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X-RAY ABSORPTION IN CHARACTERIZATION OF LASER FUSION TARGETS

X. CLEMENT, A. COUDEVILLE, P. EYHARTS, J.P. PERRINE, R. ROUILLARD,
Commissariat à l'Energie Atomique, Centre d'Etudes de Limeil, B.P. n° 27,
94190 - VILLENEUVE SAINT-GEORGES, FRANCE

Many plastic or metal coated targets are opaque, so their thickness and thickness uniformity cannot be obtained by optical means. Therefore, we have built and tested a new system using monochromatic X-ray absorption measurements. This system is also able to perform non-destructive measurements of argon fill pressure in glass microballoons.

The X-ray source is a diffraction tube with a chromium target and fine focus (0.4 x 0.8 mm^2). Since monochromatic calculations are involved in this method, we use electronic discrimination to isolate the chromium Kα line (5.4 keV) from the bremsstrahlung spectrum. The detectors are xenon-filled proportional counters. The system is composed of two beams (10 µm in diameter), one used as a reference and the other as the measurement arm. A PET desk computer is coupled to the experiment. We achieved a precision better than 10 % for gold layers in the range of 0.1 to 1 µm, and better than 20 % for argon pressures in the range of 5 - 13 bars.

I. INTRODUCTION

Since they are opaque, thickness measurements of metallic layers on glass microballoons are not possible by optical interferometry. The use of X-rays opens us two possibilities : contact microradiography /1/ /2/ /3/ and transmission absorptiometry. We present here our work on this last method.

Film thickness measurements by transmission absorptiometry use the basic relation for monochromatic X-ray beams :

$$I = I_o \exp(-\mu \rho x) \qquad (1)$$

I_o - intensity of the incident beam, I - intensity of the transmitted beam, x - thickness of absorbing layer, ρ - density of material, μ - mass absorption coefficent which is only function of absorbing material and wavelength of X-ray beam.

The system we have developed gives transmission ratio I/I_o for chromium Kα line (5.4 keV) passing through the center of the sample. So we can obtain the product ρx from eq. (1). The mass absorption coefficient μ for the different materials used in targets fabrication (Al, Ni, Au and some plastics) are known /4/ /5/.

II. EXPERIMENTAL APPARATUS

The system is built around a classical X-ray diffraction tube with a chromium target and a 0.4 x 0.8 mm^2 fine focus. Two opposite beams emerge from it giving the reference and the measurement arms (Fig. 1-a). Both are imaged on the windows of xenon-filled proportional counters by platinum pinholes, 10 μm in diameter.

The sample is located a few millimeters above the pinhole to achieve minimum probe size over the microballoon (Fig. 1-b). The whole sample positionning mechanism and pinhole is removable. An accurate coincidence of the center of the microballoon and of the pinhole is easily done,

under an optical microscope as the absorption measurement must take place along a sphere diameter. Proportional counters start two counting chains. After amplification, pulse analysis (to insure of monochromatism) and counting, the reference intensity I_o and the transmitted intensity I through the sample are obtained. A programmable counter-timer is coupled to a PET desk computer assuming the counting control and a statistical treatment to obtain the highest precision allowed by counting statistic, approximately $(N)^{-1/2}$ where N is the observed counts number.

III. RESULTS AND DISCUSSION

First experiments are made on gold plane layers deposited over 0.5 µm thick polyacetate film. The absorption due to this film is negligible in comparison with metal absorption.

Two method of deposition are used :

- d. c. sputtering operating with argon pressure of approximately 10^{-2} Torr.

- Vacuum evaporation where residual pressure is in the range 10^{-6} - 10^{-5} Torr. Thicknesses are measured with talystep onto plane glass substrate simultaneously coated.

Fig. 2-a shows the couple of curves giving Cr Kα line absorption $Ln(I_o/I)$ against gold thickness. Both are straight lines whose slopes are $\mu\rho$. In comparison with vacuum evaporated layer observed density (17 $g.cm^{-3}$) and nominal gold density (19.3 $g.cm^{-3}$) sputtering seems to give lower valûe (14 $g.cm^{-3}$) probably due to inclusion of argon in the layer during the deposition.

