materials.

Tables 1 and 2 list recommended pressures for various materials and mixtures, respectively. In each case the pressure was applied for one minute. The press is designed for a maximum pressure of $32 \times 10^8$ Pascal.

The pellets made from pure elements have been used in the beam-stop crucible of our sputtering unit (1). The pellets of $AlB_2$, AgCl + Ag, and Si + Cu have been used in the ANIS source of our 6 MV Van de Graaff Tandem (2). The remaining pellets were used in our inverted sputter source for Accelerator Mass Spectroscopy (2).

References

1. G. Sletten and P. Knudsen, Nucl. Instr. & Meth. 102 (1972) 459-463.
2. B.A. Strasters, A. Vermeer and N.A. van Zwol, Nucl. Instr. & Meth. 220 (1984) 109-111.

Table 1

Pressures recommended for the preparation of pellets from elements and compounds

| Material | Pressure ($10^8$ Pascal) |
|---|---|
| Ag | 8 a) |
| Al | 8 a) |
| $AlB_2$ | 20 |
| Au | 12 |
| C b) | 32 |
| $^{12}C$ c) | 32 |
| $^{13}C$ d) | 32 |
| Cr | 28 |
| Fe | 28 |
| Mg | 28 |
| Si | 28 |

a) At higher pressures the material becomes liquid and subsequent cleaning of the press is very difficult.

b) Natural carbon powder, purity 99.9995 %, delivered by Highways International, P.O. Box 153, 3740 AD Baarn, The Netherlands.

c) Enrichment 99.9%, delivered by Monsanto Research Corp. P.O. Box 32, Miamisburg, Ohio 45342, USA.

d) Enrichment 99%, also delivered by Monsanto Research Corp.

Table 2

Pressures recommended for the production of mixed pellets

| Mixture [a] | Weight ratio | Pressure ($10^8$ Pascal) |
|---|---|---|
| AlCl + Ag | 1 : 4 | 24 |
| $Al_2O_3$ + Cu | 1 : 10 | 16 |
| $Al_2O_3$ + Cu | 1 : 20 | 16 |
| C + Cu | 1 : 20 | 32 |
| Ge + Cu | 1 : 4 | 24 |
| NaCl + Cu | 1 : 2 | 16 |
| $PbCl_2$ + Pb | 1 : 2 | 8 |
| Si + Cu | 1 : 4 | 24 |
| $SiO_2$ + Cu [b] | 1 : 4 | 24 |
| $SiO_2$ + Cu | 1 : 9 | 24 |

a) The powders are mixed thoroughly in a mortar before compression.

b) These pellets were unstable. Therefore a new mixture has been made with a larger copper concentration.

