April 4, 1972 F. KRAUS 3,654,110

METHOD OF APPLYING A COATING BY CATHODE SPUTTERING

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Fig.1

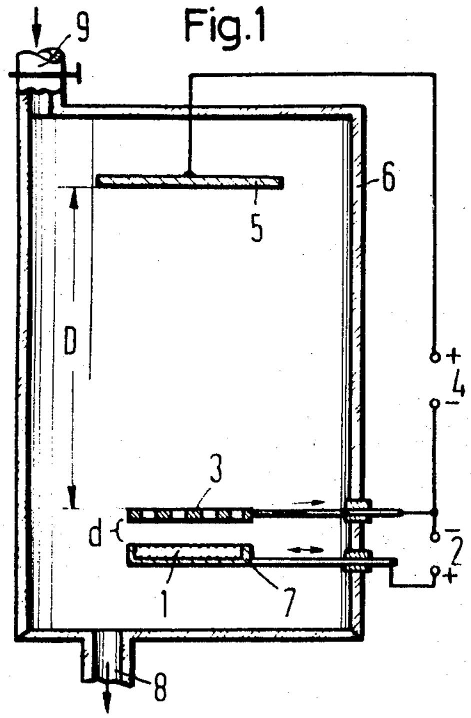


Fig.3

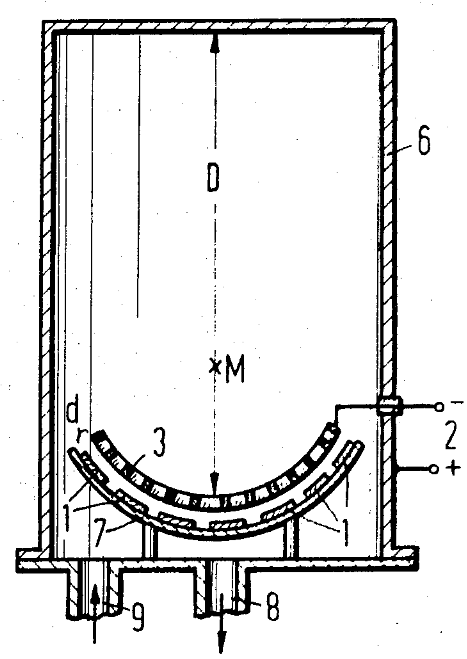
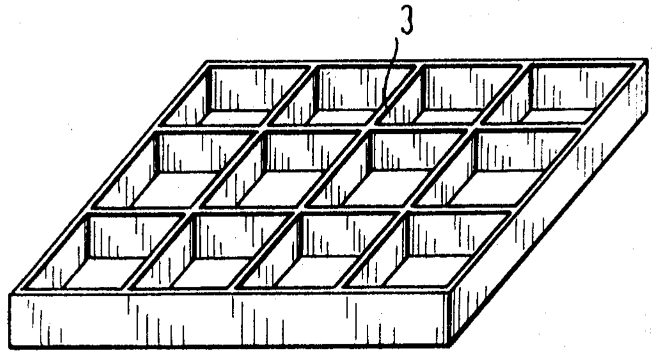


Fig.2



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METHOD OF APPLYING A COATING BY CATHODE SPUTTERING

Friedrich Kraus, Neubiberg, Germany, assignor to Siemens Aktiengesellschaft, Berlin and Munich, Germany

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ABSTRACT OF THE DISCLOSURE

The invention relates to a method of coating a layer of inorganic, solid material upon a base by cathode sputtering. The invention is characterized by the fact that a grid or sieve-like perforated cathode, which is comprised, at least at its surface, of the material is to be deposited, is arranged between anode and substrate and is negatively biased against both. The substrate is brought so close to the cathode that the space between the two is insufficient to maintain an independent gas discharge, at the adjusted pressure and the applied voltage.

It is known to use the metal particles sputtered during an electric discharge, for metallizing such objects as a semiconductor surface. As a rule, the object to be coated, if it is conductive, is connected as the anode and the material to be sputtered as the cathode of a gas discharge, which discharge is effected at an appropriately high voltage. If the body to be coated is non-conductive, instead of the above-described technique, a conductive anode, for example a metallic carrier plate, is provided next to the body which is to be coated. In all cases, between the object to be coated and the object to be sputtered, lies the cathode potential drop space of the discharge, i.e. a path of at least 5 to 100 median, free path lengths, through which the sputtered material can be diffused. As a rule, a gas pressure of 10^0 and 10^{-3} torr is adjusted in the discharge, so that one can count on a median free path length of 10^{-2} to 10 cm. Due to these conditions, one obtains small sputtering rates and considerable impurities, in connection with materials which are difficult to atomize. Improvement can be achieved partly by using hot cathodes and magnetic fields or special ion sources outside of the highly evacuated space which contains the object to be coated. This type of method is not favorable due to its intricacies and its considerable expenditure.