Fig. 2-b shows absorption of glass microballoons as a function of their thickness measured by interferometry. It is roughly a straight line whose slope gives $\mu\rho$ product of the glass forming the microballoons. For the

Cr Kα line we find experimentally 305 cm^{-1}, that is very close to the calculated value (300 cm^{-1}) obtained for average chemical composition of glass microballoons made in Limeil. Part of the dispersion is due to the slightly different chemical composition of thick microballoons used in this experiment. This determination of $\mu\rho$ for glass allows us to eliminate the part of absorption due to the wall when we measure thickness of metal layer on microballoons. We use the former results to measure r.f. sputtered gold layers on glass microballoons.

Fig. 3-a and 3-b shows respectively absorption Ln (I_o/I) against thickness measured on plane glass substrate simultaneously coated and absorption against time of deposition. Both are straight lines giving a value of 2.4 for the ratio test thickness over microballoon thickness. The good linearity versus time of deposition and comparison with thickness measurements made by microradiography on the same targets indicate a precision of 5 - 10 % (decreasing with increasing thicknesses).

Finally we used this apparatus to measure argon pressure inside glass microballoons. Because of the very low absorption of gases we first try the method on a microchamber. It is composed of a slit, machined by electrical discharge, in a 100 μm thick foil of stainless steel, closed by two mica windows (15 μm thick) allowing variable pressure filling with argon. It was positionned above the pinhole.

Fig. 4 shows the absorption as a function of inner argon pressure. The straight line obtained is in good agreement with calculated values. Slope gives 105 μm as X-ray path length, this value is very close to the mechanical size of the chamber (100 $\pm$ 5 μm). We have then measured the inner pressure of glass microballoons, without breaking them, with a precision of 1 bar.

IV. CONCLUSION AND FURTHER DEVELOPMENT

This method has a wide range of applications. We can measure thicknesses of plane or spherical deposit with a precision of 5 to 10 %. It is easy to measure with 1 bar absolute precision partial pressure of argon or other heavy gases (with better precision) inside some targets used in laser fusion experiments.

We are intending to make simultaneous absorption measurements of several Kα line. So we develop the use of solid state detectors having better energy resolution instead of xenon filled propotionnal counters.

At the same time we study adaptation of a 4π manipulator onto the existing system to allow complete observation of spherical targets.

FIGURE CAPTIONS

Arrangement of X-ray absorption experiment

Fig. 1 a) Schematic of the apparatus

b) X-ray optic drawing, showing formation of analyzing beam on a glass microballoon

Experimental results on plane and spherical targets

Fig. 2 a) Absorption of plane gold layers as a function of talystep measured thickness

b) Absorption of glass microballoon as a function of the thickness measured by interferometry

Fig. 3 Absorption of r.f sputtered gold layers on glass microballoons as a function of :

a) thickness on the plane test coated simultaneously

b) time of deposition

Fig. 4 Absorption of argon filled microchamber as a function of the inner pressure.

