

EVALUATION OF TARGET PURITY USING VARIOUS VACUUM SYSTEMS

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ABSTRACT

Gold targets were prepared under various conditions using both a cryo-pump and a conventional diffusion pump evaporator system. Measurements were made at the Argonne Tandem Accelerator System to determine the purity of these targets.

CONF-8409150--1

DE85 000075

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*Work supported by the U.S. Department of Energy under Contract W-31-109-Eng-38.

1. Introduction

One of the principal objectives when producing thin films or "targets" to be used as part of an experiment has always been high purity. With the improved sophistication and sensitivity of the experiments this becomes increasingly important. This is especially true when small effects are being studied. Thomas et al. [ref. 1] have shown that the purity of the base material critically effects the quality of the target. They also found that thin films produced by vapor deposition using a vacuum system having a diffusion pump with a conventional roughing pump do contain significant impurity concentrations. Typical impurities encountered are carbon, oxygen, and nitrogen. Much of the carbon stems from backstreaming in the diffusion pump and is related to the pumping and evaporation time. The oxygen impurity is related to the evaporation time and is more pronounced with readily oxidizing material [ref. 1]. An improvement in the purity of the target can be obtained by using a hydrocarbon free vacuum system during the evaporation process. It should be kept in mind, however, that many of the high purity target foils will be used in experiments where a hydrocarbon free vacuum can not be guaranteed. Hydrocarbons can originate either from the use of a mechanical pumping system or from gases used in the detectors. In this contribution we report on several effects that can contribute to the carbon contamination of thin Au-foils.

2. Experiment

Thin self-supporting Au foils, $50 \mu\text{g}/\text{cm}^2$, were prepared using two different vacuum systems. One consisted of a NRC VHS6 oil diffusion pump [ref. 2] with a pumping speed of 2000- ℓ /s, a 400- ℓ /s Welch 1397B roughing pump and a large capacity liquid nitrogen cold trap. A Kronos quartz crystal thickness monitor [ref. 3] was used to measure all deposited thicknesses. The second system used a 1500 ℓ /s cryo-pump [ref. 4] and an oil free mechanical/sorption pump system [ref. 5]. In this way no oil was introduced into the system during the evaporation procedure.

The diffusion pump system was typically roughed to approximately 50 mTorr before changing to the diffusion pump, and then was pumped to $\sim 1 \times 10^{-6}$ Torr before starting the evaporation. The cryo-pump system was roughed with the mechanical pump to ~ 50 Torr, then pumped to 15 mTorr with the sorption pump, and finally to $\sim 3 \times 10^{-6}$ Torr with the cryo-pump. The pumping time of the cryo-pump was normally about one-hour.

Targets were prepared under various conditions using both the cryo-pump and diffusion pump systems as shown in Table I. The Au-targets were then transferred under normal pressure to the scattering chamber of a split-pole magnetic spectrograph [ref. 6]. The target chamber was pumped with a mechanical/sorption pump system and a Cryo Torr 7 [ref. 7] 1000- ℓ /s cryo pump to pressures of $2-9 \cdot 10^{-6}$ Torr. Due to the use of an O-ring type sliding seal gasket and the use of CF_4 in the focal plane detector the vacuum could not be kept hydrocarbon free. The contamination of the Au-targets by impurities was measured by scattering 30 MeV ^{12}C ions from the Argonne FN tandem accelerator on those foils. Typical beam currents were about 10 nA. Due to the different recoil energy ^{12}C ions scattered on Au, O, C have different energies and can thus be easily separated in the focal plane of the spectrograph.

3. Results

Figure 1 shows as an example the spectrum obtained for the scattering of ^{12}C ions on a $10\ \mu\text{g}/\text{cm}^2$ Au target evaporated onto a $10\ \mu\text{g}/\text{cm}^2$ C backing measured at $\theta_{\text{lab}} = 10^\circ$. In addition to the Au and C peaks, contributions from N, O, Mg and Cl contaminants can be observed. From the intensities of the spectrum shown in Fig. 1 the impurity concentrations in ng/cm^2 can be determined. Upon measuring several targets we found that it was difficult to determine the original amount of C-impurity in the foils which were produced because the carbon contribution from the experimental set-up itself dominated. This is illustrated in Fig. 2. Figure 2a shows two energy spectra from a self-supporting $50\ \mu\text{g}/\text{cm}^2$ Au target, which was measured twice for about 22 min. One observes a clear increase of C contaminants in the second measurement. If converted to actual target thicknesses the carbon contamination increased from $55\ \text{ng}/\text{cm}^2$ to $140\ \text{ng}/\text{cm}^2$ after a beam bombardment of about 22 min. A similar behavior was observed for other targets produced with different techniques (see Fig. 2b).

