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Huffman et al.

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[54] **OFFSET TOP EJECTION VAPOR DEPOSITION APPARATUS**

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[52] **U.S. Cl.** **118/48**

[51] **Int. Cl.** **C23c 13/12**

[58] **Field of Search** 118/48-49.5, 322; 117/107.1; 239/432

[56] **References Cited**

UNITED STATES PATENTS

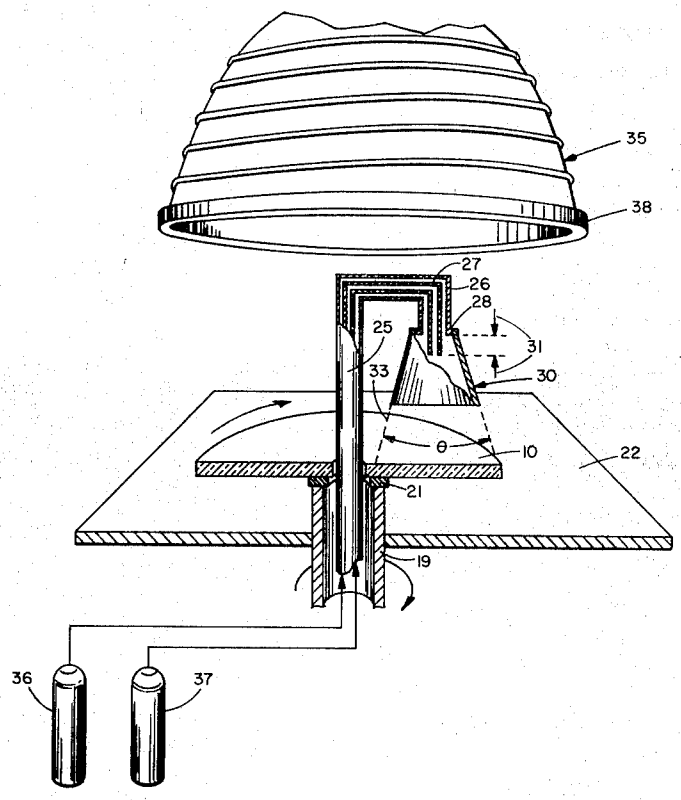
3,407,783	10/1968	Capita	118/49.5
3,408,982	11/1968	Capita	118/49.5
2,953,483	9/1960	Torok	118/48 X
3,424,628	1/1969	Winings	118/49 X
3,578,495	5/1971	Pammer et al.	118/48 X
3,126,300	3/1964	Bienefelt et al.	118/49.1
3,621,812	11/1971	Hissong, Jr. et al.	118/48
3,473,954	10/1969	Mattson	117/107.1

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[57] **ABSTRACT**

There is disclosed offset top ejection apparatus for use in vapor deposition chambers which provides a uniform contamination-free layer on top of a spinning susceptor plate. The uniformity of the layer is assured by providing an offset downwardly pointing nozzle which is off-centered from the revolving susceptor and from which the deposited material emanates. The arrangement of apertures and the taper of the conical nozzle defines the extent and uniformity of the resulting layer in the offset configuration. Off-setting an ejection nozzle permits a larger area to be uniformly coated resulting in a higher yield for semiconductor wafers carried by the rotating susceptor plate and on which are deposited a layer of dielectric, passivation or other material.

