

Nov. 5, 1974

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3,846,294

METHOD OF COATING THE INTERIOR WALLS OF THROUGH-HOLES

Filed Jan. 11, 1974

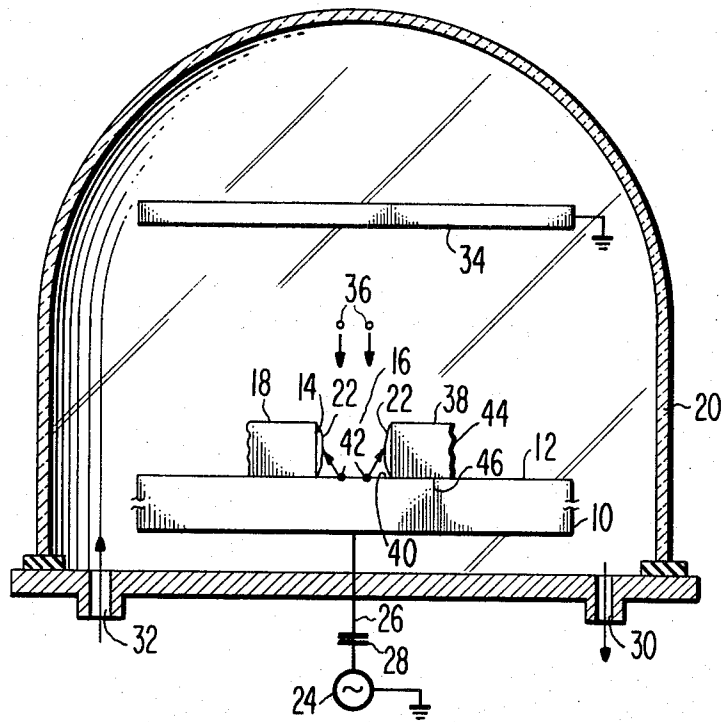


Fig. 1

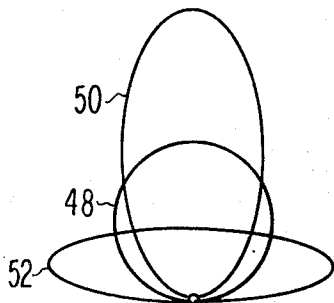


Fig. 2

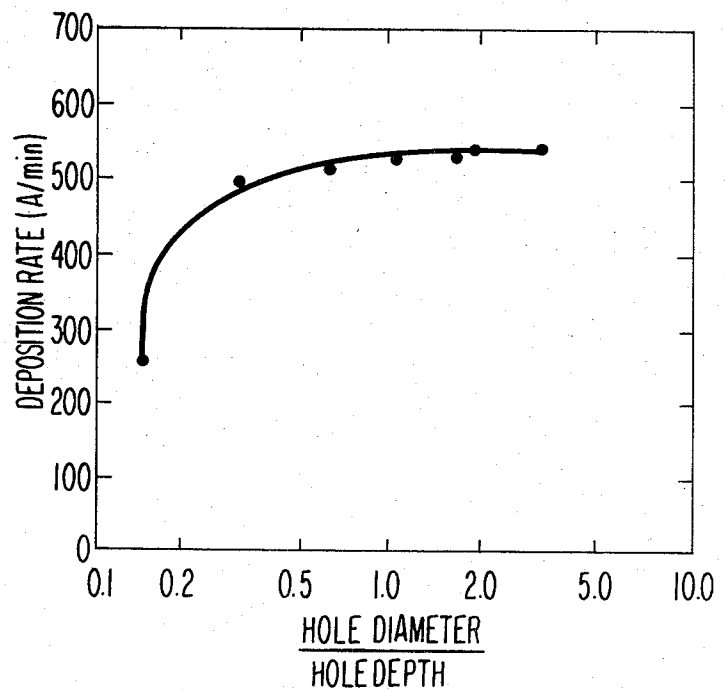


Fig. 3

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METHOD OF COATING THE INTERIOR WALLS OF THROUGH-HOLES

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Filed Jan. 11, 1974, Ser. No. 432,457