The present invention deals with this problem.

The invention relates to a method of coating a layer of inorganic, solid material upon a base, e.g. a semiconductor surface, by cathode sputtering. According to my invention, the method is characterized by the fact that a grid or sieve-like perforated cathode, which is comprised, at least at its surface, of the material to be deposited, is arranged between anode and substrate and is negatively biased against both. Furthermore, the substrate is brought so close to the cathode that the space between the two is insufficient to maintain an independent gas discharge, at the adjusted pressure and the applied voltage.

It is important that the perforated, e.g. grid-like, cathode is arranged at a distance of a maximum of approximately ten median free path lengths, from the substrate to be coated, so that the cathode drop, which maintains the discharge, is located outside of the space between substrate and cathode, namely between the latter and an anode located a greater distance away. Material, sputtered by the cathode, has, therefore, only a short diffusion path. Preferably, the grid rods of the perforated cathode will have a tape-shaped configuration, whose surfaces lie perpendicularly to the substrate surface. The shape of the cathode is similar, in this case, to that of a grating of a "shoe scraper." This improves the effectiveness even more, the radiating cathode surface is enlarged and the uniformity of the atomized layer is not impaired.

In the drawing,

FIG. 1 schematically shows appropriate apparatus for performing the method of a preferred embodiment of the invention;

FIG. 2 shows a preferred embodiment of the grid-type cathode, in an oblique top view; and

FIG. 3 shows another embodiment of the invention.

The object **1** to be coated, e.g. a semiconductor crystal of silicon or germanium, or the carrier for the conductor paths or resistor layers, is connected to the positive pole of a direct current voltage source **2**, at whose negative pole is the cathode **3**. An additional direct voltage source **4** is between the cathode **3** and the anode **5**. This arrangement, with the exception of the direct current voltage sources (e.g. batteries), is arranged in a vessel **6**, for example made of glass, which can be evacuated. The distance *d* between the substrate **1** to be coated and the perforated cathode **3** is less than ten median free path lengths, which at a preferable gas pressure $p=2\times10^{-2}$ torr inside the evacuated vessel **6**, is a path of 20 mm., and is preferably 10 mm. The distance D between the cathode **3** and the anode **5** is 20 cm. During practical application, the substrate **1** is located on a holder **7** which serves, at the same time, as an electric lead and which makes it possible to regulate the distance *d* between substrate **1** and cathode **3**. It is also possible to swing the cathode **3** out from the space between substrate **1** and anode **5** to apply an appropriately high voltage between the anode **5** and the substrate **1**. In this manner the substrate is cleaned by exposure of its surface to ion bombardment. The process is preferably carried out at a continuous evacuation apparatus, just as it is sometimes expedient to effect the actual coating of the substrate **1** with a continuous evacuation pump. Connection to a vacuum pump (not shown) is indicated as **8**. Argon, for example, is introduced at **9** via a needle valve, which regulates the gas pressure. To effect the actual coating, the cathode **3** is then placed between substrate **1** and anode **5** and, in accordance with the present invention, the dimensioning of the distance *d* is observed. The voltages between substrate **1**, cathode **3** and anode **5** are so selected that in any event only one sputtering of the cathode surface takes place while such action is prevented at the surface of the substrate. At an appropriate dimensioning of the distance *d* a satisfactory coating quota is obtained at the surface of the substrate, even when the metals involved are distinctly difficult to atomize, such as tungsten, molybdenum, chromium, tantalum, titanium, and aluminum. Semiconductors and non-metals, as well as appropriately resistant chemical compounds such as oxides, nitrides, carbides, silicides and other such compounds can be atomized or applied as coating. In cases where the conductivity of said materials is insufficient for maintaining an undisturbed cathode function, it is best to coat two electrodes with the respective material, one of which is perforated in accordance with the invention and is arranged immediately ahead of the substrate, whereby a high-frequency alternating voltage is connected between the two.

