A SIMPLE METHOD OF FABRICATING LINEARLY GRADED FILMS

B. S. RAMPRASAD AND T. S. RADHA

(*Central Instruments and Services Laboratory, Indian Institute of Science, Bangalore 560012*)

Received on January 16, 1974

ABSTRACT

A simple mask to prepare evaporated films with linear gradation is described. It is shown how this can be used in a laboratory to prepare a three layer variable wavelength interference filter.

Key words: Graded optical films: Thin film technology.

1. INTRODUCTION

One of the important applications of evaporated thin films is the production of graded filters for varying the light intensity in a desired manner. Graded filters can be used to make simple monochromators and neutral density filters of known gradation which find a wide range of applications. Graded filters can be fabricated by evaportation of single or multiple layers of thin films of variable thickness. Several techniques exist for the preparation of linearly graded films [1–6].

A simple mask was designed to deposit linearly graded films on several microscope slides simultaneously. Durable wedged films of Nichrome with different ranges of densities prepared on 3″ × 1″ slides were used for the linear attenuator, to balance the reference-to-object beam ratio, in a holographic setup, fabricated in the authors' laboratory. This was found to be very simple compared to fabricating and using a variable density beam splitter. The same method was tried successfully to make a metal-dielectric-metal graded interference filter which works as a simple monochromator. In this paper the experimental technique, is described and some of the results are presented. Any laboratory having a small vacuum coating plant can easily adapt the experimental technique reported here.

This type of mask is known in literature and has been used for determining the intensities of special lines. However its use in vacuum deposition of metal films does not seem to have been exploited so far.

2. EXPERIMENTAL TECHNIQUE

Figure 1 shows the configuration of the mask used for a 12″ vacuum coating plant. The profile of the mask is an Archimedes spiral having an increment of 30 mm radially for every 30 degrees of rotation of the radius vector. With this configuration the hatched portion in Fig. 1 has a period of 100 degrees which means that as the mask rotates, the edge of the slide away from the centre is open to evaporation during 260 degrees of the revolution. This should yield a linear variation in thickness of 4000 to 7000 Å from the periphery to the centre.

