620

Simple, compact, high-purity Cr evaporator for ultrahigh vacuum

J. J. McClelland, J. Unguris, R. E. Scholten, and D. T. Pierce
National Institute of Standards and Technology, Gaithersburg, Maryland 20899

(Received 12 January 1993; accepted 5 June 1993)

A simple, compact Cr evaporator is constructed by electroplating Cr metal onto the tip of a W hairpin filament. At 5 cm from the evaporator, deposition rates up to 10 nm min^{-1} (flux $\approx 10^{19}$ atoms $\text{m}^{-2}\,\text{s}^{-1}$) have been obtained, with total deposition thickness in excess of 400 nm. Auger analyses of thin films deposited in ultrahigh vacuum show impurities below detectability.

I. INTRODUCTION

The magnetic behavior of thin films has become the subject of an increasing amount of study in recent years. Along with this increased amount of work has arisen a need for simple, convenient ways to produce thin films of transition metals. Thin films of Cr have been of particular interest recently, because of the oscillatory thickness dependence of the magnetic exchange coupling between layers in Fe/Cr/Fe systems.[1]

While Cr evaporators are commercially available, they are typically large, high-current devices with only a limited selection of geometries. Many applications require a source with compact geometry and low power, to minimize local heating of the vacuum system and consequent outgassing.

We have developed a simple technique for fabricating compact, low-current evaporation sources of Cr metal that produce high-purity beams with good lifetimes. Cr is electrodeposited onto a W wire bent into a hairpin shape. The wire is then mounted in the vacuum system and heated resistively in a standard filament configuration. After initial outgassing, we have found that many hours of clean evaporation can be obtained with this type of evaporator.

II. METHOD

We have carried out investigations on two sizes of evaporator, a small type made with a 0.25 mm (0.010 in.) diameter wire, and a large one made with 0.5 mm (0.020 in.) wire. The wires are cleaned with 600 grit sandpaper, followed by ultrasonic cleaning in acetone and methanol. After being bent into a hairpin shape, the filaments are placed in an electroplating bath with the tip submerged approximately 2 mm. The electroplating bath consists of[2]

100 ml H_2O (deionized),
30 g CrO_3,
5 g NaOH (add slowly),
0.6 g H_2SO_4,
0.1 ml ethanol.

Electroplating is carried out with a Pb anode (+). Currents of about 90 and 45 mA per filament are used for the large and small filaments, respectively. This corresponds to a current density of order 10^4 A m^{-2}. The plating voltage is about 3 V.

Electroplating for 18 h typically deposited 75 and 250 mg on the small and large filaments, respectively, as shown in Fig. 1. Usually the Cr has a smooth, granular appearance as seen in the figure, but occasionally the Cr grows in clusters of balls. We believe the cleanliness of the W wire before electroplating is a factor in determining whether the clusters form. In any case, the form of the Cr on the evaporator has not been observed to affect the performance in any way.

Before placing in the vacuum system, the evaporators are rinsed in deionized water and methanol. After installation, degassing at 5–6 A (small filaments) or 15–16 A (large filaments) is done before bakeout of the ultrahigh vacuum (UHV) chamber. The evaporators are outgassed a second time during the UHV chamber bakeout procedure, as the vacuum vessel cools. Once outgassed, the final base pressure of 8×10^{-8} Pa did not increase when operating the small evaporators.

III. RESULTS

Deposition rates were measured with a cooled quartz crystal microbalance thickness monitor. With the small filaments placed 5 cm from the thickness monitor typical deposition rates of 0.4 nm per minute were obtained at a filament current of 7 A. Rates as high as 10 nm min^{-1} were possible at currents up to 9 A. These deposition rates correspond to fluxes from 5.5×10^{17} to 1.4×10^{19} atoms $\text{m}^{-2}\,\text{s}^{-1}$. The larger evaporators were tested at 10 cm from the thickness monitor, producing 0.4 nm min^{-1} at 20 A and 4 nm min^{-1} at 25 A. Both filaments produced a total deposition thickness in excess of 400 nm at these working distances. The evaporation rates at a given current

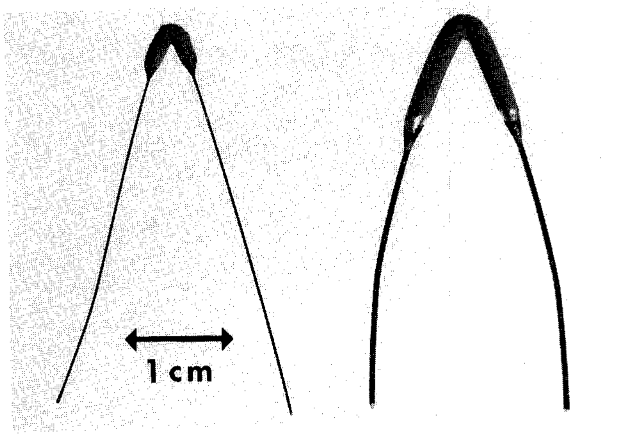

FIG. 1. Photograph of electrodeposited Cr evaporator filaments with 0.25 and 0.50 mm wire diameters.

are typical but vary depending on the amount and configuration of the Cr on the filament and on the filament mounting and surroundings. Thus the evaporation characteristics must be determined individually for each evaporator.

Auger spectra of Cr films deposited with a thoroughly outgassed small filament evaporator found that contaminants were below detectability. This Auger analysis was not sensitive to impurities below 1% atomic content. Auger spectra taken from a Cr film deposited during the initial outgassing found oxygen as the principal contaminant. Once exhausted, a porous green Cr oxide residue was found on the filaments, but this did not appear to affect the purity of deposited Cr. These evaporators have been used to produce thin films of sufficient purity for studies of the magnetic properties of multilayer structures.[1,3]

We note in closing that in addition to providing a very useful evaporation source for thin film studies, the large (0.5 mm) evaporator has also proven useful in an atomic spectroscopy experiment. Using the evaporator as an atomic beam source, a collimated beam was formed. Laser induced fluorescence spectra were obtained using a tunable dye laser, allowing a measurement of the hyperfine structure and isotope mass shifts in the Cr $^7S_3 \rightarrow {}^7P^0_{2,3,4}$ transitions.[4]

ACKNOWLEDGMENTS

This work was supported by the U.S. Department of Energy, Office of Energy Research, Division of Chemical Sciences, and the Technology Administration of the U.S. Department of Commerce.

[1] J. Unguris, R. J. Celotta, and D. T. Pierce, Phys. Rev. Lett. **67**, 140 (1991).
[2] *Encyclopedia of Chemical Technology*, edited by H. F. Mark *et al.* (Wiley, New York, 1979), Vol. 6, p. 104.
[3] J. Unguris, R. J. Celotta, and D. T. Pierce, Phys. Rev. Lett. **69**, 1125 (1992).
[4] R. Scholten, J. J. McClelland, and R. J. Celotta (to be published).