July 30, 1968 C. A. BENTLEY, JR 3,394,679

VACUUM COATING APPARATUS

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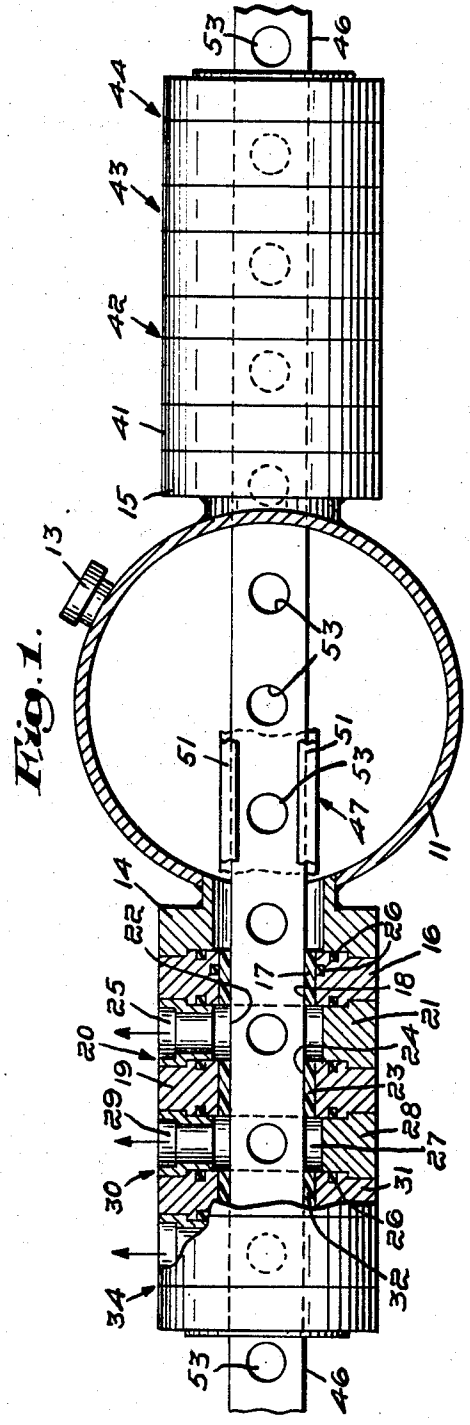

Fig. 1.

