PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(19)

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(54) IMPROVEMENTS RELATING TO SPUTTERING

(71) We, THE ELECTRICAL RESEARCH ASSOCIATION, A British Company, of Cleeve Road, Leatherhead, Surrey, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The use of a radio-frequency supply source for the process of sputtering coatings is now well established as it also the use of a double electrode system in conjunction with such a source. The preferred type of source is a self-excited radio-frequency power generator usually with a non grounded balanced output which has advantages of cost and ruggedness in use.

One arrangement of electrodes which can be used in such a system in a pair of similar coplanar rectangular electrodes mounted side by side within a sputtering chamber and such an arrangement is described, for example, in the publication of Edwards High Vacuum (Plant) Limited, numbered 11820. This arrangement is intended primarily for use in an in-line system in which substrates to be coated are passed through successive chambers in which successive stages of the process are carried out. The direction of movement of these substrates is parallel with the common transverse axis of the two electrodes and during the sputtering process itself the substrates may be either moving or stationary. Such an arrangement leads to reasonable uniformity of deposition as shown in the publication referred to above. Despite this there are applications where greater uniformity of deposition may be required.

The present invention is based on the principle of increasing the uniformity of deposition by the use of appropriately shaped electrodes or by variation in the spacing between the electrodes and the substrates along the length of the electrodes. If the first alternative is adopted, a pair of similar electrodes are mounted side by side and each decreases progressively in width from the edges to the centre at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur. In other words the slight decrease in the thickness of coating which occurs towards the edges of the substrates in the prior arrangement is counteracted so as to produce substantial uniformity of thickness. The reference to the edges as compared to the centre is intended to apply to a direction transverse to the line joining the centres of gravity of the two electrodes so that the width of the electrodes is measured in the direction of travel of the substrates.

The width of each electrode will need to vary in a curve such that the width of the electrode increases at a rate which is roughly the same as the thickness of deposition would decrease if the electrodes were rectangular. The precise shaping may need to be detrmind in each particular instance by firstly carying out a trial with rectangular electrodes, measuring the variations in thickness of deposition and then shaping the electrodes to compensate for this. As a first approximation the percentage increase in the width of the electrodes at a position xcm. from the common axis is given by the expression.

$$\frac{T_o - T_x}{T_x} \times 100\%$$

where T_o is the film thickness on a parallel plane substrate at a position perpendicular to the centre of the electrode and T_x is the film thickness x cms. from this position in a direction perpendicular to the direction of travel of the substrate, the values T_o and T_x being determined from the trial previously mentioned.

If the compensation is to be obtained by variation of the spacing, i.e. by making this less at the edges than at the centre this can be achieved by appropriate shaping of either the electrodes or the substrates, preferably the former. If the electrodes are to be shaped, the spacing between them and the substrates which are flats needs to decrease towards the edges at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur, in other words they will need to be generally concave towards the substrates, being curved about an axis (or axis in the case of a compound curve) parallel to the line joining the centres of gravity of the two electrodes, i.e. parallel to the direction of movement of the substrates. This geometrical configuration in conjunction with the nature of the polar distribution characteristic of the emitted target material leads to improved uniformity in the deposit perpendicular to the direction of substrate travel.

A similar effect can be obtained by leaving the electrodes flat and so shaping the substrates that the spacing between them and the electrodes decreases towards the edges at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur. In other words the substrates need to be curved in a manner similar to that just described for the electrodes so that their edges (i:e: the sides parallel with the direction of travel) are closer to the electrodes than their central portions.

As with the first method referred to above the variation in the spacing may need to be determined in each particular instance by firstly carrying out a trial with flat electrodes and flat substrates, measuring the variations in thickness of deposition and then adjusting the spacing between the electrodes and substrates either by curving the electrodes and leaving the substrates flat or vice versa so as to compensate for the variations in thickness.

Different methods in accordance with the invention will now be described by way of example with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a plan view illustrating the shaping of electrodes used in a first method,

Figure 2 is a perspective view showing a pair of electrodes in accordance with Figure 1 in relation to a substrate being coated,

Figure 3 is a view corresponding to Figure 2 and illustrating an alternative method, and

Figure 4 is a further view similar to Figures 2 and 3 and illustrating a third method.

