SURFACE MOTION OF SPUTTERED PARTICLES

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Introduction

The condensation of cadmium from an atomic beam has been studied by Cockcroft (1) and by Esterman (2). Cockcroft showed that in the early stages of condensation the particles move about on the surface and have a certain probability of re-evaporating before they are bound by the formation of aggregates. Esterman investigated this surface motion by allowing the atomic beam to fall on a fine V-shaped aperture placed close to the surface. It was found that even when deposits could be obtained in the wider part of the aperture no deposit was found in the part less than about 0·05 mm. in width. This was explained on the view that loss of particles by surface migration from the surface under the narrower part of the aperture acted in the same way as an increase in the rate of re-evaporation, and so prevented the formation of a stable deposit.

Experiments very similar to those of Cockcroft and Esterman were carried out by Ditchburn ((3) and (4)) using cadmium particles obtained by sputtering at low pressures. It was found that the sputtered particles condense much more readily than those produced by boiling; this was attributed to a removal of absorbed gas from the surface by positive ions of the discharge. This cleaning of the surface was assumed to increase the surface forces and so reduce re-evaporation. Sputtered deposits were obtained through a V-shaped aperture, and it was found, as in Esterman's experiment, that no deposit was obtained when the width of the aperture was less than about 0·06 mm.

Two explanations of this result were put forward. The first is that it was due to a true surface motion. The second is that the positive ions are unable to penetrate the narrower parts of the slit owing to the collection of surface charges on it and on the surface. The purpose of the present experiment was to investigate these two possibilities.

Experimental

Preliminary experiments were carried out with apparatus similar to that of Ditchburn (4). Deposits obtained on glass and on gold surfaces confirmed his results.

Further experiments were then performed with a discharge tube similar to Ditchburn's but with a different kind of shield placed over the target. This new

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shield was designed to produce a series of very fine apertures side by side and very close to one another. This was done by preparing a rectangular frame two sides of which were formed of screws of fine pitch. By winding wires of diameters a little less than the pitch, fine apertures were obtained. V-shaped apertures could be produced either by using screws of different pitch at the two sides or by winding the wires into alternate grooves at one side. These gratings were spaced from the surface by pieces of mica 0·04 mm. thick.

With this arrangement, loss in the narrow parts of a space should be partially compensated by the arrival of material which is moving away from the two adjacent spaces. Deposits should therefore be obtainable where the wire spacing is considerably less than the slit width of 0·06 mm.

It was found that deposits could be obtained when the width of the space was about 0·01 mm. There was also definite evidence of the presence of a deposit on the part of the target behind the wires. This material was not reflected from adjacent wires since the same type of deposit was obtained behind single wires. The possibility of the deposit behind the wires being due to the collision of sputtered particles with gas molecules can also be excluded, first because the mean free path at the gas pressure used was much greater than the distance between the cathode and the grating, and secondly because the shadow cast by the frame of the grating at a distance of 3 mm. from the glass was much sharper than would be expected if sufficient collisions were taking place to account for the deposits behind the wires of the grating. These results therefore support the theory of surface motion in the sputtered deposit.

The next objective of the experiments was to test for the possibility of re-evaporation of part of the sputtered material. This was done by estimating the amount of material found both on those parts of the target covered by the wires and on those parts corresponding to the spaces. If there were no re-evaporation, the total amount of material so found should be equal to that falling on an area equal to the area of the spaces. The ratio total amount of material/area of spaces should thus remain constant when the relative width of spaces and wires is altered.

The estimations of the amounts of material were made by measuring the optical densities of the deposits on a microphotometer. By a series of subsidiary experiments a rough calibration curve showing the relation between the density of the deposit and the amount of material was obtained. Although the measurements were not susceptible of high accuracy, it was quite clear that the amount of material found in the deposits obtained through the gratings was always considerably less than would be expected if there were no re-evaporation. The defect also increased very rapidly when the spaces between the wires were made very narrow. Considerably more elaborate experiments would be needed to

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provide a quantitative relation between the width of the space and the fraction of atoms re-evaporating.

The experiments thus support the view that surface-motion and re-evaporation can take place in deposits obtained by sputtering.

SUMMARY

The deposits formed by allowing sputtered material to fall on a glass plate, through a fine grating of wires placed close to the plate, are studied in detail. Evidence obtained showing the presence of material in the shadow of the wires and other less direct evidence gives strong support for the view that the sputtered material is able to move about on the surface. It is also shown that when the grating is very fine a considerable fraction of the incident material is not condensed.

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