One must make sure, however, that all remaining parts in the recipient are always positively charged with respect to both electrodes. Another possibility of atomizing or sputtering non-conductive chemical compounds, in the manner suggested by the present invention, is first to produce said compounds in the gas chamber in such a way that a conductive component, e.g. silicon, is sputtered as a cathode in a non-inert gas, e.g. oxygen, nitrogen or their compounds, whereupon the substrate will be coated with the compound which results. Experience has shown that an optimum voltage exists with a selection of $d=1$ cm., $D=$ 20 cm. and a cathode material comprised of nickel and argon, at 1–4 kv.

The perspective view of the cathode **3**, illustrated in FIG. 2, shows plainly the preferred, tape or band-like structure of the individual rods which form the cathode. The tapes can also be oriented diagonally to the surface of the substrate.

The coated layers obtained according to the method of the invention, particularly metal or semiconductor layers, have a particularly good adherence if the distance is less than approximately one median free path length. It is moreover recommended to move the cathode in parallel to the substrate surface, respectively to shift the substrate **1** back and forth beneath the cathode during the atomizing process in order to improve, in this manner, the uniformity of the coated layer.

If the largest possible number of small parts, such as semiconductor components produced with the planar method, glass or ceramic plates, are to be provided with a tightly adhering layer, then in accordance with FIG. 3, the carrier for these parts can be constructed as a spherical segment **7** whereby the space of the recipient will be utilized to the utmost. The grid-shaped perforated cathode **3** is then also curved. In accordance with the invention, the grid is arranged closely to the inside surface of the carrier segment **7**. The metal wall **6** of the recipient which is at ground potential can serve as the anode and can be in conductive connection, if necessary, with the carrier segment **7**. This arrangement also makes it possible for the cathode **3** to swing out of the way prior to or following the sputtering process and to place an evaporization source into the center point M of the carrier segment as well as to vapor-depoist an additional material upon the parts **1** which are to be coated.

I claim:

1. A method of applying a layer of inorganic solid material upon a substrate, by means of a cathode sputtering, which comprises placing a grid-like perforated cathode, comprised at least at its surface, of the material to be sputtered, between the anode and the substrate, said cathode being negatively biased with respect to both the anode and substrate, the substrate being so close to the cathode that not independent gas discharge can occur between the two.

2. A method of supplying a layer of inorganic solid material upon a substrate, by means of a cathode sputtering, which comprises placing a grid-like perforated cathode, comprised at least at its surface, of the material to be sputtered, between the anode and the substrate, said cathode being negatively biased with respect to both the anode and substrate, the substrate being so close to the cathode that no independent gas discharge can occur between the two, the distance between cathode and substrate being a maximum of ten median, free path lengths of the particles, sputtered from the cathode.

3. The method of claim **2**, wherein a perforated cathode whose band-like surfaces are oriented vertically to the surface of the substrate to be coated, is used.

4. The method of claim **3**, wherein at the onset of the process a discharge is effected between the substrate to be coated and the anode with the cathode removed, whereby a cleansing occurs at the surface of the substrate, thereafter placing the cathode between the substrate to be coated and the anode and applying the voltage needed for sputtering the cathode material to coat the substrate.

5. The method of claim **4**, wherein there is a relative movement, between the cathode and the substrate to be coated, during the coating process.

6. The method of claim **5**, wherein the voltage between anode and cathode is 1 to 4 kv., and between the cathode and the substrate to be coated, 0 to 10 kv.

7. The method of claim **6**, wherein a gas pressure of 1 to 10^{-3} torr is maintained in the cathode sputtering chamber and the gas discharge is effected in the residue of argon and/or another inert gas.

8. The method of claim **7**, wherein the geometrical configurations of anode and cathode is such that a focussing takes place, of the positive ions emitted by the anode, upon the cathode.

9. The method of claim **8**, wherein a metal semiconductor, or insulating coating, is further reinforced through vapor deposition.

10. The method of claim **8**, wherein the discharge takes place in a chemically active gas, which reacts with the cathode material, so that a coating of the substrate takes place with the resulting compound.

11. The method of claim **8**, wherein a metal semiconductor or insulating coating is further reinforced by galvanic means.

References Cited

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JOHN H. MACK, Primary Examiner

S. S. KANTER, Assistant Examiner

U.S. Cl. X.R.

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