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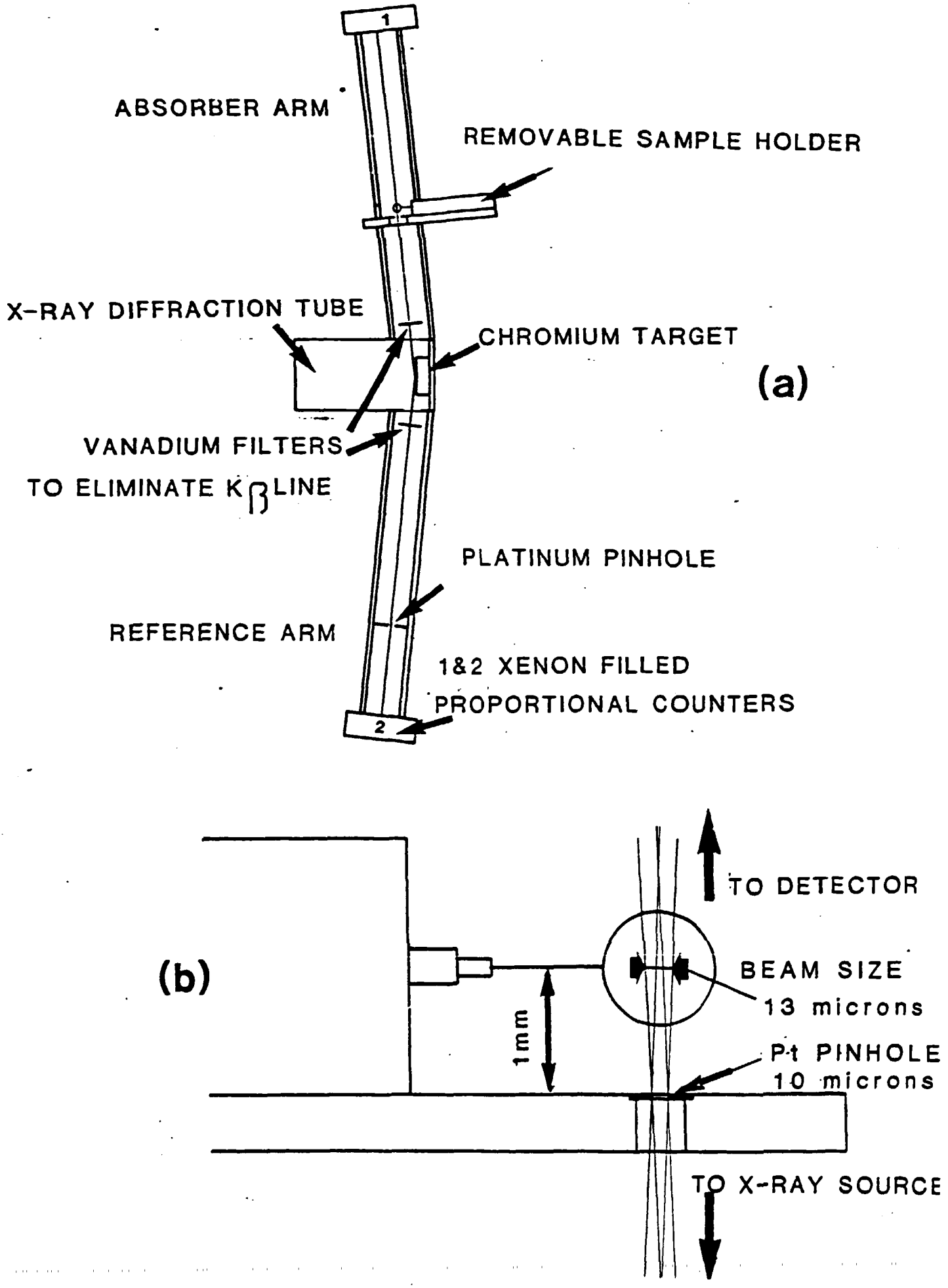
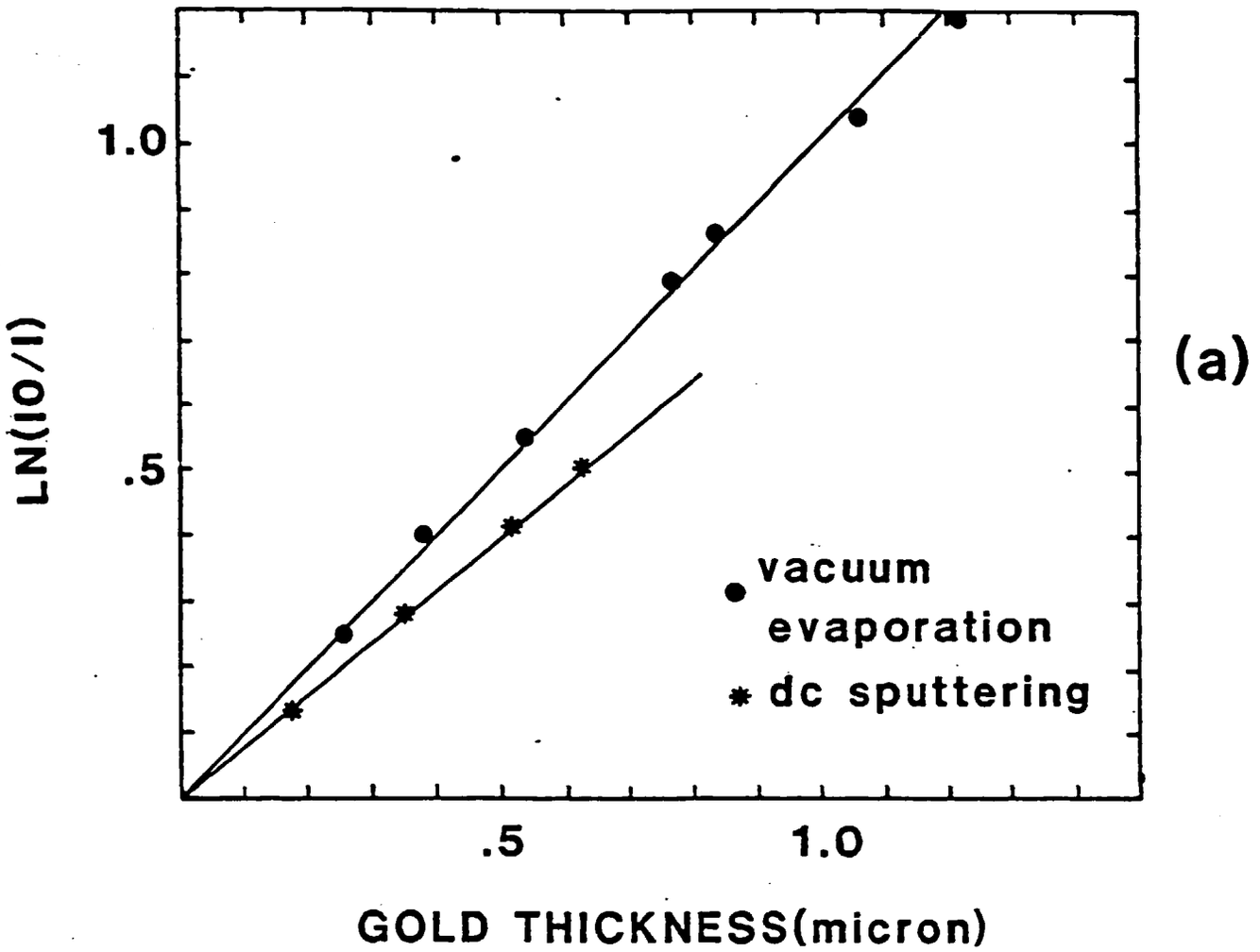