The other important parameter determining the C buildup on the Au targets is the pressure in the scattering chamber during the ^{12}C -bombardment. Figure 3 shows the carbon contamination after a 20 min beam bombardment on 4 targets prepared by a 2 min evaporation with the cryo pump system measured at different pressures in the scattering chamber. There is a clear increase of the carbon contamination with increasing pressure in the target chamber.

If targets prepared by different evaporation techniques are to be compared one must therefore be sure that the experimental conditions during the actual measurements were identical. Figure 4a shows energy spectra for 3 targets prepared with the diffusion pump set-up and measured under the same conditions. The C/Au ratio is higher for the targets prepared in a 10 min or

60 min evaporation if compared to the 1 min evaporation time. This effect might be due to increased backstreaming from the diffusion pump during long evaporations. For comparison Fig. 4b shows similar spectra for two targets prepared with the cryo pump set-up. The C/Au ratio is slightly lower than the one obtained for the 1 min diffusion pump target in Fig. 4a and no increase is observed for longer evaporation times.

4. Conclusions

Comparing all targets measured in this experiment it appears that those prepared with a cryo pump set-up show only slightly less C than the one produced with a diffusion pump set-up using short (1 min) evaporation times. When placed in the beam this higher purity of the targets, however, is soon overcome by the carbon deposition from the residual gases in the scattering chamber. We have made no measurements to determine if the storage time causes an increase of carbon impurity on these foils. From our experience we find that the cryo-pump system is easy to use and has been quite trouble free. These systems are used extensively in the production of semi-conductor devices. With further development, the oil free cryo-pump system should become a very useful tool for the target maker.

References

- [1] G. E. Thomas, S. K. Lam and R. W. Nielsen, Methods to Reduce Contamination in Targets Prepared by Vacuum Deposition, published in Preparation of Nuclear Targets for Particle Accelerators, edited by Jozef Jaklovsky (Plenum Press, New York, 1981), p. 277.
- [2] Varian/NRC 3117 vacuum coating system manufactured by Varian, Palo Alto Vacuum Division, 611 Hanson Way, Palo Alto, CA 94303.
- [3] Kronos thickness monitor, Model QM 321. Distributed by Veeco Instruments Inc., Terminal Drive, Plainview, NY 11803.
- [4] Sargent Welch Cryo-Source II, 1150 μ /sec., 15 cm ASA flange/water cooled. Distributed by Sargent Welch, 7300 W. Linder, Skokie, IL.
- [5] Mechanical vacuum pump, model 6H-4V, 1/3 HP VAC motor. Distributed by Fluid Power Engineering, 5877 N.W. Highway, Chicago, IL 60630.
- [6] J. E. Spencer and H. A. Enge, Nucl. Instr. & Meth. 49 (1967) 181; Also H. A. Enge, Nucl. Instr. & Meth. 28 (1964) 19.
- [7] Cryo-Torr 7 High Vacuum Pump CTI-Cryogenics, Kelvin Park, Waltham, MA 02154.