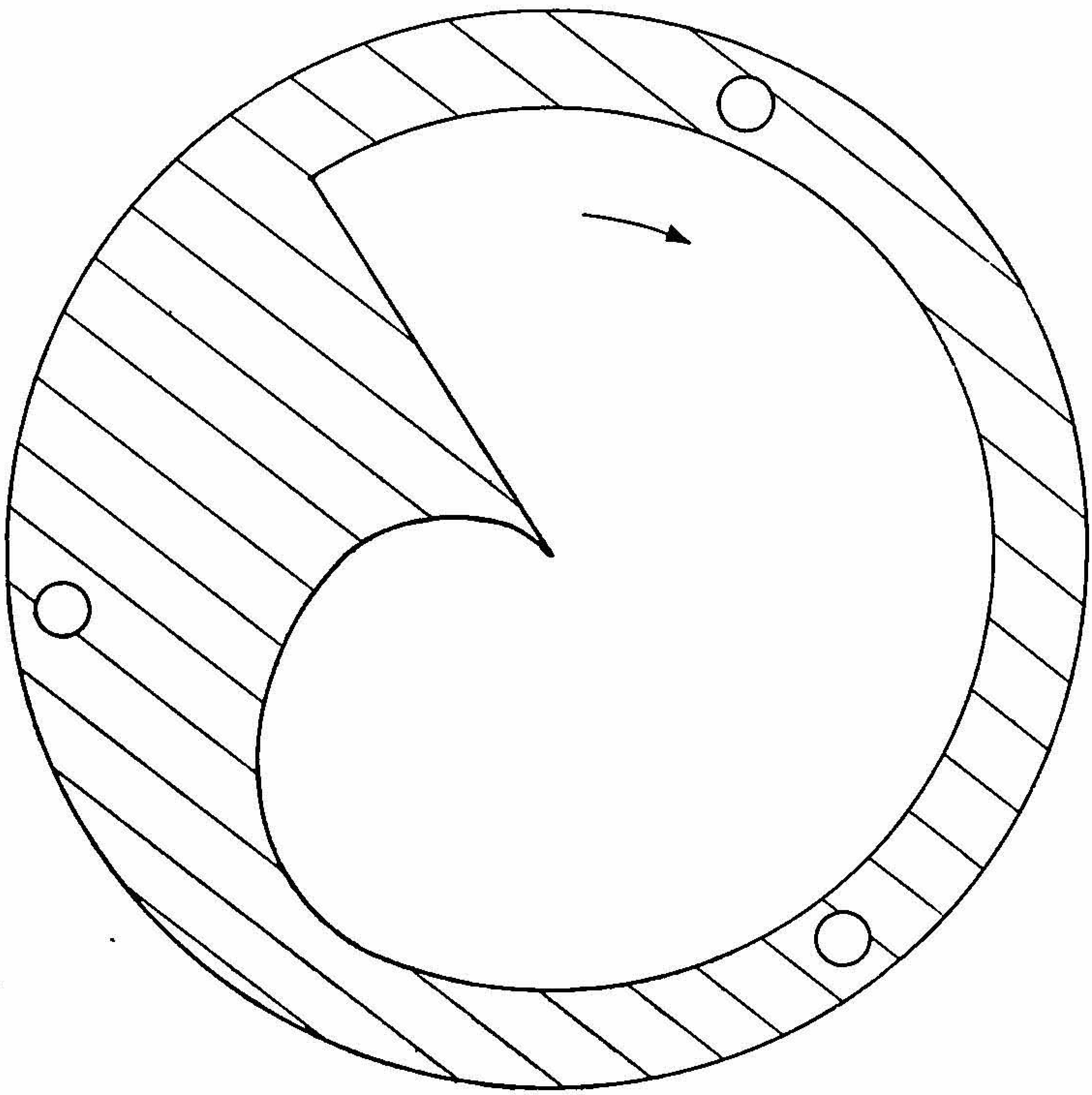

FIG. 1. Vapour interceptor mask—arrow shows direction of rotation, holes for mounting.

In the design of the mask it is assumed that the film thickness distribution over the area of the substrate is uniform, without the mask. Uniformity of film thickness is achieved by rotating the substrate at a suitable distance from the source which is offset from the axis of rotation [7]. In order to achieve variation in thickness the mask must also be rotated, besides the substrate at a relatively higher speed. This involves complicated design of hardware.

A simpler method is to use a stationary substrate and a rotating mask with central evaporation, for which the film thickness distribution is given by Holland [8]. It can be seen that the thickness decreases from the centre to the edge of the substrate for a particular source-to-substrate height. In order to account for this non-uniformity a correction can be made to the mask so that it is open at the edge of the substrate for an additional period proportional to the decrease in thickness.

Example.—For a change of thickness from 7000 Å–4000 Å from the centre to the edge the mask should be closed at the periphery for (7000–4000)/7000 = 3/7th of the time. There is a drop in thickness at the edge (radius 100 mm) of about 25% for the particular geometry of source and substrate used in the present experiment. To compensate for this the mask should be open an additional 25% of the time at the edge. This means that it should be open 5/7th of the time.

3. Applications

Case 1. *Neutral Density wedged film for holography*

Nichrome was evaporated from a stranded tungsten wire basket. The mask is positioned so that it is close to the substrate. The substrate is stationary and the mask is rotated at about 80 rpm. Several wedged films were obtained with different densities. Obtaining rapid or slow gradation in density depends only on the design of the contour of the spiral. Several ranges of graded filters were made in this way.

Case 2. *Graded interference filter*

Uniform silver films were deposited on four substrates using optimum geometry for the source and substrate [7]. Weighed quantity of cryolite was deposited on these silver films with the rotating mask in position to form the wedged spacer layer. Over this the second silver film is deposited as mentioned before. Since the film thickness was not monitored, predetermined quantity of evaporant material was used for all the evaporations,