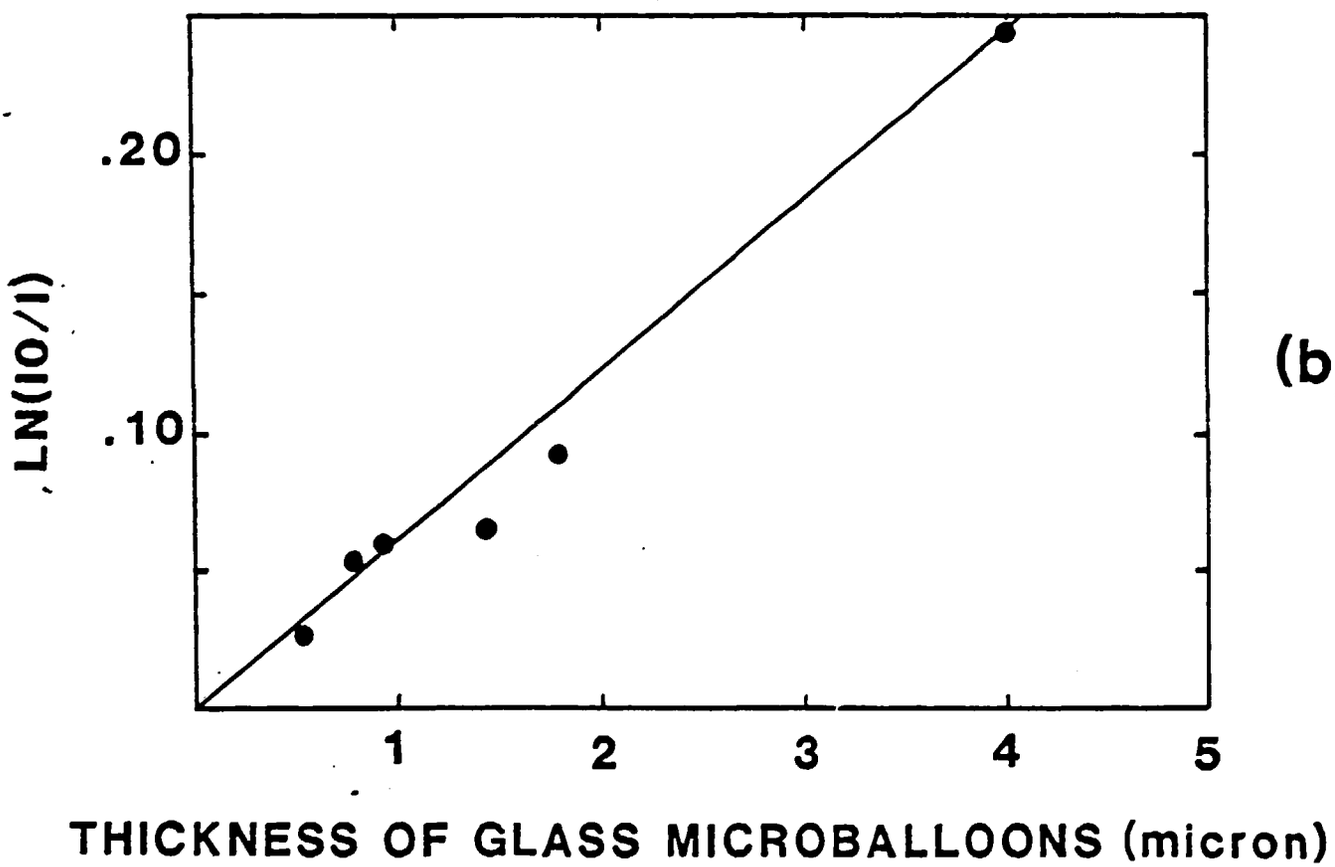
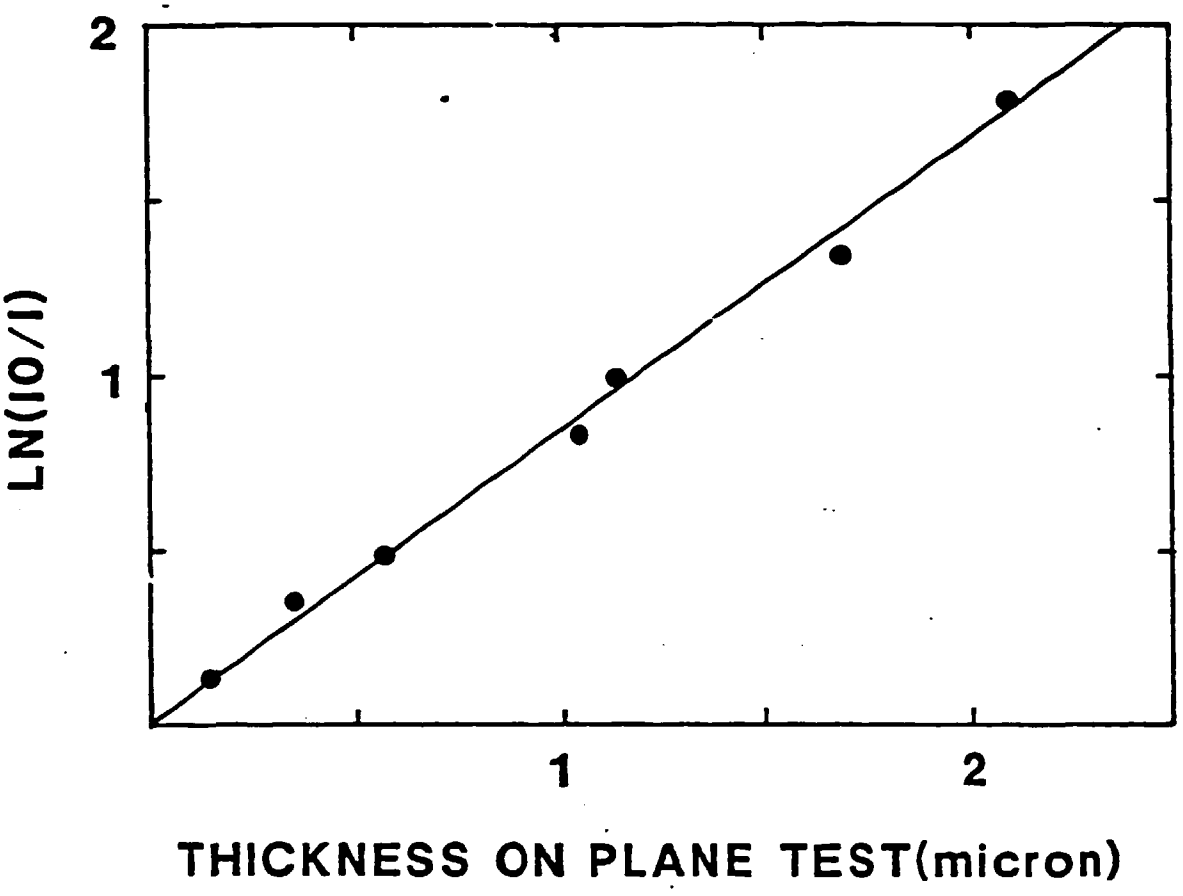