Table I. EXPERIMENTAL DATA

Run Number	Evaporation System	Evaporation Vacuum ($\times 10^{-6}$ Torr)	Evaporation Time (minutes)	Time In Beam (minutes)	# of Times In Beam	Split Pole Spectrometer Vacuum ($\times 10^{-6}$ Torr)	Count Ratio C/Au ($\times 10^{-4}$)
3	cryo.	6.2	1	28.2	1	8	1.88 ± 0.31
6	cryo.	4.3	2	22.7	1	2.8	1.08 ± 0.22
8	cryo.	4.3	2	21.5	2	< 2.5	2.61 ± 0.35
15	cryo.	4.3	2	8.5	1	8	2.63 ± 0.59
16	cryo.	4.3	2	23.4	2	5	2.96 ± 0.38
17	cryo.	4.3	2	8.9	1	4	1.30 ± 0.36
18	cryo.	4.3	2	9.7	1	4	2.17 ± 0.51
5	cryo.	4.6	10	23.2	1	3	1.22 ± 0.24
7	cryo.	4.6	10	23.0	2	< 2.5	2.64 ± 0.36
9	cryo.	2.6	60	9.1	1	8.5	
10	cryo.	2.6	60	16.6	2	~ 5	1.95 ± 0.21
11	cryo.	2.6	60	16.0	3	3	4.26 ± 0.61
12	diff.	1.3	1	17.4	1	< 2.5	1.39 ± 0.23
14	diff.	1.3	1	23.7	2	< 2.5	2.28 ± 0.32
13	diff.	1.0	10	25.3	1	< 2.5	2.18 ± 0.38
4	diff.	1.0	60	41.2	1	4	2.52 ± 0.35

Figure Captions

- Fig. 1 Energy spectrum from the Split Pole Spectrograph using a "standard" foil produced using a diffusion pump evaporator system. The target consisted of $10 \mu\text{g}/\text{cm}^2$ Au evaporated onto a $10 \mu\text{g}/\text{cm}^2$ C foil.
- Fig. 2a Energy spectra illustrating the carbon buildup during the beam bombardment. See text for details.
- Fig. 2b Increase of carbon contamination (in ng/cm^2) as a function of the bombarding time.
- Fig. 3 Carbon buildup on $50 \mu\text{g}/\text{cm}^2$ Au targets as function of the pressure in the scattering chamber. The evaporation time was 2 min.
- Fig. 4 Energy spectra taken at the same experimental conditions for several targets prepared using the diffusion pump system (top) and the cryo pump system (bottom) with evaporation times as indicated in the figure. Values for the carbon concentration are also included.

