

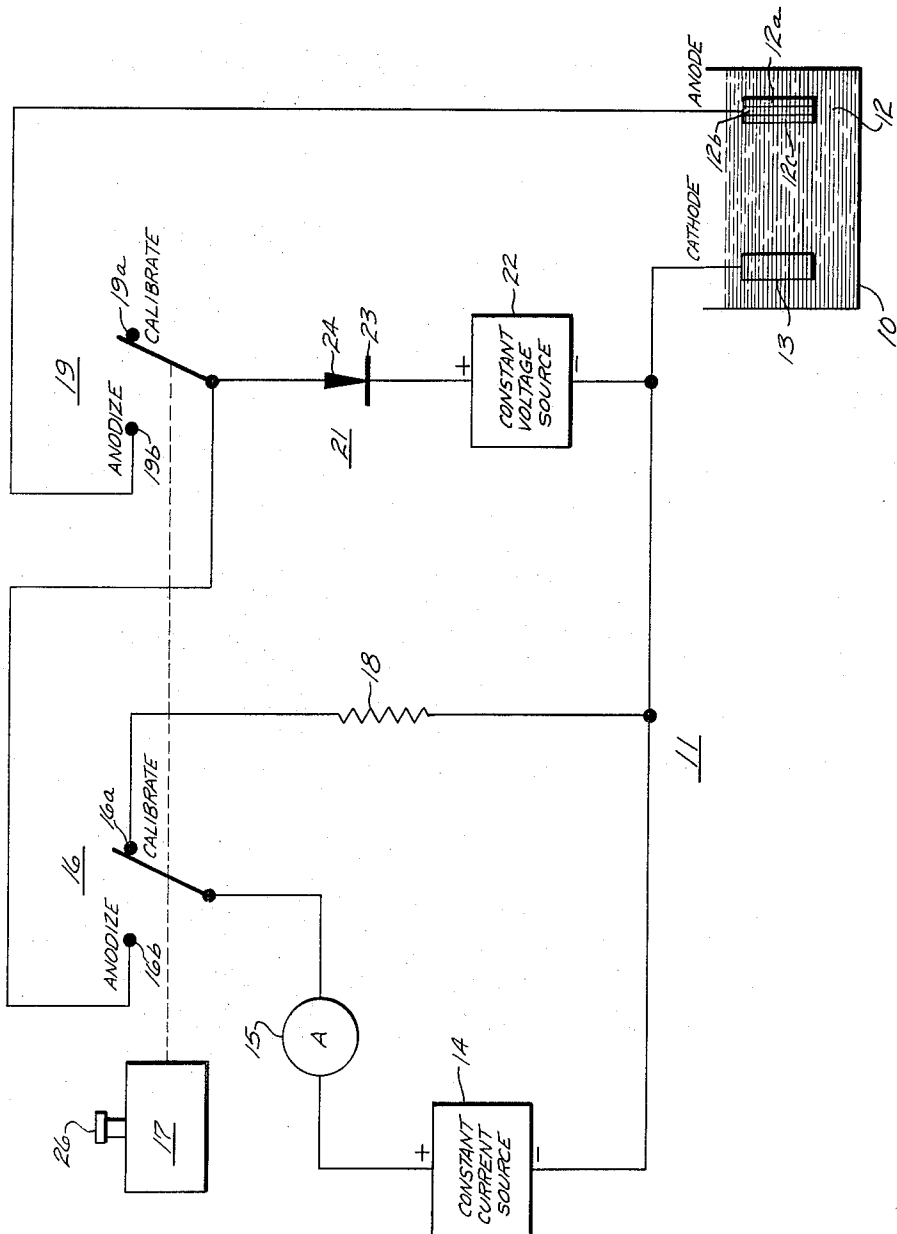
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ANODIZING APPARATUS

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## ANODIZING APPARATUS

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This invention relates to anodizing apparatus and particularly to an apparatus for anodizing a metal to form a thin film electrical device.