2 Claims, 5 Drawing Figures



PRIOR ART

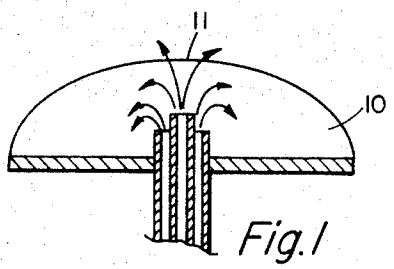


Fig. 1

PRIOR ART

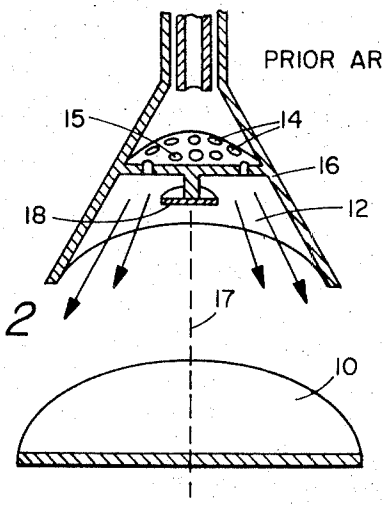


Fig. 2

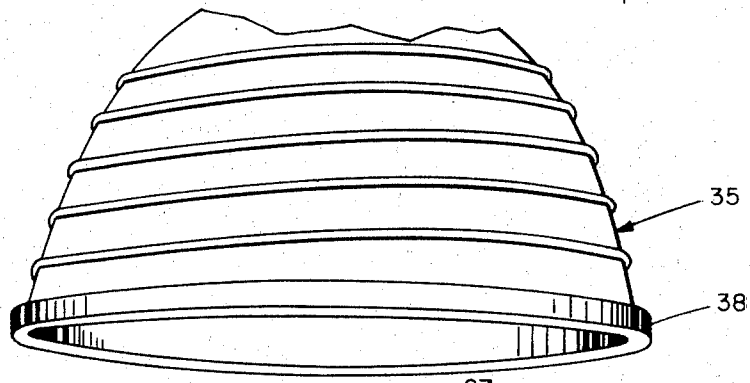
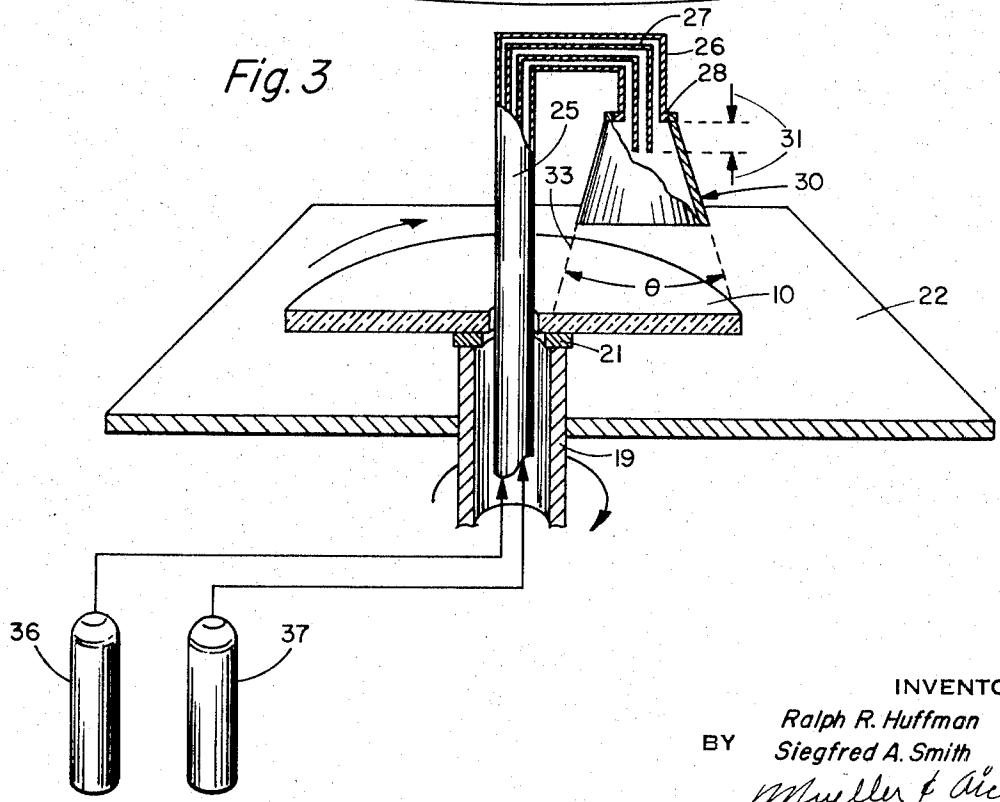