1
ABSORBER ARM
REMOVABLE SAMPLE HOLDER
X-RAY DIFFRACTION TUBE
CHROMIUM TARGET
(a)
VANADIUM FILTERS
TO ELIMINATE Kβ LINE
PLATINUM PINHOLE
REFERENCE ARM
1&2 XENON FILLED
PROPORTIONAL COUNTERS
2
(b)
TO DETECTOR
BEAM SIZE
13 microns
1mm
Pt PINHOLE
10 microns
TO X-RAY SOURCE


1.0
.5
LN(IO/I)
vacuum
evaporation
dc sputtering
.5
1.0
GOLD THICKNESS(micron)

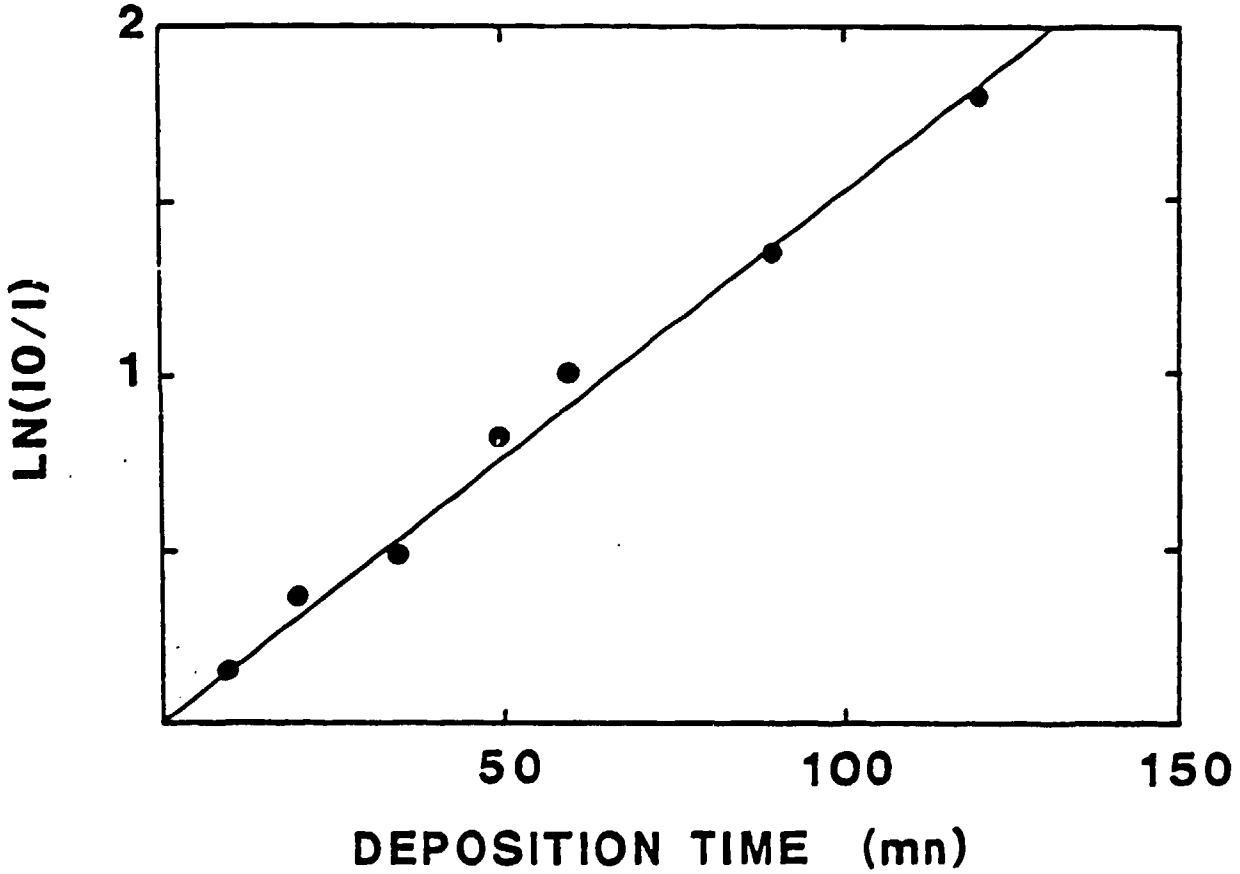
(a)