MAXIMUM FORCE ON ROD : 40 000 N

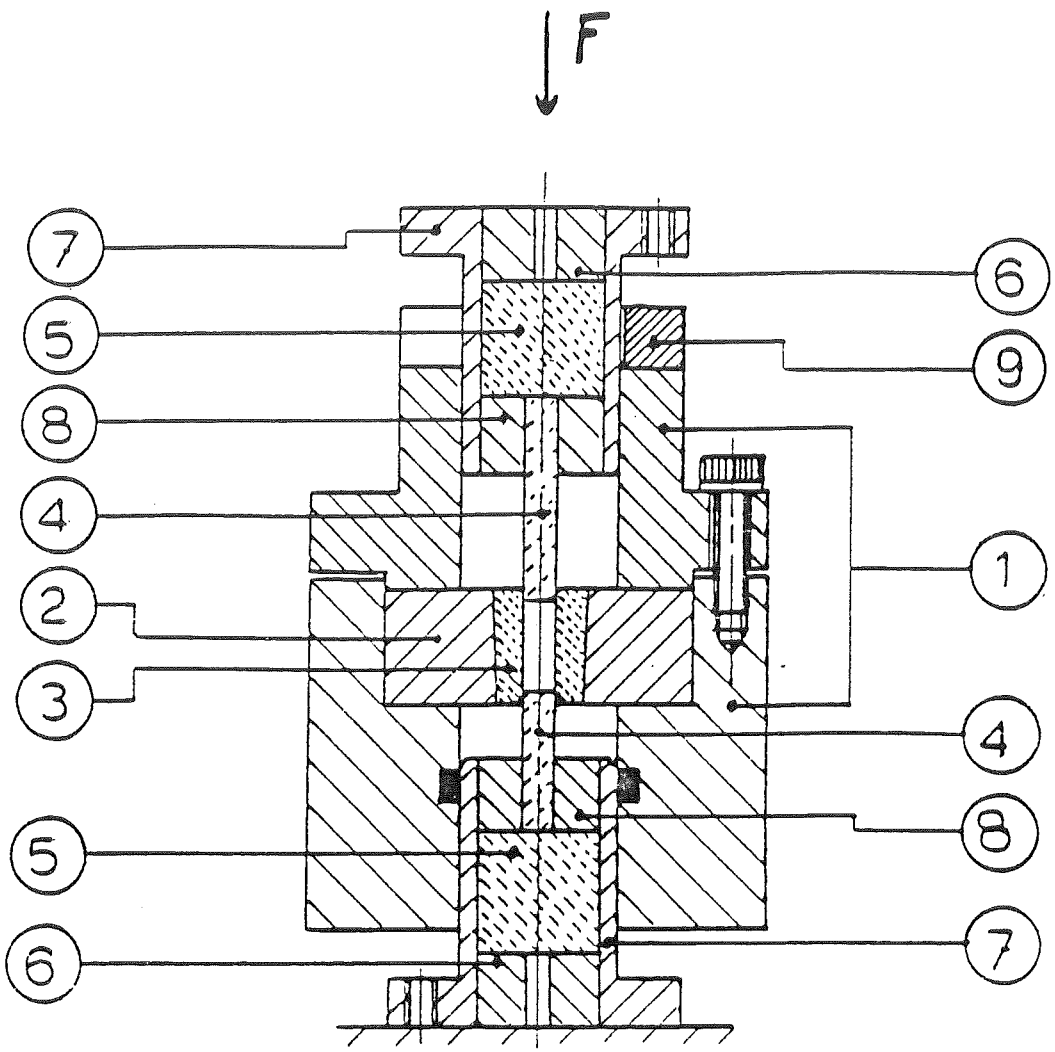


Fig. 1. The Utrecht powder press:

1. brass casing,
2. die housing hardened steel, hardness 58 Rochwell C,
3. widia housing,
4. widia rods,
5. widia core,
6, 7 and 8. stainless steel,
9. brass collar.

Activity report

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K.O. Zell

Efficient method to prepare thin silicon targets

13 mg enriched (Oak Ridge) $^{28}Si$ was pressed as a pellet and put into a tantalum tube of 2 mm inner diameter and 5 mm height which was heated from the top by an electron gun. This tube melted at the top when the silicon was evaporated but a small hole remained through which the silicon passed. On a glass plate coated with a mixture of betainmono-hydrate and sugar at a distance of 5 cm from the tube a 313 $\mu g/cm^2$ layer condensed and selfsupporting targets of 1.5 cm diameter could be made from it.

Thin target from small amounts of enriched platinum

As platinum alloys with all metals evaporation from a carbon crucible heated by an electron gun was tried but only carbon was evaporated. Better results were obtained using a mini crucible made from a 3 mm diameter carbon rod of 4 cm length in the center of which a 1.5 mm diameter hole with 2 mm depth was drilled. This rod was placed between two thicker rods (as reported by Maier-Komor [1]) for the evaporation of carbon) and heated by electric current. 3 mg of $^{196}Pt$ (Oak Ridge) were evaporated onto a glass plate coated with NaCl in 5 cm distance and self-supporting targets of approximately 80 $\mu g/cm^2$ looking grey were obtained. The carbon rod always broke at the place of the hole when all platinum was evaporated.

Thin chromium, cobalt, and nickel targets

300 $\mu g/cm^2$ chromium was made by evaporating it from a tungsten tube onto a copper foil heated to 350°C which was etched afterwards.
180 $\mu g/cm^2$ nickel was made by evaporation on a glass plate coated with KJ and heated to 300°C. 0.4 $mg/cm^2$ cobalt on 5 $mg/cm^2$ gold backing was made by evaporation from a tungsten boat in 7 cm distance. It was important to heat the gold by the radiation from the boat. Condensation on a cold gold foil resulted in large tensions.