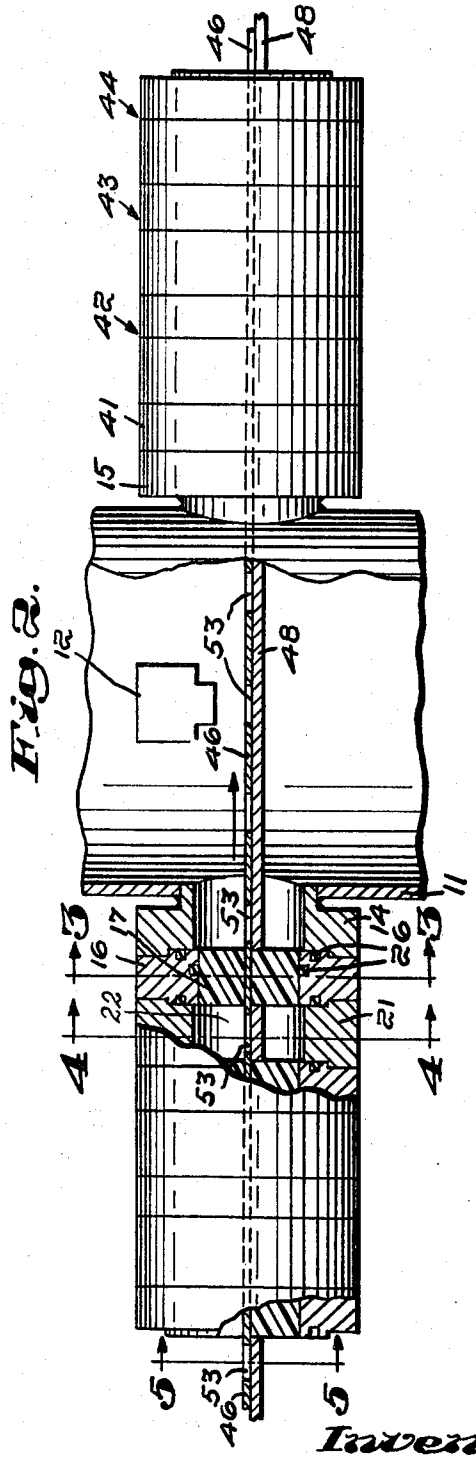

Fig. 2.

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Fig. 3.

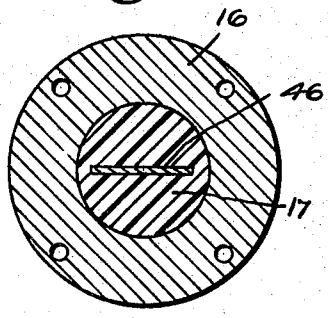


Fig. 4.

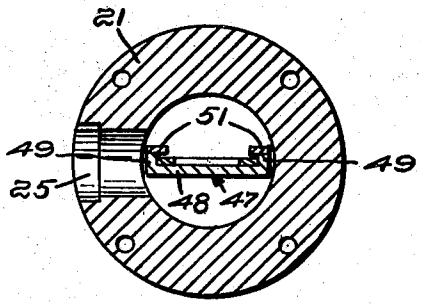


Fig. 5.

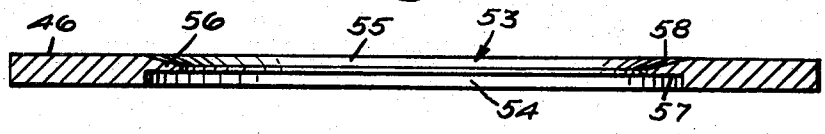


Fig. 6.

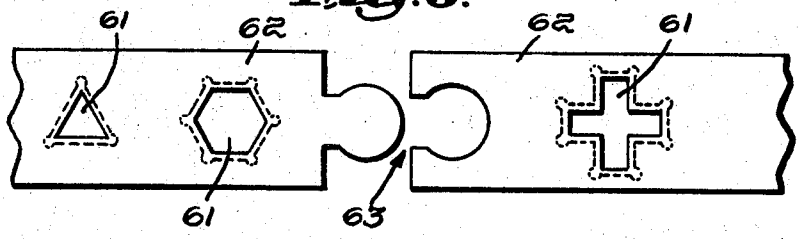
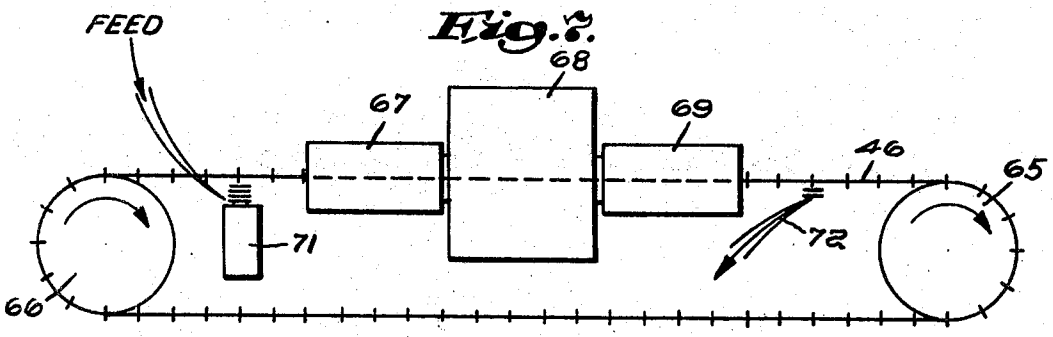


Fig. 7.