ANL-P-17,645

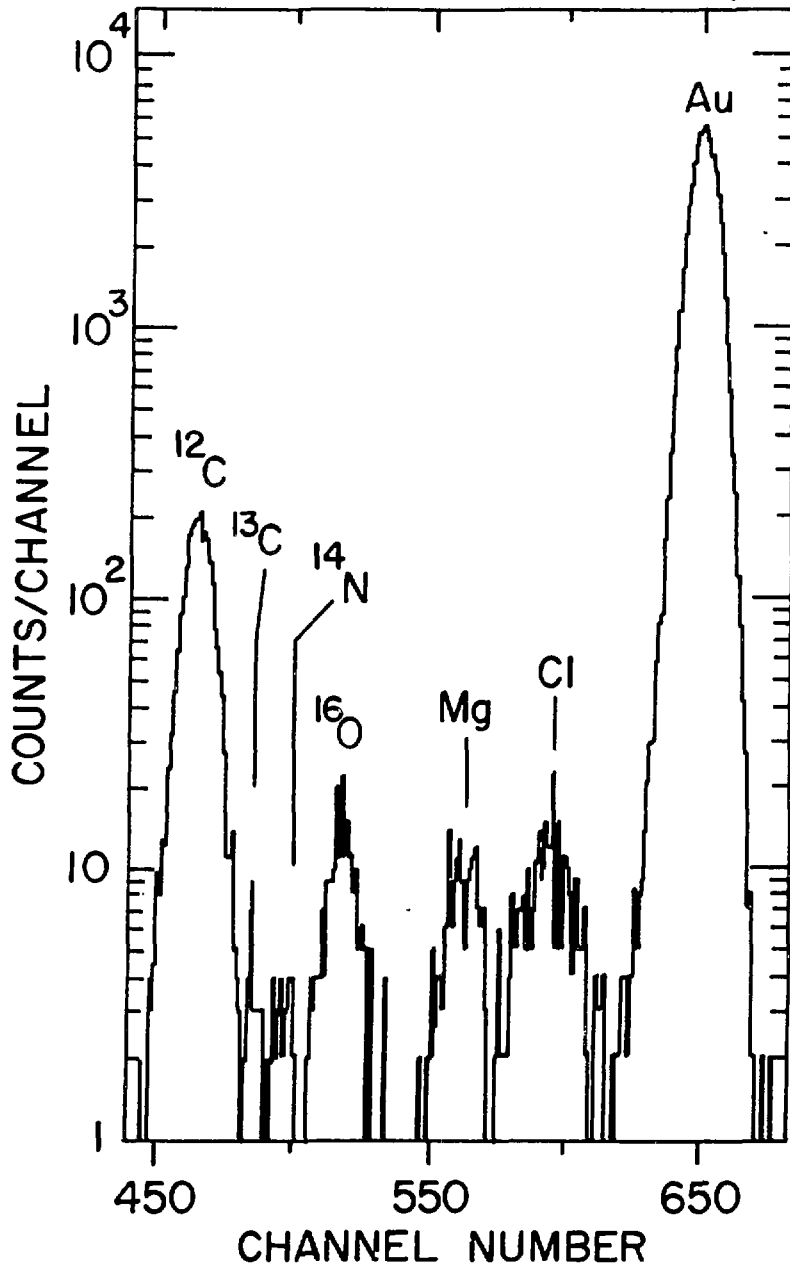


Fig. 1

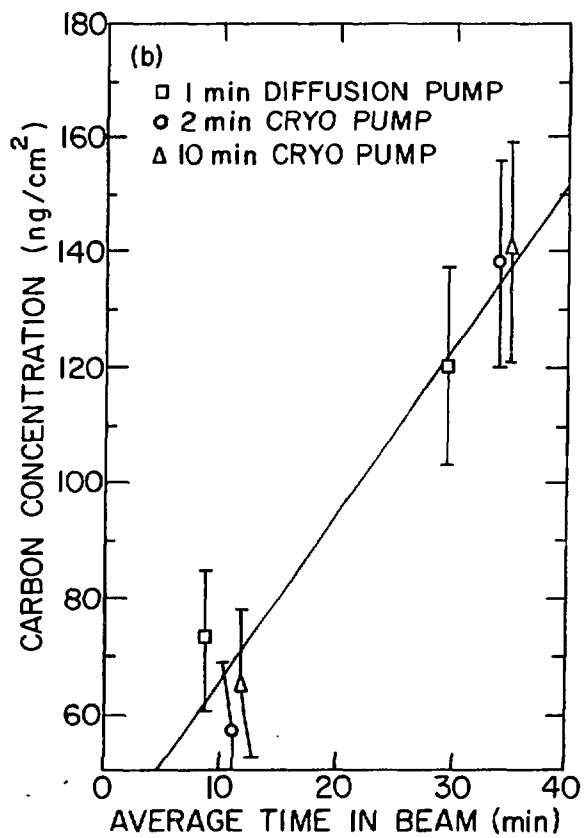
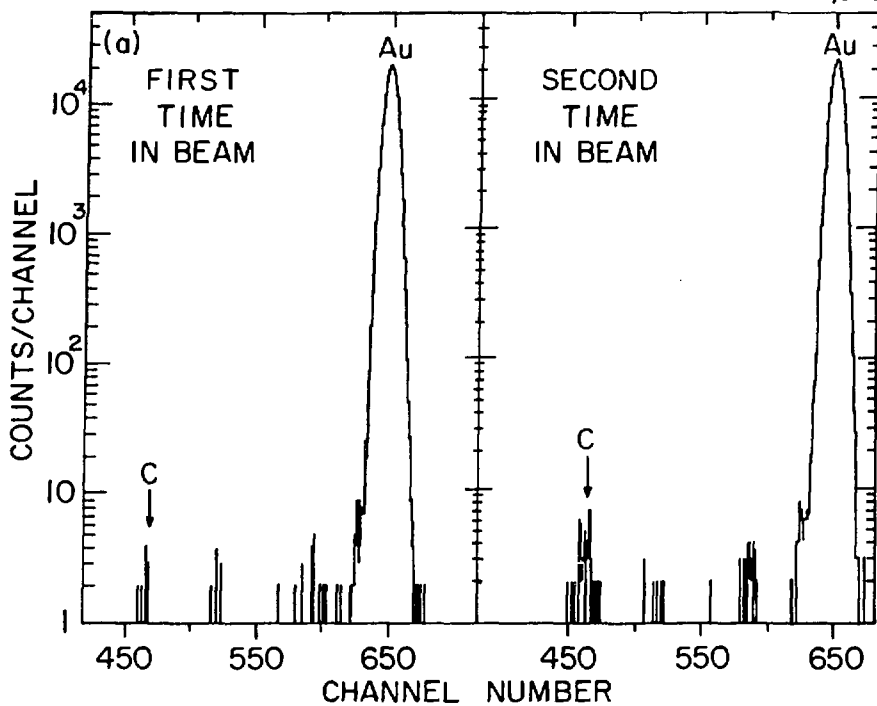