Zirconium, molybdenum, and chromium targets made by rolling

Powder of russian zirconium and molybdenum isotopes and powder of natural chromium was molten by an electron gun and rolled to 3 mg/cm$^2$. Isotopically enriched chromium powder from Oak Ridge could only be molten with large difficulties as it tended to splash and the molten metal broke when we attempted to roll it.

KJ, BiJ, and Te targets made by rolling powder

30 mg KJ were distributed on a stainless steel plate on an area of 1 x 1.5 cm$^2$ and rolled in three passes to a 14 mg/cm$^2$ piece.

Te powder was rolled to a 10 mg/cm$^2$ piece between steel plates which were heated by a gas flame to such a temperature that there was no condensation of water from the flame any more on them.

For BiJ a 3 mg/cm$^2$ bismuth foil was rolled onto a stainless steel plate in such a way that it sticked. The powdered BiJ (120 mg) was distributed by ultrasonic vibrations in some milliliters acetone. The surface outside the bismuth foil was limited by an O-ring (4 cm diameter) not touching the bismuth foil and the acetone poured into it. After drying the foil with the powder was rolled two times resulting in a layer of 9.5 mg/cm$^2$ BiJ on 3 mg/cm$^2$ Bi.

Thin lead foils

25 mg lead were evaporated from a tungsten tube in 10 cm distance on a glass plate coated with a betain and sugar mixture. The 150 µg/cm$^2$ foils were floated in water and taken out as fast as possible. The inner edges of the frames were dried by a piece of paper and the rest dried fast under an infrared lamp. The foils are dissolved from the water if one works slow.

[1] P. Maier-Komor, Nucl. Instr. and Meth. 102 (1972) 585

ACTIVITY REPORT

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A.H.F. MUGGLETON

Two fine beam saddle field ion sources have been designed and constructed for the preparation of nuclear targets by ion-beam sputtering.

The use of ion-beam sputtering for producing nuclear targets has the following advantages over vacuum evaporation techniques.

i) The source produces a 2 mm diam. beam allowing the use of small amounts of rare separated isotopes.

ii) The source induces a temperature rise less than 10°C in the evaporant ensuring no damage to substrate or film release agent. The substrate can be mounted very close to the source ensuring a high sputtering efficiency.

iii) Source construction is simple, inexpensive and physically small (4 cm long by 4 cm diameter).

iv) Electrical power supplies are relatively simple and inexpensive compared to those needed for duoplasmatron ion sources.

v) There is no magnetic field, only an electrostatic one.

vi) High melting point low vapour pressure target materials, e.g. W, Os, Ta etc., and materials with poor 'sticking-factors', e.g. Zn, Cd, Mg, which are difficult to produce by vacuum evaporation, can be deposited using ion-beam sputtering.

An ion-beam source can also be used for thinning delicate foils and for cleaning contaminated target surfaces.

Tests with the first saddle ion source were highly encouraging although there was a tendency for HV breakdown and after running for $\sim$ 1 hour the source became quite hot which caused instability. By radiusing and polishing all sharp internal edges, more accurately aligning the electrodes and water cooling the outer casing the stability of operation was improved.

To date gold, tungsten, hafnium and platinum films have been successfully prepared. Attempts to produce titanium films were unsuccessful as the titanium did not adhere to the metal substrate.

It was observed that sputtering rate is critically dependent upon the surface quality of the material. A smooth, flat surface had a sputtering rate up to three times higher than that of a rough surface for the same material.