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VACUUM COATING APPARATUS

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12 Claims. (Cl. 118—49)

ABSTRACT OF THE DISCLOSURE

A vacuum coating installation including a vacuum chamber with inlet and outlet openings which snugly accommodate and maintain a vacuum seal with a moving conveyor belt possessing substrate retaining cavities.

This invention relates generally to vacuum coating apparatus and, more particularly, to apparatus of this type for use in vacuum deposition of thin films onto insulated substrates.

There is a large and growing market for electronic components of reduced size and weight. One popular method of producing these microelectronic components entails the coating of integrated circuitry onto insulator substrates by thin film deposition techniques. Although the components produced by this process are excellent functionally, the process costs have been high primarily because of the requirement that the thin film deposition be accomplished under vacuum. Not only is the vacuum equipment itself relatively expensive, but the attainable quantity of product output relative to the capital equipment costs has been low because the vacuum system must be cycled between atmospheric and vacuum pressures for each batch of output product.

Attempts to alleviate these problems have resulted in various types of continuous or semi-continuous vacuum coating systems wherein substrate elements are fed into a vacuum chamber for application of a desired coating and then discharged therefrom while a suitable vacuum pressure is continuously maintained. Typically, such continuous systems involve the use of inlet and outlet lock chambers through which the substrate elements pass during entrance into and exit from the vacuum chamber in which the coating process occurs. However, the difficulties in providing economical and efficient continuous vacuum systems for this application are sizable and the heretofore known systems have been less than satisfactory.

The object of this invention, therefore, is to provide a continuously operable vacuum apparatus capable of producing coated electronic components at a reduced unit cost.

One feature of this invention is the provision of a vacuum coating apparatus including a conveyor belt adapted to move into and out of an evacuable chamber through openings having cross-sections, in planes perpendicular to the direction of belt movement, substantially the same as the transverse cross-section of the belt, and which retains within internal cavities the substrate elements to be coated. In this apparatus, an unbroken vacuum seal is continuously maintained between the inner surfaces of the vacuum chamber's inlet and outlet openings and the outer surfaces of the conveyor belt. Thus, continuous coating is possible without periodic cycling of the vacuum chamber between atmospheric pressure and the reduced pressure required for the coating process.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured type wherein the vacuum chamber inlet and outlet openings have lengths greater than those of the belt cavities thereby insuring that a continuous vacuum seal will be maintained between the inner surfaces of the vacuum chamber openings and the outer surfaces of the conveyor belt.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured type wherein the cavities are formed by apertures extending through the conveyor belt which includes reentrant surface portions projecting into the apertures and adapted to provide coating masks by partially covering substrate elements positioned in the cavities.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured types wherein the reentrant belt portions have oppositely facing flat and beveled surfaces, both recessed from the top and bottom surfaces of the conveyor belt so as to form adjoining substrate and coating cavities. In this arrangement, the flat reentrant surface engages the substrate element deposited in the substrate cavity and the beveled surface functions as a coating mask which prevents a shadow effect and provides a recessed surface for accommodating coating material accumulation in the coating cavity.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured types including a substrate element feeder positioned outside the vacuum chamber and adapted to deposit substrate elements into the substrate cavities and a coating substance supplier positioned within the vacuum chamber on the opposite side of the belt conveyor and adapted to direct the coating substance through the coating cavity and onto that surface of the substrate element which is not masked by the reentrant belt portion.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured types wherein the substrate elements are deposited in substrate cavities formed in the bottom surface of the belt conveyor as it enters the evacuable chamber and including conveyor belt guides having surfaces which contact the bottom surface of the conveyor belt so as to prevent dislodgment of the retained substrate elements.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured types including at least one inlet and one outlet lock chamber which communicate with the evacuable chamber through the inlet and outlet openings thereof and wherein the lock chambers also include inlet and outlet openings adapted to receive and having the same cross-section as the conveyor belt.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured type including vacuum pumping means connected to each of the lock chambers and to the evacuable chamber so as to permit independent evacuation thereof.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured types wherein the belt conveyor is a continuous belt and including drive means for producing movement of the belt through the evacuable chamber.