Fig. 2

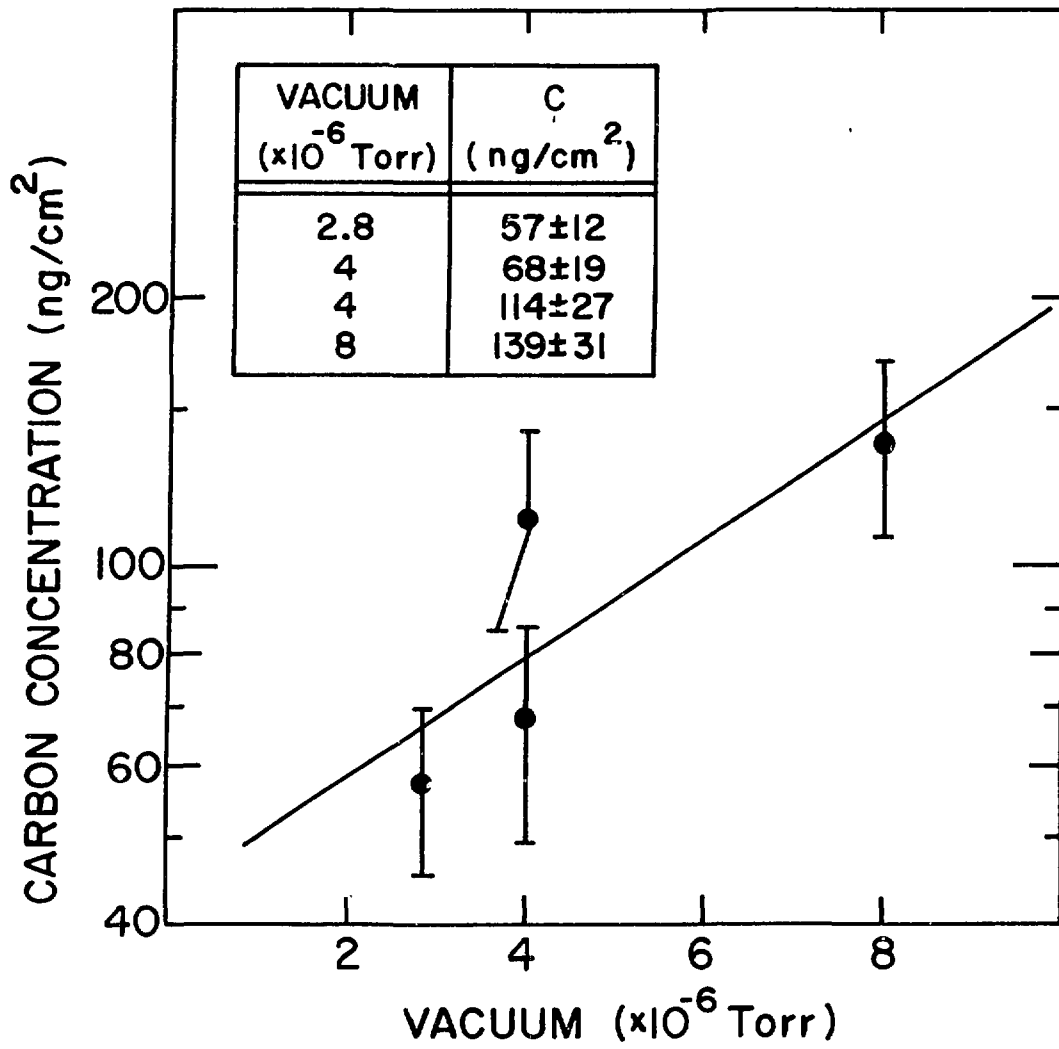
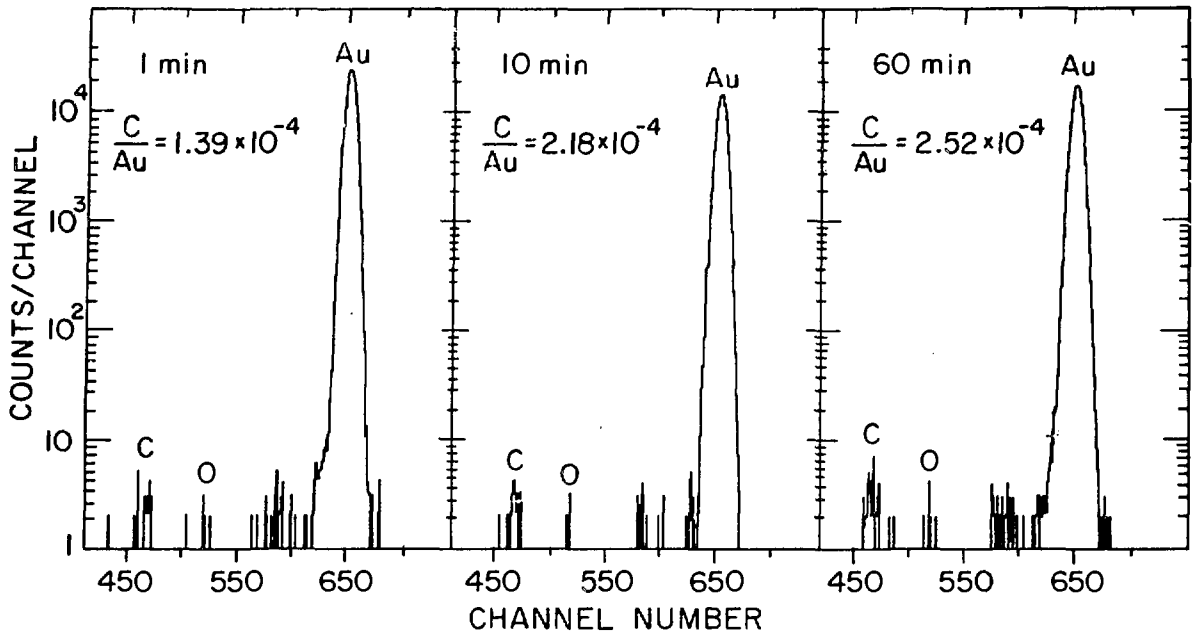