Targets Prepared

| Target Material | Starting Material | Method | Backing | Target Thickness ($\mu g/cm^2$) |
|---|---|---|---|---|
| Al | Al | a | SS | 20 |
| Au | Au | a | C & SS | 2-1000 |
| BaCℓ | BaCℓ | a | C | 20-100 |
| $^{134,136}$BaCℓ | $Ba(NO_3)_2$ | a | C | 20-100[g] |
| $Ba^{35,37}Cℓ$ | NaCℓ | a | C | 20-100[g] |
| $BiF_3$ | $BiF_3$ | a | C | 20-100 |
| C | C | a | SS | 2-50 |
| $^{48}$Ca | $CaCO_3$ | b | C | 100[h] |
| Ce | Ce | c | SS | 6000 |
| $^{140}$Ce | $CeO_2$ | d | SS | 6000[i] |
| $^{166}$Er | $Er_2O_3$ | a | C | 100 |
| Hf | Hf | p | Ta | 500 |
| $^{204}$Hg | HgO | e | Cu | 45000[j] |
| In | In | a | Cu&Bi | 2500 |
| La | La | a | C | 100 |
| $^{6,7}$Li | Li | a | C | 100 |
| $^{6,7}$LiF | $Li_2CO_3$ | a | C | 50-100[k] |
| $^{24}$Mg | MgO | b | C | 100[l] |
| Os | Os | f | Fe | 1500 |
| $^{208}$Pb | Pb | c | SS | 1500 |
| $^{208}$PbS | $Pb(NO_3)_2$ | a | C | 10[m] |
| Pr | Pr | c | SS | 2000 |
| $^{192,194,196,197,198}$Pt | Pt | a | C | 5-50 |
| $^{196}$Pt | Pt | p | Cu | 500 |
| $^{28-30}SiO_2$ | $SiO_2$ | a | SS | 150 |
| $^{32,34,36}Ag_2S$ | S | a | C | 100[n] |
| $^{144,147,149,150,152,159}$Sm | $Sm_2O_3$ | d | SS | 1500-6000 |
| $^{130}$Te | Te | a | C | 250 |
| $^{169}$Tm | Tm | a | C | 50 |
| $^{170,174,176}$Yb | $Yb_2O_3$ | d | C | 50-100 |
| $^{182,184,186}WO_3$ | W | a | Fe | 50[o] |
| $^{182,184}$W | W | p | Fe | 500-1000 |
| $^{90}$Zr | Zr | a | C | 5-50 |
| $^{90}ZrO_2$ | $ZrO_2$ | a | C | 5-50 |

a. Vacuum evaporation

b. Simultaneous reduction of the oxide and vacuum evaporation of resulting metal.

c. Cold rolling between stainless steel plates.

d. Reduction of the oxide using Th or La and simultaneous vacuum evaporation of the resulting metal. Metal condensed, collected and cold rolled between stainless steel plates.

e. Oxide reduced to the metal by heating.

f. Electroplating.

g. Compound chemically converted to barium chloride which was vacuum evaporated.

h. Carbonate converted to oxide which was reduced to metal by mixing with Ti powder and heating in Ta boat. Simultaneous reduction and evaporation.

i. $CeO_2$ converted to $Ce_2O_3$ which was reduced to the metal and cold rolled.

j. See footnote e.

k. Carbonate chemically converted to LiF before vacuum evaporation.

l. Oxide reduced to metal by mixing with Ti powder and hearing in a Ta boat. Simultaneous reduction and vacuum operation.

m. Nitrate chemcially converted to sulphide before vacuum evaporation.

n. Silver film evaporated onto carbon backing. When heated in a sulphur atmosphere the silver film was converted to $Ag_2S$.

o. Tungsten metal converted to oxide by heating in a $O_2$ atmosphere. Resulting oxide evaporated from collimated Pt boat.

p. Ion beam sputtering.

Carbon Foils

Approximately 750 stripper foils, 3-5 $\mu g/cm^2$ thick, were produced as well as routine carbon foils for target backings.

Work for other Departments

An investigation was undertaken for the Laser Group, Engineering Physics into the preparation of classically opaque metallic films which become highly transparent under certain conditions. Sandwich films of $MgF_2$-Ag-$MgF_2$ were vacuum deposited onto glass prisms. The most satisfactory technique was to deposit the initial $MgF_2$ onto the glass substrate which was maintained at 350° during the evaporation: Various $MgF_2$ and Ag film thicknesses were tried.

The following work was undertaken for other external groups:

i) Aluminium coated glass mirrors for Engineering Physics.

ii) Gold interferometer mirrors for the Plasma Group.

iii) Iron and nickel evaporations for the Laser Group.

iv) Gold on thin carbon backings for University of Newcastle.

v) Carbon stripper foils for DSIR, Lower Hutt, New Zealand.

vi) Laser mirrors for Fibre Optical Co.,