Another feature of this invention is the provision of a vacuum coating apparatus of the above featured type wherein the conveyor belt comprises disconnectable, interlocking belt length portions which possess cavities of different shape so as to accommodate dissimilar substrate elements and permit deposition thereon of various coating configurations.

These and other features and objects of the invention will become apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 shows a partial schematic plan view of a preferred coating apparatus embodiment;

FIG. 2 is a partial schematic side view of the embodiment shown in FIG. 1;

FIG. 3 is a cross-sectional view taken along lines 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view taken along lines 4—4 of FIG. 2;

FIG. 5 is an enlarged cross-sectional view taken along lines 5—5 of FIG. 2;

FIG. 6 illustrates an interlocking section conveyor belt embodiment of the invention; and

FIG. 7 is a schematic illustration of a continuous belt embodiment of the invention.

Referring now to FIGS. 1–5, the evacuable process chamber **11** encloses the schematically illustrated vapor coating source **12** and has the flanged evacuation port **13** adapted for connection to a conventional vacuum pumping system (not shown). The inlet flange **14** and outlet flange **15** are aligned on opposite sides of the process chamber **11**. Connected to the inlet flange **14** is the annular access flange **16** enclosing the closely fitted plug **17** made of a suitable, good vacuum material such as polytetrafluoroethylene resin. The rectangular, elongated slot **18** through the center of the plug **17** forms an inlet opening providing access into the process chamber **11**.

Connected to the access flange **16** is the inlet lock assembly **20** including the inlet lock access flange **19** and the mating inlet lock chamber flange **21** which defines the inlet lock chamber **22**. The inlet lock access flange also encloses a fitted plug **23** having the centrally located, elongated slot **24** which provides access into the inlet lock chamber **22**. Evacuation of the lock chamber **22** is accomplished through the lock evacuation port **25** adapted for connection with a conventional vacuum pumping system (not shown). Vacuum tight seals between the various components are made with the O-ring gaskets **26**.

The intermediate inlet lock chamber **27** is formed by the annular intermediate flange **28** having the evacuation port **29** adapted for connection to a suitable vacuum pumping system (not shown). Attached to the intermediate flange **28** is the intermediate access flange **31** having the centrally slotted plug **32**. As shown, the intermediate inlet lock assembly **30** formed by the intermediate lock flange **28** and the intermediate access flange **31** is identical to the inlet lock assembly **20**. Similarly, there is connected to the intermediate access flange **31** the initial inlet lock assembly **34** which is structurally identical to the intermediate and inlet lock assemblies **20** and **30**.

Joined to the outlet flange **15** is the annular exit flange **41** which is identical to the access flange **16** associated with the inlet flange **14**. The outlet lock assembly **42** is coupled between the exit flange **41** and the intermediate outlet lock assembly **43** which is in turn connected to the final outlet lock assembly **44**. The outlet lock assemblies **42**, **43** and **44** are identical to the inlet lock assemblies **20**, **30** and **34** and are similarly adapted for connection to suitable pumping systems (not shown).

The conveyor belt **46** is adapted for movement into the process chamber **11** through the inlet lock assemblies **20**, **30** and **34** and for exit therefrom to the outlet lock assemblies **42**, **43** and **44**. Support for the conveyor belt **46** is provided by the discontinuous guide track **47** which includes segments adjacent the initial inlet lock assembly **34** and final outlet lock assembly **44** as well as within each of the inlet and outlet lock chambers and the process chamber **11**. Forming each of the guide track segments **47** is a flat base **48** which supports the bottom surface of the conveyor belt **46**, side portions **49** which contact the edges of the conveyor belt **46** and top portions **51** which overlap the outside marginal regions of the conveyor belt top surface. As shown in FIG. 3, the transverse cross-section of the uniform conveyor belt **46** is substantially identical to those through the slots in each of the closure plugs **17**, **23**, **32** etc., taken in a direction perpendicular to the movement of the conveyor belt **46**. Thus, there is provided between the outer surfaces of the conveyor belt **46** and the inner surfaces of the individual plug slots a slight interference fit which permits relative movement between the conveyor belt and the plugs while also providing a vacuum seal therebetween. The various system flanges and the conveyor belt **46** are preferably made of a good vacuum material such as stainless steel.