.20
.10
LN(IO/I)
1
2
3
4
5
THICKNESS OF GLASS MICROBALLOONS (micron)

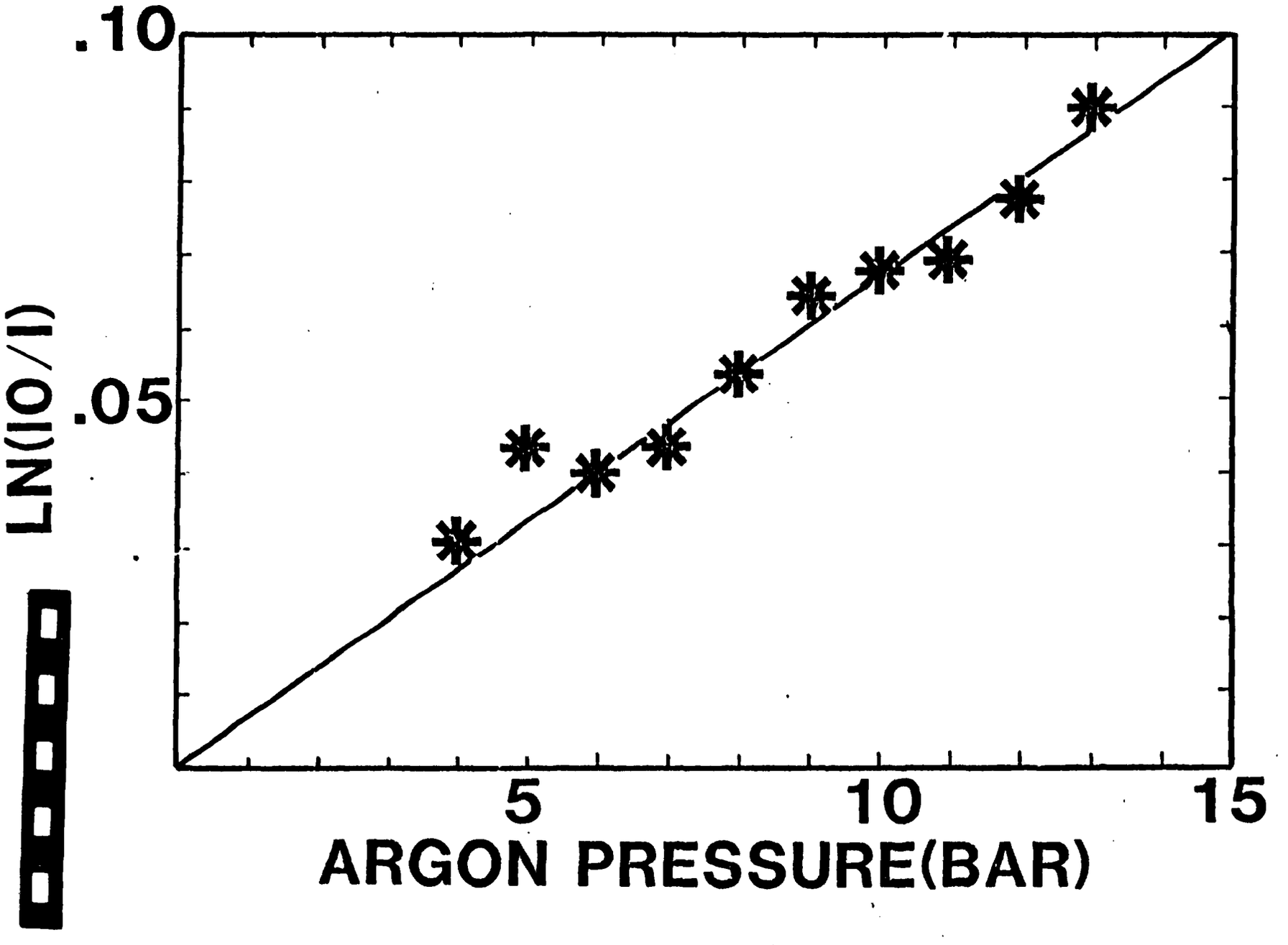
(b)


2
1
LN(IO/I)
1
2
THICKNESS ON PLANE TEST(micron)

(a)


2
1
LN(IO/I)
50
100
150
DEPOSITION TIME (mn)

(b)


.10
.05
LN(IO/I)
5
10
15
ARGON PRESSURE(BAR)