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SIGNALLING DEVICE FOR VACUUM EVAPORATION SYSTEM

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The present invention relates generally to techniques for vaporizing metal in vacuum, and more particularly to a signalling device adapted to indicate the need for replenishment of material in a vacuum evaporation system, the signalling device controlling a dispenser to feed a charge of material to a heater.

Films can be deposited on metal or non-metal surfaces by condensation of vapor. The process of vapor deposition is carried out in three steps; namely, the generation of vapor, diffusion to the object being plated, and condensation on its surface. In the thermal evaporation technique, the vapor is generated by direct heat, usually produced by an incandescent tungsten filament. The material to be evaporated is supplied to the filament in wire or pellet form. The charge material may be an electrically conductive metal or a semi-conductive substance such as silicon, selenium, germanium, lead sulphide, etc.

One of the processes entailed in the manufacture of quartz crystal frequency-control elements is the deposition of a metallic substance on one of the crystal faces. The crystal to be so plated is inserted in a vacuum chamber containing a filament on which is placed a charge of metal to be evaporated. This charge may take the form of a pellet of metal or a metal wire staple which in the molten state adheres by surface tension to the filament. As the material is gradually vaporized from the filament, the amount of molten metal is gradually diminished until a point is reached where vapor generation ceases.

Heretofore, the metallic plating of crystals by vacuum evaporation was conducted under the manual control of an operator whose function it was to replenish the material on the filament when the charge thereon became exhausted. Each time a quartz crystal was to be plated, the operator would inspect the evaporation filament and determine by experience whether sufficient material remained on the filament from the previous plating operation to carry out the next operation. In order to maintain a high rate of production, the operator's decision had to be a correct one, otherwise plating could not be completed and time would be lost exposing the partially finished crystal to air, adding a fresh charge of material to the filament and re-evacuating the chamber before again proceeding with the plating.

In view of the foregoing, it is the major object of the invention to provide a signalling device for indicating the need for replenishment of metal to be evaporated in a thermal evaporation system. The device in accordance with the invention is of particular value when applied to the sequential processing of components by vacuum evaporation or where it is important that the plating of any one component is not to be interrupted because an inadequate amount of material remains on the filament. It is effective when controlling any aspect of a vacuum evaporation process which depends upon a minimal amount of an electrically-conductive evaporating material remaining on an electrically-conductive filament or crucible.

Also an object of the invention is to provide an auto-

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matic loading device which dispenses a charge of evaporating metal onto a filament or other form of heater in response to a control signal indicating the need for replenishment.

A further object of the invention is to provide a signalling system which expedites the processing of crystals or other articles to be plated and which is efficient and reliable in operation.

Briefly stated, in a signalling device in accordance with the invention, a conductive probe is provided in the proximity of the evaporation filament. The probe is displaced from the filament to an extent whereby when a sufficient charge of material is contained on the filament, the charge, which is conductive or semi-conductive, acts as a bridge effecting electrical continuity between the probe and the filament. This continuity is disrupted when the charge falls below a minimal value. The probe and filament are connected in a switching circuit which functions to operate a charge dispenser when continuity between the probe and filament is broken, thereby replenishing the charge on the filament.

The amount of material remaining on the filament can be determined while the material is molten and under vacuum, or when the filament is cold and the evaporating material has solidified, e. g., when the chamber is exposed to air. New material can be added while in atmosphere or when the chamber is under vacuum.

For a better understanding of the invention as well as other objects and further features thereof, reference is had to the following detailed description to be read in conjunction with the accompanying drawings, wherein like components in the various views are identified by like reference numerals.

In the drawings:

Fig. 1 is a schematic diagram of a signalling device in accordance with the invention.

Fig. 2 is a diagram illustrating one filament charge condition.

Fig. 3 is a diagram illustrating another filament charge condition.

Fig. 4 is a diagram illustrating still another charge filament condition.

Referring now to the drawing, there is shown a vacuum chamber, represented by block 10, in which there is supported an evaporation filament 11 which may be formed by a tungsten wire bent to define a V-shaped portion designated by numeral 12 whose arms diverge from the apex 12a. The filament is electrically heated by current supplied from a power source 13.

The filament is loaded by a metal charge which in practice may take the form of a wire staple 14 discharged from an electromagnetically-actuated stapling machine 15, the staple straddling the V portion 12 of the filament. The stapling machine may be of standard design such as the type in which the staples are pre-cut and assembled into a bank or cartridge 16 of separable staples which are individually discharged. Alternatively, the stapler may be of the type in which a reel of wire is provided and the stapler acts to shape and cut the wire into the usual staple form. The metal wire may be of any desired material, such as aluminum, gold or silver. The metal staple which is dropped on the heated filament is vaporized and deposited on the surface of a crystal 19. It will be understood that any suitable surface may be plated and that the invention is by no means limited to crystal-plating.

In Fig. 1, loading device is shown within the confines of the chamber. In practice, the loading device may in fact be outside the chamber and the need for gold is sensed while the chamber is open. The gold-loading device comes forward, places a charge of gold on the filament

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and then retracts out of the way so that the chamber can be closed.