As shown most clearly in FIG. 5, the conveyor belt **46** possesses a plurality of spaced apart apertures **53**. Each aperture **53** forms in the bottom surface of the conveyor belt **46** a substrate cavity **54** adjoining a coating cavity **55** formed in the upper surface thereof. Partially separating the substrate cavities **54** and coating cavities **55** are the reentrant belt portions **56** which project into the apertures **53**, as shown. The reentrant belt portions **56** have flat bottom surfaces **57** adapted to accommodate the flat surface of a substrate element and beveled upper surfaces **58** which are inwardly tapered to prevent formation of a shadow effect during coating of a retained substrate element. The recessed beveled surfaces **58** also are capable of supporting a limited accumulation of coating material without changing the clearance between the plug slots and the upper surface of the conveyor belt.

To operate the invention, one either constructs or selects a suitable conveyor belt **46** having substrate cavities **54** with shapes which closely conform to those of substrate element discs which are to coated and with reentrant portions **56** whose edges form the shape of the desired coating. The cavities and reentrant mask portions formed in the conveyor belt **46** may be of uniform shape or may be, as shown in FIG. 6, of varying form depending upon the final coated product requirements of a particular application. Also, as shown in FIG. 6, a desirable flexibility of output may be attained by utilizing a conveyor belt formed by individual belt segments **62** having various cavity forms **61** and interlocked by, for example, male-female socket connections **63**.

After selecting an appropriate conveyor belt, substrate elements are positioned either manually or by suitable mechanical means into the accommodating substrate cavities **54** and the conveyor belt **46** pulled with suitable drive means through the process chamber **11**. Depending upon application, the conveyor belt **46** may be either non-continuous or continuous. In the latter case, the schematic arrangement illustrated in FIG. 7 is desirable. As shown, the conveyor belt **46** is driven by the rotary driver **65** around the rotary guide wheel **66**, and through the inlet locks **67**, the processing chamber **68** and the outlet locks **69**. Positioned at the entrance to the inlet locks **67** and below the entering conveyor belt **46** is a substrate feed device **71** which automatically positions individual substrate elements into the substrate cavities **54**. The schematically illustrated discharge device **72** is adapted to remove the coated substrate elements from the substrate cavities **54** after discharge from the outlet locks **69**.

As the conveyor belt **46** moves through the coating apparatus, the individual substrate elements will pass through decreasing pressure zones within the inlet lock chambers, into the process chamber **11** maintained at a desired processing pressure, and through increasing pressure zones within the outlet lock chambers finally exiting into the atmosphere. For example, the belt retained substrate elements may pass through inlet lock chambers maintained, respectively, at 10 torr, .1 torr and 10^{-6} torr before entry into the process chamber also maintained at 10^{-6} torr. Similarly, after discharge from the chamber **11**, the substrate elements may pass through outlet chamber lock chambers maintained at, respectively, 10^{-6} torr, .1 torr and 10 torr. It will be appreciated that the use of plural inlet and outlet lock chambers to reduce pressure differentials between adjacent volumes is desirable since the vacuum seal provided be-