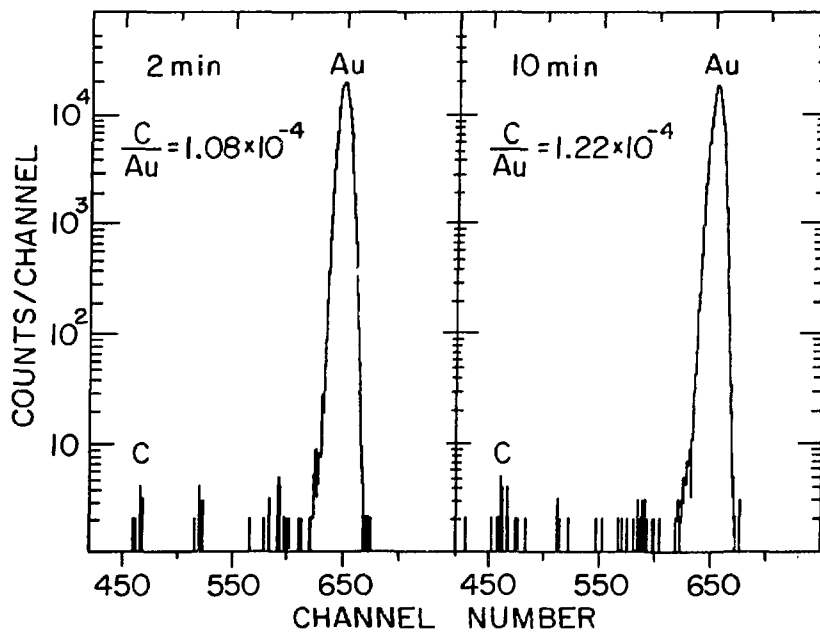


Fig. 3



(a) DIFFUSION PUMP



(b) CRYO PUMP