Int. Cl. C23c 15/00

U.S. Cl. 204—192

4 Claims

ABSTRACT OF THE DISCLOSURE

The interior walls of through-holes in a substrate are selectively coated with a thin film of a desired material by sputter-etching a target having a surface comprised of the material to be deposited. The substrate containing the through-holes is disposed directly upon the surface of the target. The target material is sputter-etched from the surface of the target directly beneath the through-hole and is coated on the interior walls of the through-holes.

FIELD OF THE INVENTION

This invention relates to coating the interior walls of through-holes. More particularly, this invention relates to a method for selectively coating the interior walls of small diameter through-holes in a substrate with a thin film of target material by sputter-etching.

BACKGROUND OF THE INVENTION

Selectively coating the interior walls of a small diameter through-hole, e.g. through-hole diameters of about 10^{-2} to 10^{-3} inches, in a substrate is difficult. Conventional methods for thin-film deposition, including conventional sputtering techniques, electroplating, electroless-plating, ion plating, and vapor-plating, are not entirely satisfactory for solving this problem.

A conventional sputtering technique for coating the interior walls of a through-hole is to coat the entire substrate, with the exception of the interior walls of the through-hole, with a photoresist mask, deposit the film material over the entire substrate including the interior walls of the through-hole and remove the photoresist mask to undercut the film material. This technique leaves only the interior walls of the through-hole coated, but involves several steps.

Sputtering is a useful and valuable process for depositing thin films. It is versatile since, theoretically, any target material may be used and, in the case of film deposition, the rate of deposition and film thickness are easy to maintain. Also, the film which is deposited is uniform in thickness and stoichiometry and has excellent mechanical properties (adhesion, etc.). Techniques and equipment for sputtering which are pertinent to the instant invention are described in the following:

- (1) J. L. Vossen et al., "R-F Sputtering Processes," RCA Review, 29, No. 2, 149-179 (June 1968).
- (2) L. I. Maissel and R. Glang (ed.), "Handbook of Thin Film Technology," McGraw-Hill Book Co., New York, N.Y., 1970.
- (3) J. L. Vossen et al., "Back Scattering of Material Emitted from RF Sputtering Targets," RCA Review, 31, No. 2, 293-305 (June 1970).

Sputter-etching is a standard technique used to clean surfaces and etch patterns in materials. The techniques of sputter-etching are described in references 1 and 2. The instant invention coats the interior walls of a through-hole with a thin film in one step by sputter-etching.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a substrate containing a through-hole, mounted on a target assembly.

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FIG. 2 is a representation of the angular distribution of material emitted from a sputtering target surface at differing sputtering voltages.

FIG. 3 is a representation of the deposition rate of palladium on the inside walls of through-holes in steel vs. the aspect ratio of the hole, i.e. hole diameter/hole depth.

SUMMARY OF THE INVENTION

In accordance with the instant invention, a technique is described for selectively coating the interior walls of through-holes in a substrate by sputter-etching. The surface of the target for sputter-etching is comprised of the material to be deposited on the interior walls of the through-holes. The substrate containing the through-holes is disposed directly on the target to be sputter-etched. When the target is sputter-etched, target material from the target surface directly beneath the through-holes in the substrate is emitted from the surface of the target and deposited on the interior walls of the through-holes.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to FIG. 1, a target 10, having a surface 12 which is composed of the material or materials to be deposited on the interior wall 14 of a through-hole 16 in a substrate 18 is placed within a vacuum chamber 20. The substrate 18 having a through-hole 14 the interior wall 18 of which is to be coated with a film 22 is disposed against the surface 12 of the target 10. The target 10 is electrically coupled to a radiofrequency source 24 via a lead 26 and a capacitor 28. The capacitor 28 and the radiofrequency source 24 may be replaced by a direct current power supply if the target 10 is an electrical conductor.