In the anodization of tantalum, for example, to form a thin film electrical device, such as a capacitor, a substrate having sputtered tantalum thereon is placed in an electrolytic solution and serves as the anode therein, the cathode being a strip of tantalum. The sputtered tantalum is then anodized by passing a constant direct current through the solution from anode to cathode. As a result, a film of tantalum pentoxide is formed on the anode. The thickness of the film thus produced is proportional to the magnitude of the direct current applied and the time interval over which it is applied. Further, it has been found that the voltage developed from anode to cathode during the application of the current is a function of the thickness of the tantalum pentoxide film. Consequently, to produce a tantalum pentoxide film having a predetermined thickness, it has been the practice to terminate the anodizing process when the voltage from anode to cathode indicated that the desired thickness has been reached. However, it has also been found that in order to equalize the film, i.e., equalize the thickness of the film throughout the entire area being anodized, it is necessary to continue the anodization at constant voltage for an additional period of time.

Heretofore, this was accomplished by applying the constant direct current and having an operator observe the buildup of the voltage between anode and cathode by means of a meter. When a voltage was reached which indicated that the film had reached the desired thickness, the operator would cut out the constant current supply and switch in a constant voltage supply to accomplish the equalization. Manifestly, such manual operation is time consuming and is thus not economically compatible with mass production techniques.

Accordingly, it is the general object of this invention to provide a new, improved and simple apparatus for anodizing a metal to form a thin film electrical device.

Another object of this invention is to provide a new, improved and simple apparatus for anodizing tantalum to form a thin film electrical device.

A further object of this invention is to provide an anodizing apparatus which will accomplish the transition from constant current to constant voltage automatically.

Apparatus, embodying certain features of the invention, for anodizing a metal object to form an oxide film of a desired thickness thereon, may include, a constant current source connected in a parallel electrical relationship with a constant voltage source, the output of the parallel circuit being applied to the input of an anodizing solution having the metal object to be anodized immersed therein. The output voltage of the constant voltage source is set to a value indicative of the desired oxide film. A diode is provided intermediate the constant voltage source and the output of the constant current source for automatically maintaining the voltage at the input of the anodizing solution at a value which is indicative of the desired film thickness when such thickness is reached.

The invention will be more readily understood from the detailed description which follows when read in

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conjunction with the single appended drawing which illustrates schematically an embodiment of the invention.

Referring now to the drawing, the apparatus illustrated therein includes a receptacle 10 having an electrolytic solution therein. Disposed within the solution and adapted to be connected to an electrical control circuit, designated generally by the numeral 11, is an anode 12 and a cathode 13. Advantageously, the anode 12 may comprise a glass substrate 12a with sputtered tantalum 12b thereon and the cathode 13 may comprise a strip of tantalum.

The electrical control circuit 11 includes a constant direct current source 14, the positive terminal thereof being connected through a D.C. ammeter 15 to a first set of contacts, designated generally by the numeral 16, of a conventional timing device 17. In the CALIBRATE position the constant current source 14 is connected through contact 16a to a calibrate resistor 18. In the ANODIZE position source 14 is connected through contact 16b, and a second set of contacts, designated generally by the numeral 19, of the timing device 17, to an anode 12. In the ANODIZE position contact 16b also connects source 14 to a diode 21 and a constant voltage source 22. The cathode 23 and anode 24 of diode 21 are connected respectively to the positive terminal of voltage source 22 and contact 16b (via the common pole of contacts 19). The cathode 13, the negative terminal of voltage source 22, one end of resistor 18 and the negative terminal of current source 14 are all connected to a common ground. The constant current and voltage sources 14 and 22, and the timer 17 may all be of well known and commercially available types.