Fig. 3



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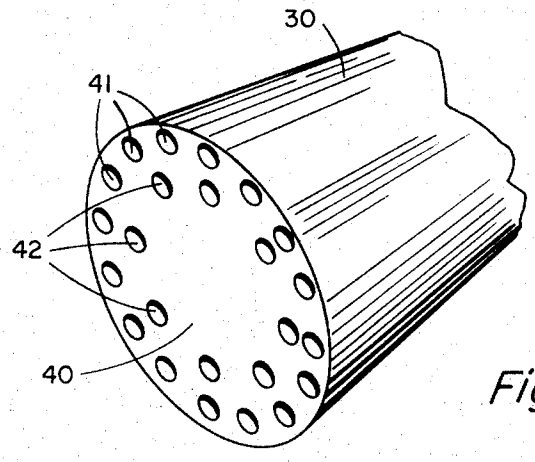


Fig. 4

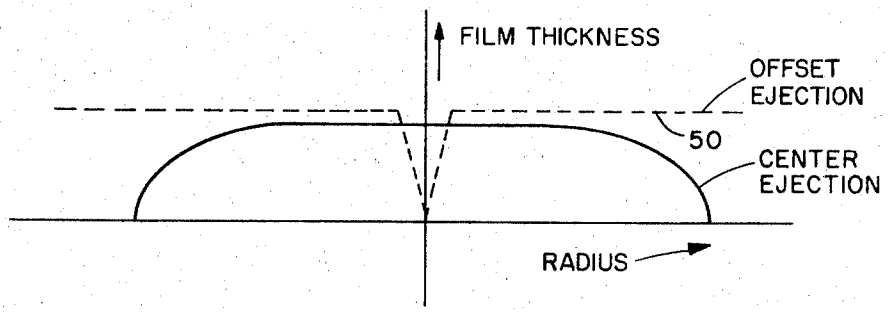


Fig. 5

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OFFSET TOP EJECTION VAPOR DEPOSITION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to vapor deposition techniques utilized in the manufacture of semiconductor devices and more particularly to an offset top ejection nozzle for depositing a layer or film over a semiconductor wafer which not only increases yield but also results in a deposited layer of uniform thickness which is relatively contamination-free.

Prior art vapor deposition techniques for depositing uniform layers of insulating or passivating material on a wafer either involve a central, upward "through-the-susceptor" ejection or a downward (top) ejection from a nozzle symmetrically positioned over top of a spinning plate or "susceptor" as the spinning substrate is called in the art. The central ejection tehcnique involves the upward ejection of the desired material in gaseous form through the center of a rotating susceptor plate with the ejectant being deposited on the susceptor after reacting in the deposition chamber above the rotating susceptor plate. Top ejection systems, on the other hand, involve the deposition of the material from a conical nozzle centered above the spinning susceptor such that the ejector nozzle is symmetrical about an axis which passes through the center of the spinning susceptor.

The problems with both of the prior art techniques involve the non-uniformity of the layer deposited on the susceptor and the semiconductor wafers carried thereby, in which the thickness of the film or layer varies from location to location. This non-uniform thickness is due to contaminants from reacted particles formed prior to deposition and from flow patterns developed at the surface of the susceptor plate. In the prior art the flow patterns can be to some extent controlled by the heat distribution across the susceptor plate. The problem of the contaminants in the film or layer is due to particulate matter in the form of flaking which causes protrusions of the deposited material to exist across the deposited layer. These flakes are usually reacted bits or portions of silicon dioxide which form on the sides of the deposition chamber during the deposition process. In addition to these first two problems and especially with regard to the top ejection techniques, is the problem of alignment of the nozzle above the rotating susceptor plate. In general, it was thought that this nozzle had to be centered with respect to the rotating plate so that a uniform film could be deposited. Alignment, in and of itself, is time consuming. Also time consuming is the cleaning necessary in both of the aforementioned techniques which is due to ejectant build-up on the sides of the deposition chamber. A final problem which has been a factor in this type of deposition is the yield. Since it is difficult to provide a large area with a uniform layer it is difficult to increase the yield of deposition chambers utilizing rotating susceptors because only a small portion of the plate or susceptor is coated with a truly uniform layer.