The vacuum chamber 20 is evacuated via outlet 30 connected to a vacuum pump (not shown). The vacuum chamber and pump system should be capable of reducing the pressure in the vacuum chamber to about 10^{-6} torr. An ionizable gas, such as argon, is admitted to the chamber 20 via inlet 32. The ionizable gas used is determined by the nature of the target surface 12 and the required deposition rate. The preferred pressure of the ionizable gas is about 70 millitorr, since this pressure was found to yield the highest deposition rate of film 22. It should be noted that film deposition will occur, but at reduced rates, for any gas pressure at which it is possible to sustain a glow discharge.

A grounded electrode 34 is placed opposite target 10 to induce a glow discharge in the ionizable gas when a radiofrequency field is applied to the target 10. The method described in the instant invention uses a radiofrequency power source to induce a glow discharge in an ionizable gas. However it is obvious to one skilled in the art that other power sources, such as a dc power source, can be used to induce a glow discharge and sputter-etch the target surface. These techniques are described in references 1 and 2.

The glow discharge created by applying the radiofrequency voltage ionizes the argon ions 36 between the electrode 34 and the target 10. The positively charged argon ions 36 are accelerated in the plasma and bombard the surface 38 of the substrate 18 and the surface 40 of the target 10 directly beneath the through-hole 16. Upon striking the target surface 40 beneath the through-hole 16 the momentum of the charged argon ions 36 is transferred to atoms 42 on the target surface 40 and, as a result of the rupture of surface bonds, atoms 42 are emitted from the target surface 40. The emitted atoms 42 strike the interior wall 14 of the through-hole 16 and adhere to the surface of the interior wall 14 forming a film 22 without appreciably coating the surface 38 of the substrate 18. Since the argon ions 36 usually have

some collisions with other ions when traversing the ionic sheath surrounding the target 10, the argon ions 36 have an energy distribution varying from 0 ev. to an energy corresponding to the applied voltage. As a result of these energy losses the angular distribution of the emitted atoms 42 is modulated resulting in a uniform coating of the interior wall 14 of through-hole 16. Since the angle of incidence of the incoming sputtering ions 36 relative to the sidewalls 14 is nearly zero, there is virtually no sputtering of the film 22 deposited on the sidewalls 14. Further modulation of the incoming ion energy occurs automatically in radiofrequency sputter-etching because of the time-varying nature of the target potential. Still further modulation of the energy of the ions 36 can be achieved by removing the filtering network from the power supply in the radiofrequency generator. The resulting radiofrequency signal is amplitude modulated by the power line frequency, or one of the power line harmonic frequencies.

In the above process, all non-planar surfaces are coated, i.e. the side edges 44 of the substrate 18 as well as the interior wall 14 of the through-hole 16. This can be eliminated by making the surface 46 of the substrate 16 disposed directly on the target 10 larger than the target surface 12.

It is well known that the angular distribution of material emitted from a sputtering target surface varies with the incident ion energy. As represented in FIG. 2 at moderate energies (1-5 Kev.), the angular distribution is cosine 48, i.e., there is more normal than side-wise emission from the surface. At higher energies (>10 Kev.) the distribution is over-cosine 50, i.e. much more normal than side-wise emission. At lower energies (<1 Kev.) the distribution is under-cosine 52, i.e. more side-wise than normal emission. For purposes of the instant invention, low voltages (~ 500 volts) are used for the most efficient coating of interior wall 14 of through-hole 16. Since sputtering yields are low at low voltages the sputtering gas pressure should be relatively high (~ 70 millitorr) to improve efficiency. It should be noted that virtually any combination of gas pressure and voltage will eventually result in side wall coating, but as the parameters for gas pressure and voltage deviate farther from those cited above, the process becomes progressively slower.