In operation, contacts 16 and 19 of the timing device 17 are in their respective CALIBRATE positions, as shown. Accordingly, the current from current source 14 passes through the calibrate resistor 18. This current is then set to a desired value by adjustment of current source 14. The value to which the current is set depends upon, among other things, the rate at which it is desired to build up the tantalum pentoxide film. The output of constant voltage source 22 is then set to a value which is proportional to the desired thickness of the tantalum pentoxide film.

When timing device 17 is activated, such as by depressing the pushbutton 26 pictorially illustrated, contacts 16 and 19 are operated to place circuit 11 in the ANODIZE condition.

As a result, the current from current source 14 is applied to the anode 12 and commences the anodization thereof. As the anodization proceeds, the tantalum pentoxide film 12c formed on the sputtered tantalum 12b increases in thickness, and the voltage developed between anode 12 and cathode 13 increases in magnitude.

At this point, it should be noted that as long as the voltage developed between anode 12 and cathode 13 is less than the output voltage of voltage source 22, current is precluded from passing through diode 21. However, as soon as the voltage developed between anode 12 and cathode 13 is equal to the output voltage of voltage source 22, current will flow through diode 21 and the voltage developed between anode 12 and cathode 13 will be "clamped" to the output voltage source 22. Accordingly, it is seen that the tantalum pentoxide film builds up to a predetermined thickness, determined by the output voltage of source 22, at which time any further increase is precluded because of the clamping action of diode 22. A constant voltage is then maintained between anode 12 and cathode 13 for a predetermined time during which equalization of the thickness of the tantalum pentoxide film takes place. The timing device is set to expire after

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an interval which is the sum of the approximate time necessary for the desired thickness to build up and the time necessary for equalization. Accordingly, at the expiration of timing device 17, contacts 16 and 19 return to their respective CALIBRATE positions and the circuit 11 is decoupled from anode 12, thus terminating the anodizing.

One application of the invention is in the production of thin film capacitors. In this case the tantalum pentoxide film serves as the capacitor dielectric.

It is to be understood that the above-described arrangement is simply illustrative of the application of the principles of the invention. Numerous other arrangements may be readily devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof. For example, a plurality of thin film devices may be anodized at one time. In this case, assuming that there are N devices, each requiring a current I, the devices would be connected in parallel and the current source 14 would be set to deliver a current equal to NI.

What is claimed is:

1. An electrical energizing and control circuit for anodizing the surface of a workpiece in an electrolytic anodizing cell, first at a constant current with increasing applied voltage until a desired film thickness has been reached and then at a constant voltage with decreasing current flow through the cell to equalize the thickness of the film, the circuit comprising:

a constant-current D.C. source connected across the cell for applying a constant anodizing current thereto of sufficient magnitude to anodize the workpiece at a desired rate, the voltage drop across the cell, and consequently the applied voltage, increasing as the anodizing process proceeds to a value dependent on the thickness of the anodized film at any time;

an adjustable constant-voltage D.C. source connected across the cell in parallel with the constant-current source, and having an output voltage that is preset

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to equal the voltage drop across the cell when the desired film thickness has been reached; and a unidirectional conducting device connected in series with the constant-voltage source so as to block the flow of current from the constant-voltage source to the cell at all times, while permitting the flow of current from the constant-current source through the constant-voltage source after the voltage drop across the cell has risen to the preset voltage of the constant-voltage source, indicating that the desired film thickness has been reached, thus maintaining the voltage drop across the cell constant at the preset value after the desired film thickness has been reached so as to equalize the thickness of the film.

2. An electrical energizing and control circuit as recited in claim 1, wherein the unidirectional conducting device comprises a diode having its cathode connected to the positive terminal of the constant-voltage source and its anode connected to a junction point between the positive terminal of the constant-current source and the anode of the cell.

3. An electrical energizing and control circuit as recited in claim 1, wherein a switching circuit, including an adjustable timer, is provided for connecting the D.C. sources to the system at the start of an anodizing operation, and for disconnecting the D.C. sources from the system after a time preset to correspond with the time estimated to complete the anodizing process.

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