Turning first to Figure 1 the electrode 1 is illustrated in relation to the intended direction of substrate travel indicated by the arrow A. As can be seen from the drawing the width of the electrode 1 (as measured in the direction of the arrow A varies along its length as indicated by an arrow B, being a minimum at the centre and a maximum at the two edges. Each side 2 of the electrode is in the form of a relatively smooth curve which needs to be determined in advance by firstly carrying out a trial with rectangular electrodes, measuring the variations in thickness of deposition on a substrate and then shaping the electrodes appropriately. In other words the width of the electrode increases in the direction B at a rate which is roughly the same as the thickness of deposition would decrease if the electrodes were rectangular.

Figure 2 shows a pair of electrodes 1 shaped as just described mounted side by side in a sputtering chamber 3. The electrodes 1 are applied from a radio-frequency generator indicated diagrammatically at 4. The sputtering carried out in the chamber 3 constitutes one stage of an in-line process in which the substrates are moved through successive chambers. In the chamber 3 successive substrates, one of which is shown as 5, are moved in a direction indicated by an arrow C along the line joining the centres of gravity of the two electrodes 1. During the sputtering process itself the substrates may be either moving or stationary. When rectangular electrodes are used the thickness of deposit on each substrate is found to decrease slightly towards its edges indicated as 6 by the use of electrodes shaped as shown in Figure 1 substantial uniformity of deposit is obtained.

The precise shaping of the electrodes 1 is derived as previously described, i.e. by firstly carrying out a trial with rectangular electrodes and measuring the variations in thickness of the coating thus obtained. The shaping of the electrodes can then be derived from the expression previously quoted and if necessary a further trial can then be carried out in case any final adjustments of shaping are required to give the degree of uniformity of deposition necessary in any particular circumstances. These trials are carried out at the beginning of a run and once the shaping has been finalised large number of substrates can be coated with the required degree of uniformity. Similar results are obtained with the alternative arrangement of Figures 3 and 4 in which similar features are identified by the same reference numerals. In Figure 3 the width of the electrodes shown at 31 is constant but instead of being flat they are curved so that the spacing between the electrodes 31 and the substrates 5 is less at the edges than at the centre. The curvature required to give the necessary degree of uniformity of deposition is derived in the same way as described with reference to Figures 1 and 2, i.e. by carrying out one or more preliminary trials starting with flat electrodes and measuring the variations in the thickness of deposition.

In the alternative of Figure 4 flat rectangular electrodes shown as 41 are used but the spacing between the electrodes and the substrates, one of which is shown at 45, is made less at the edges than at the centre by appropriate curvature of the substrates themselves as shown in this figure. Once again the shaping of the substrates is determined by one or more preliminary trials at the beginning of a run.

With any of the three arrangements shown in Figures 2, 3 and 4 a magnetic field may be associated with the electrodes but is not indicated in the drawings. When such a magnetic field is used the flux lines are preferably oriented parallel with one of the three axes of the system, transverse orientations being useful for controlling electron bombardment of the substrates.

To give an example of the scale involved, the following typical dimensions apply to all three examples:—

Minimum central width=50 mm
Length of electrodes=100 mm or greater
Minimum separation at any point between electrode and substrate=20 mm.

WHAT WE CLAIM IS:—

1. A method of sputtering coatings on to substrates within an evacuated chamber by means of a radio-frequency supply source connected to a pair of similar electrodes mounted side by side, the sputtering constituting one stage of an in-line process in which the substrates are movel through successive chambers, the movement in the evacuated sputtering chamber being parallel with the line joining the centres of gravity of the two electrodes, and in which method electrodes are used which decrease progressively in width from the edges to the centre at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur.

2. A method of sputtering coatings on to substrates within an evacuated chamber by means of a radio-frequency supply source connected to a pair of similar electrodes mounted side by side, the sputtering constituting one stage of an in-line process in which the substrates are moved through successive chambers, the movement in the evacuated sputtering chamber being parallel with the line joining the centres of gravity of the two electrodes, and in which method the electrodes are so shaped that the spacing beween them and the substrates which are flat decreases towards the edges at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur.