These problems are solved by the use of an offset top ejection nozzle in which the ejectant is projected downwardly onto the susceptor plate from a position above the susceptor plate which is offset from the center thereof to such an extent that only that portion of the susceptor underlying the nozzle to one side of the center is coated. The use of the offset nozzle to coat only

that portion of the susceptor to one side of the center of the susceptor plate results in an unexpectedly uniform deposited layer. The nozzle is both small and inexpensive and is supported by and positioned by a shaft running through the center of the susceptor plate and then off to one side. As a result of this type configuration, the aforementioned alignment problems are eliminated since the deposition chamber need not be of any particular configuration and need not be shifted in order to align the nozzle with the appropriate portion of the susceptor plate. In addition and most importantly flow pattern problems resulting in the variability of the distribution of the layer on the susceptor plate simply do not exist in the offset configuration. Although the explanation of this phenomenon is not clear, offset ejection offers a substantial advantage over conventional techniques because it eliminates the control of troublesome flow pattern parameters in the deposition process by conventional heat gradient control. Flaking problems associated with the central ejection techniques and also with the top ejection techniques (when the nozzle is located in the top of a bell jar type deposition chamber) are eliminated because very little of the ejectant from the nozzle reaches the sides of the bell jar. This results also in fewer cleaning steps and shorter cleaning times for the entire apparatus. As has been mentioned before, the use of this small offset ejection nozzle within the bell jar makes possible the use of any shape bell jar. Heretofore the shape of the bell jar was critical both in the central ejection techniques and in the top ejection techniques. Prior art techniques currently specify the use of a conical bell jar for increased uniformity in the layers deposited. These conically shaped bell jars are an order of magnitude more expensive than the offset nozzle to be described hereinafter. In addition, by appropriate setting of the distance between the face of the offset nozzle and the top surface of the susceptor, larger susceptors may be utilized resulting in higher yields. These higher yields are made possible by the uniformity of the layer deposited in the subject manner. In one experimental configuration, a triple "through-put" was experienced in which triple the amount of wafers were given uniform coatings in one operation. Finally, and most importantly, the use of the offset top injection nozzle minimizes the dependence of the uniformity of the layer on the heat gradients across the susceptor face.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an improved apparatus for depositing a film or layer of material on a rotating substrate.

It is a further object of this invention to provide an offset downwardly pointing nozzle for use in the deposition of a uniform layer of material on a rotating substrate beneath the nozzle.

It is a still further object of this invention to provide a nozzle which is both offset from the center of a rotating susceptor and which involves arrangement of apertures at the face of the nozzle in which the center of the nozzle is occluded.

Other objects of this invention will become more fully apparent upon reading the following description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a prior art central ejection system for depositing a layer of material over a rotating substrate.

FIG. 2 shows a prior art deposition system in which material is ejected from a nozzle which is centered with respect to and over top of a rotating substrate.

FIG. 3 shows a deposition system involving the use of a centrally supported offset nozzle for providing a uniform layer of material on top of a rotating substrate.

FIG. 4 is a diagram showing one configuration of the apertures in the face of the offset nozzle utilized in connection with the nozzle shown in FIG. 3, and

FIG. 5 is a graph of the thickness of a layer or film on top of a rotating substrate as a function of the distance of the material from the center of the substrate.

BRIEF DESCRIPTION OF THE INVENTION

There is disclosed offset ejection apparatus for depositing a layer of material on top of a rotating substrate or susceptor plate in which the nozzle from which the material is deposited is located over top of the plate and is offset in such a manner that the material emanating from the nozzle is deposited only to one side of the rotating plate. The nozzle itself is frustoconical in shape and is fed with a concentric conduit feed in which the central conduit extends a predetermined distance into the truncated portion of the nozzle. Apertures in the face of the nozzle are positioned so as to leave the center portion of this face occluded permiting uniformity in the deposition of the layer therefrom. The angle of the truncated cone as well as the distance of the cone above the susceptor plate are the only parameters which affect the area of the deposited layer. Thus, by raising up the nozzle or increasing the flare of the truncated cone, the deposition area can be enlarged without experiencing detrimental flow patterns, nonuniformity in the thickness of the layer, or contamination.