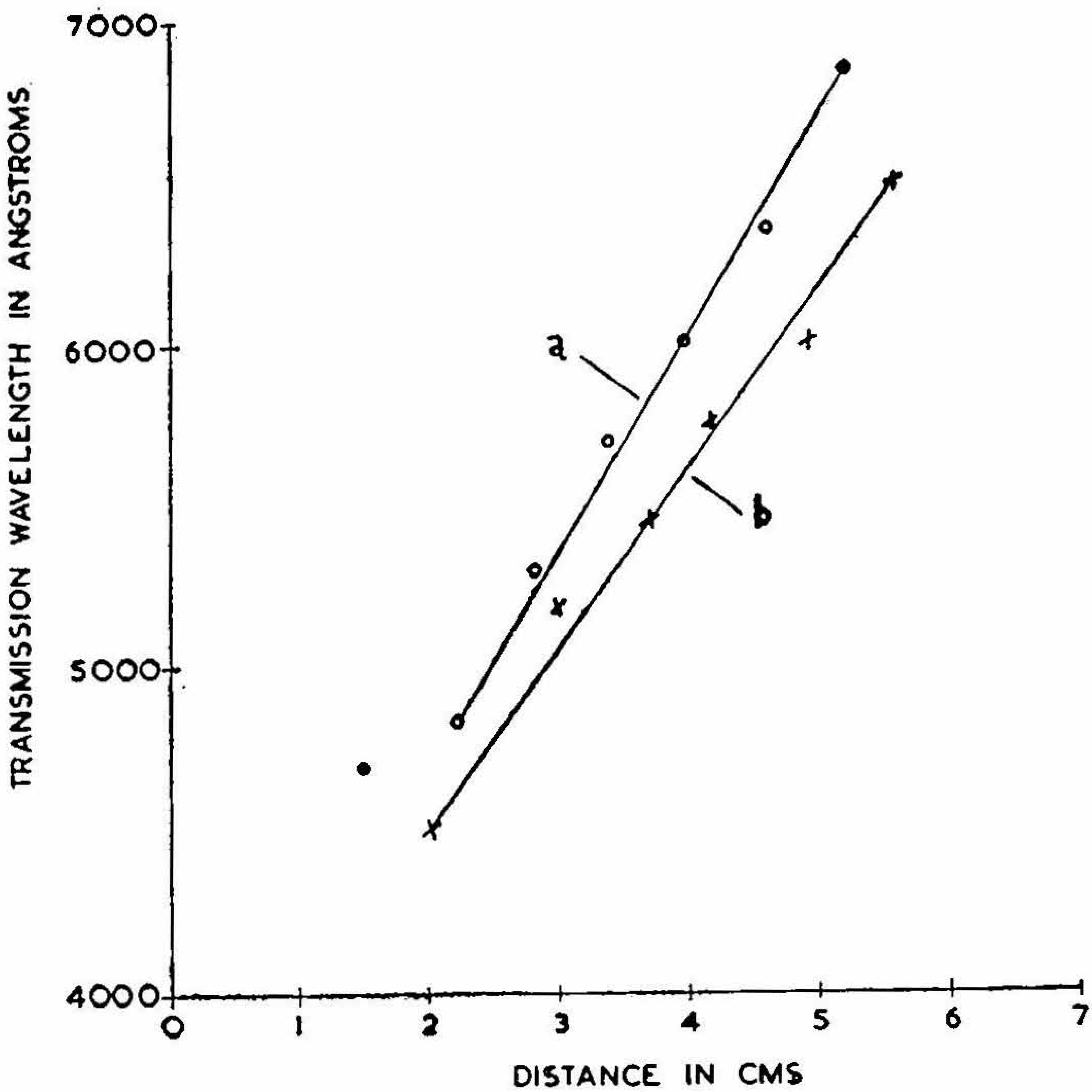

FIG. 2. Transmission characteristics of two graded interference filters: (*a*) made in the laboratory; (*b*) imported.

By having separate rotary drives for the mask and the substrate it would be possible to produce a filter without breaking the vacuum. However in these experiments since only one rotary drive was available in the vacuum coating plant used [9], the filters were made by letting in air into the chamber after each evaporation to position the substrate and mask. Some oxidation of the silver films could be expected to happen because of letting in air. However it was found that it did not affect the performance of the filter in any noticeable manner. Another point to be noted is that for the same thickness of the silver film transmission is higher for the lower wavelength than for the higher wavelength [2]. This would affect only the bandwidth at different wavelengths.

The peak transmission for each wavelength was measured as a function of the distance from the edge of the filter using a hand spectroscope. Figure 2 compares the characteristics of the filter made in the laboratory with a commercial imported filter. It can be seen that some points fall off from the median line and similar gradation is obtained over almost the same length of the filter, in both cases.

References

[1] Brian O' Brien and Russel, T. A. Preparation and optical properties of evaporated metal wedge films. *J. Opt. Soc. Am.*, 1934, **24**, 54.

[2] Par Ch. Dufour .. Mechanisme pour la preparation par evaporation dans le vide de filtres interferentiels a couleur variable, 1950/ **11**, 353–354.

[3] Barkley, D. W. and Libby-Owens-Ford Glass Co. Method of producing graded coating., *U.S. Patent* 2,676,114, *Vacuum*, 1954, **4**, 362.

[4] Ward, J. and Barnes, W. W. Variable wavelength optical interference filters. *Technical Note PD* 94, W.R.E., Australian Defence Scientific Service, 1968.

[5] Kent, J. C. .. Fabrication of graded filters for knife edge replacement in laser Schlieren optical systems. *Appl. Opt.*, 1969, **8**, 2148.

[6] Howard Herzig and Rodney S. Spencer Vacuum evaporation method for manufacturing neutral density filters with non linear density profiles. *Appl. Opt.* 1973, pp. 1113–1114.

[7] Ramprasad, B. S., Radha, T. S. and Ramakrishna Rao, M. An algorithm for optimization of experimental parameters for maximum uniformity of film thickness. *J. Vac. Sci. Technol.*, 1972, **9**, 1227–1228.

[8] Holland, L. .. *Vacuum Deposition of Thin Films*, Chapman and Hall Ltd., London, (1961), Ch. 5, 146.

[9] Ramprasad, B. S., Radha, T. S. and Ramakrishna Rao, M. Rotary system for uniform deposition of thin films, *Indian Journal of Technology*, 1971, **19**, 8–10.