3. A method of sputtering coatings on to substrates within an evacuated chamber by means of a radio-frequency supply source connected to a pair of similar electrodes mounted side by side, the sputtering constituting one stage of an in-line process in which the substrates are moved through successive chambers, the movement in the evacuated sputtering chamber being parallel with the line joining the centres of gravity of the two electrodes, and in which method the electrodes are flat and the substrates are so shaped that the spacing between them and the electrodes decreases towards the edges at a rate so chosen as to compensate at least to a major extent for variations in the thickness of coating which would otherwise occur.

4. A method according to any one of the preceding claims in which, as a preliminary step, a coating is sputtered using flat rectangular electrodes and flat substrates, the variation in thickness of the coating so obtained is measured, and the measurements thus obtained are used in choosing the degree of compensation.

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1332791 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1.

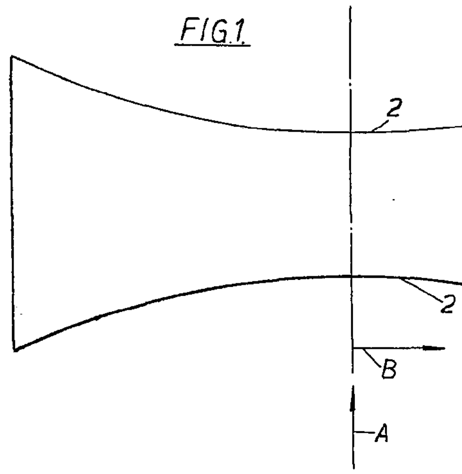

FIG.2.

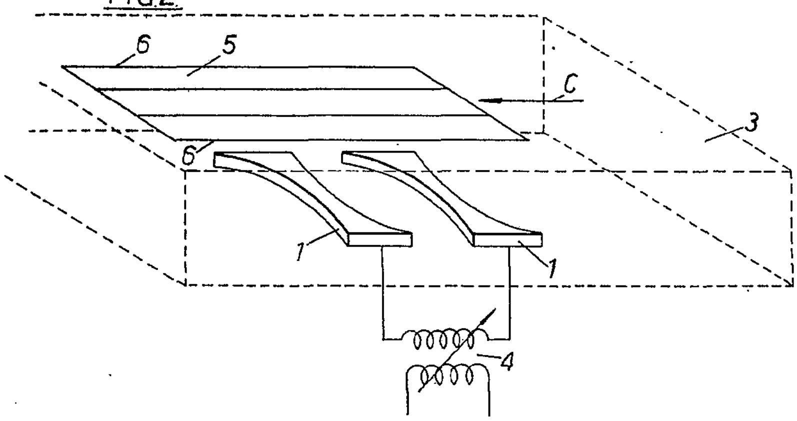

FIG.3.

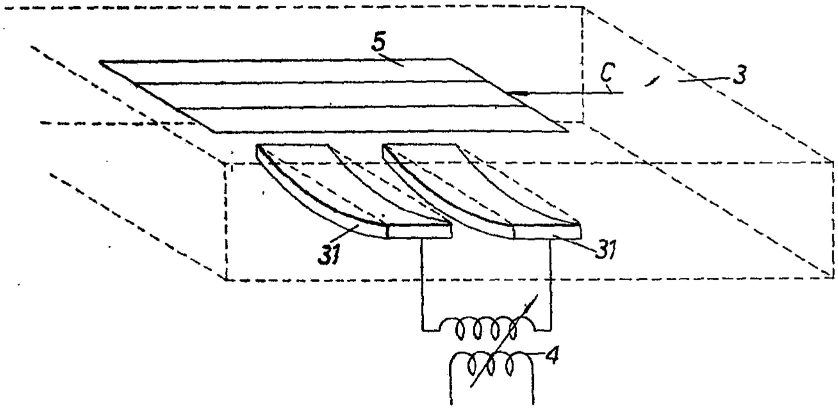

FIG.4.