Other factors which influence the deposition rate include:

1. The aspect ratio, i.e. the ratio of hole diameter to hole depth, of the through-hole.—FIG. 3 illustrates the deposition rate of palladium films on the inside of reamed holes of various aspect ratios in a steel sheet. The experimental conditions were:

Sheath voltage: -500 volts

Sputtering gas (Argon) pressure: 70 millitorr

Target composition: Palladium.

As shown, when the aspect ratio is greater than about 0.3, the deposition rate is nearly constant.

2. The sputtering yield of the material to be deposited.—Using the conditions cited above, the interior walls of holes having an aspect ratio of 0.3 were coated with various materials. The materials, their yields and deposition rates are given in Table I.

TABLE I
Rate of Sidewall Coating by Various Materials

Material	Sputtering yield, atoms/ion at -500 ev.	Deposition rate, A./min.
Ag-----	3.4	650
Pd-----	2.4	500
Mo-----	0.9	135
C-----	0.2	20

3. The roughness of the through-hole walls.—For a given material and set of operating conditions, the deposition rate decreases with increasing roughness.

Several examples of the present invention are described in detail below. These examples are included merely to aid in the understanding of the invention and variations may be made by one skilled in the art without departing from the spirit and scope of the invention.

EXAMPLE 1

Molybdenum was deposited in holes in Foto-Form Glass measuring 0.006 inches in diameter and 0.02 inches deep. The experimental conditions were:

Sheath voltage: -500 volts

Sputtering gas (Argon) pressure: 70 millitorr

Target composition: Molybdenum

Sputtering time: 1 hour.

Under the above conditions the holes were coated with a film of molybdenum 10,000 A. thick.

EXAMPLE 2

The holes in a ceramic substrate used in a grid structure for a color kinescope were required to be coated with a resistive material so that the resistance from one side of the hole to the other was between 10^5 and 10^7 ohms. The holes were about 0.025 inches in diameter and 0.015 inches deep and had a resistance $>10^{18}$ ohms. Silicon doped with antimony was used as the resistive material. The substrate was heated to a temperature of about 300° C. during sputtering to ensure that the antimony did not precipitate on the silicon grain boundaries and would go into active sites. The experimental conditions were:

Sheath voltage: -500 volts

Sputtering gas (Argon) pressure: 70 millitorr

Substrate temperature: 300° C.

Target composition: Si+15 a/o Sb

Sputtering time: 80 minutes.

Under the above conditions the holes were coated with a thin film of target material resulting in a resistance of 4.3×10^6 ohms across each hole.

What is claimed is:

1. A method for selectively coating interior walls of through-holes in a substrate with a thin film of a material by sputtering, comprising:

- (a) providing a target with a surface comprised of said material to be sputtered,
- (b) disposing against said surface of said target a substrate in which the through-holes to be coated are formed,
- (c) including a glow discharge in an ionizable gas plasma, and
- (d) sputtering said material from said target surface onto said through-hole walls.

2. The method defined in claim 1, wherein the surface of said substrate disposed on said surface of said target is larger than said surface of said target.

3. The method defined by claim 4, wherein the energy of the excited ions in said ionizable gas plasma is modulated by fluctuations in an ac line voltage connected to the radiofrequency source.

4. The method defined in claim 1, wherein said glow discharge in said ionizable gas plasma is induced by a radiofrequency power source.

References Cited

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IBM Technical Disclosure Bulletin, "Reducing Dust-Induced Pinholes in Sputtered Films," by E. Stern, vol. 12, No. 1, June 1969.

JOHN H. MACK, Primary Examiner

W. A. LANGE, Assistant Examiner

U.S. Cl. X.R.

**UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION**

Patent No. 3,846,294 Dated November 5, 1974

Inventor(s) John Louis Vossen

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the claims:

Column 4, line 46, change "including" to --inducing--.

Column 4, line 53, change "3" to --4--, and "4" to --3--.

Column 4, line 54, change "4" to --3--.

Signed and sealed this 11th day of February 1975.

(SEAL)

Attest:

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