When the wire is deposited on the V portion of the heated filament, the wire is liquefied and forms a meniscus or crescent-shaped film 17 which by surface tension spans the converging arms of the V-shaped portion 12 of the filament. Inasmuch as the resistivity of the filament circuit is lowest at the apex portion of the wire which is spanned by the molten material and highest at the portions of the wire remote from the meniscus of molten metal, the wire is hottest away from the meniscus and coolest at the V portion. This heat differential tends to keep the molten metal in the region of the V of the filament and as the metal evaporates, the meniscus shrinks until ultimately what metal remains is collected at the very tip.

A metallic probe 18 of non-volatile material, such as tungsten or tantalum, etc., is positioned normal to the plane of the filament, the probe lying intermediate the arms of the V portion 12 of the filament and being displaced from the apex thereof to a pre-determined extent. The function of the probe is to determine whether a sufficient amount of material remains on the filament to justify continued processing or whether replenishment is necessary. The manner in which this is accomplished is illustrated in connection with Figs. 2, 3 and 4. The nature of the probe material should be such that it does not alloy with the material being plated.

As shown in Fig. 2, the probe 18 lies between the arms of the V-shaped portion 12 at a position displaced from the apex 12a. In the absence of molten or solidified metal on the filament, the probe is electrically out of connection with the filament, but when a full charge of molten metal is on the filament, the probe lies within the meniscus 17 and electrical contact is established between the probe and the filament.

As the meniscus shrinks with continued vaporization, as shown in Fig. 3, the probe 18 continues to make electrical contact with the filament until the extent of shrinkage, as shown in Fig. 4, is such as to reduce the area of the meniscus to exclude the probe, at which point the probe is out of connection with the filament. Thus the probe may be positioned relative to the apex of the filament whereby when the charge on the filament falls below a minimal value, the connection between the filament and the probe is broken to indicate the need for replenishment. The manner and circuit means by which this is accomplished are as follows.

A double-pole single-throw switch command 21 is provided, one pole 21a being connected to one end of filament 11, the associated fixed contact 21b being connected to one end of the solenoid of a relay 22. The other end of the solenoid is connected through an energizing battery 23 to the probe 17. The other pole 21c of the command switch is connected to one terminal of an electromagnetic actuator 24 for the stapler 15, the associated fixed contact 21d going to the fixed contact 22a of the relay. The structure of switch 21 is such that when actuated circuit 21b closes first, followed by closure of circuit 21d, the armature 22b, which normally engages fixed contact 22a when the relay is unenergized, is connected to one terminal of the control circuit 25 for the stapler actuator, the other terminal of this circuit being connected to the second terminal of the actuator 24.

In operation, when an indication of the status of the evaporation material is desired, the command switch 21 is closed. If the circuit including the evaporation filament 11 and probe 18 has continuity through the molten metal 17, and electrical current supplied by source 23 will flow through relay 22, to actuate armature 22b and break engagement with contact 22a.

Command switch element 21c—21d is in series with relay switch element 22a—22b, this series circuit being interposed between the control circuit 25 and the stapler actuator. The control circuit is designed to energize the

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stapler actuator if, when the command switch is closed, the relay switch 22a—22b remains closed, thereby indicating depletion of the material on the filament. Thus in this condition the stapler acts to replenish the evaporating material. But if when the command switch is closed, relay switch 22a—22b is caused to open, thereby indicating the presence of a sufficient amount of material on the filament, the stapler is not activated.

By controlling the distance between the evaporation filament and the probe, one can predetermine the minimal amount of evaporating material remaining on the filaments before new material is added. Thus the complete depletion of evaporation material in the midst of a cycle can be prevented.

The operation of the command switch may be coordinated with a sequential system for feeding and removing crystals into and out of the chamber, whereby with each new crystal the switch is operated to sense the filament condition and to supply a fresh charge in the event the filament material is depleted below the required level.

While there has been shown what is considered to be a preferred embodiment of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. For example, the probe could also dip into a crucible and thus establish the level of evaporating material therein. It is intended, therefore, in the annexed claims to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

1. In a vacuum evaporation system wherein a charge of evaporation material is placed on the apex portion of a bent filament wire to form a meniscus spanning the arms of the filament, the meniscus area contracting in the course of evaporation, a signalling device to indicate the state of the charge on said filament and including a probe projecting between the arms of said apex portion at a position to engage said meniscus only when the area thereof exceeds a predetermined size, and circuit means including said probe and said filament to indicate the charge condition.

2. A signalling device as set forth in claim 1, wherein said circuit means includes a voltage source connected through a switch defined by said probe and filament to an indicator.

3. In a vacuum evaporation system wherein a charge of evaporation material is placed by a dispenser on the apex portion of a bent filament to form a meniscus spanning the arms of the apex portion, the meniscus area contracting in the course of evaporation, a signalling device to indicate the state of the charge on said filament and including a probe projecting between the arms of said apex portion at a position to engage said meniscus only when the area thereof exceeds a predetermined size, and circuit means including said probe and said filament to indicate the charge condition, and means responsive to said indication to actuate said dispenser to deposit a fresh charge on said filament when said charge is below said predetermined size.

4. In a system as set forth in claim 3, wherein said dispenser is electromagnetically actuated by the de-energization of a relay connected in a circuit including said probe and said filament, said circuit being interrupted when said charge is depleted.

5. A system as set forth in claim 1, wherein said charge is of metallic material.

6. A system as set forth in claim 1, wherein said charge is of semi-conductive material.

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