tween the relatively movable surfaces of the conveyor belt **46** and the closure plug elements cannot be made absolute according to known practical sealing methods. In this regard, it is highly preferred that the slotted plugs **17, 23, 32,** etc., have a length greater than the maximum dimension of the cavities **54** and **55** in the direction of conveyor belt movement. This prevents formation by the cavities **54** and **55** of relatively high conductance leak paths between adjacent chambers.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. For example only, the device may be used for coating substrate elements having shapes other than those illustrated or the position of the conveyor belt **46** may be reversed with the substrate cavities **54** positioned in the top portion thereof and the coating device **12** positioned below the belt. Similarly, a conveyor belt may be provided which does not function as a substrate mask but merely serves to retain and transport the individual substrate elements through the processing chamber. In this case, suitable coating masks (not shown) may be rigidly supported within the processing chamber between the coating source and the movable conveyor belt. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A vacuum coating apparatus comprising an evacuable chamber having an inlet and an outlet opening, coating means positioned within said evacuable chamber, belt conveyor means adapted for movement into and out of said evacuable chamber through said inlet and outlet openings, said belt conveyor means having a transverse cross section of uniform size substantially the same as the cross sections of said inlet and outlet openings in planes perpendicular to the direction of movement of said belt conveyor means, said belt conveyor means having a plurality of apertures extending therethrough and including reentrant portions extending into said apertures, each aperture and associated reentrant portions defining a substrate cavity opening to one surface of said belt conveyor means adapted to receive a substrate element to be coated and a coating mask adjacent to the opposite surface of said belt conveyor means partially covering the substrate element positioned in said cavity, guide means adapted to guide movement of said belt conveyor means through said evacuable chamber and adjacent said coating means so as to allow coating thereby of substrate elements positioned in said cavities, and said guide means comprising support surface means which engage said one surface of said belt conveyor means to prevent dislodgement of substrate elements from said cavities.

2. A vacuum coating apparatus according to claim **1** wherein said reentrant portions are recessed from both top and bottom surfaces of said belt conveyor means.

3. A vacuum coating apparatus according to claim **2** wherein each of said apertures comprises a substrate cavity located on one side of said reentrant portion and adapted to receive a substrate element, and a coating cavity located on the opposite side of said reentrant surface portion.

4. A vacuum coating apparatus according to claim **1** wherein said inlet and outlet openings are of a length

greater than the greatest dimension of said apertures in the direction of movement of said belt conveyor means.

5. A vacuum coating apparatus according to claim **1** including a substrate element supply means positioned outside said evacuable chamber on one side of said belt conveyor means and adapted to deposit substrate elements into said substrate cavities and wherein said coating means is positioned on the opposite side of said belt conveyor means.

6. A vacuum coating apparatus according to claim **1** wherein said belt conveyor means is a continuous belt and including drive means for producing movement of said continuous belt through said evacuable chamber.

7. A vacuum coating apparatus according to claim **1** wherein said belt conveyor means comprises disconnectable interlocking belt length segments.

8. A vacuum coating apparatus according to claim **1** including at least one inlet lock chamber communicating with said evacuable chamber through said inlet opening and having an inlet lock opening adapted to receive said belt conveyor means, and at least one outlet lock chamber communicating with said evacuable chamber through said outlet opening and having an outlet lock opening adapted to discharge said belt conveyor means and wherein said inlet lock and said outlet lock openings have cross sections in planes perpendicular to the direction of movement of said belt conveyor means substantially equal to said belt conveyor means transverse cross section.

9. A vacuum coating apparatus according to claim **8** including vacuum pumping means connected to each of said evacuable chamber, said inlet lock chamber and said outlet lock chamber.

10. A vacuum coating apparatus according to claim **8** wherein said inlet and outlet openings are of a length greater than the greatest dimension of said apertures in the direction of movement of said belt conveyor means.

11. A vacuum coating apparatus according to claim **8** including a substrate element supply means positioned outside said evacuable chamber on one side of said belt conveyor means and adapted to deposit substrate elements into said substrate cavities and wherein said coating means is positioned on the opposite side of said belt conveyor means.

12. A vacuum coating apparatus according to claim **11** wherein said inlet and outlet openings and said inlet lock openings and said outlet lock openings are of a length greater than the greatest dimension of said apertures in the direction of movement of said belt conveyor means.

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