DETAILED DESCRIPTION OF THE INVENTION

The deposition of passivation or dielectric films or layers on top of a number of wafers involves the deposition of an amount of material which must be both uniform in thickness and homogeneous. In addition, the material must be free of contaminants which cause protrusions in the deposited film. While the subject matter of this invention will be described in connection with the deposition of dielectric films, it will be appreciated that any film which can be deposited from a vapor or gas carrier is within the scope of this invention. It is a general practice in the semiconductor industry to provide a passivation layer on a number of wafers or chips by placing the wafers or chips on a rotating plate which is called a susceptor plate. The susceptor plate is usually in a circular configuration supported and rotated about its center. Susceptor plates are, in general, made of graphite when dielectric layers or films are to be deposited. After the wafers or chips have been located on the top surface of the susceptor plate, a bell jar is normally superimposed over the entire structure so as to provide for uniform heating and deposition of the layer or film. In addition, the susceptor plate is heated to a predetermined temperature depending on the layer which is to be deposited on the wafers or chips. It is important during the deposition of the film or layer that the film be uniform and have a uniform thickness over all of the wafers of chips on the susceptor plate. In order to arrange for this uniformity, the ejectant may be ejected centrally in an upward direction as shown in FIG. 1 or may be centrally ejected from a nozzle symmetrically disposed above the susceptor plate. In both FIGS. 1 and 2, the susceptor plate is shown by the reference numeral **10**. In FIG. 1, the ejectant shown by arrows **11** is shown to be vertically ejected falling to the surface of the susceptor plate **10** as the susceptor plate **10** rotates about its center. In FIG. 2, the ejectant is shown ejected by arrows **13** from orifices **14** in a baffle **15** located within a symmetrically oriented cone-shaped member **16**. The symmetrical orientation of the cone **16** above the susceptor plate **10** is shown by the dotted center line **17**. Ejectant is kept from being deposited on the center of the susceptor plate **10** by the plate **18** supported centrally on the baffle **15**. The entire nozzle shown in FIG. 2 is usually supported in the top of a bell jar which overlies the entire rotating susceptor plate. The purpose of the bell jar is to provide a uniformly heated atmosphere for the deposition process. In order to provide the aforementioned alignment of the cone shaped member **15** above the susceptor plate **10**, the bell jar, which is in general heavy and difficult to manage, must be centered. If it is not centered there will be a build-up of material on the susceptor plate **10** having a greater thickness in one area than in another.

Referring now to FIG. 3, the subject offset nozzle is shown. The susceptor plate **10** shown here in partial cross-section is supported on a ring type flange member **21** to which is welded or attached a central driving shaft **19**. Through the center of the susceptor plate **10** is passed a tubular support member **25** which is comprised of an outer conduit **26** shown in partial cutaway and an inner concentrically located conduit **27**. The support member **25** is bent in a horizontal direction and then bent in a downward direction where is it provided with a flange **28** having threads on the outer surface thereof. Screwed into this support member is a frustoconical nozzle **30**. The concentric conduit **27** extends downwardly into the chamber formed by the frustoconical nozzle a predetermined distance shown by the arrows **31**. The sides of the frustoconical member **30** subtend an angle θ shown by the dotted lines **33**. It will be appreciated that the angle θ and the distance of the face of the frustoconical nozzle from the surface of the susceptor plate define the area of the deposition. By increasing the height of the nozzle above the plate and the horizontal distance of the offset of the nozzle from the central axis or by varying the taper of the frustoconical nozzle, the area of the layer to be deposited can be extended almost indefinitely without flow patterning or non-uniformity problems. It will be appreciated that the material ejected from the nozzle **30** is ejected to one side of the susceptor plate **10**. From an instantaneous point of view, no portion of the ejectant ejected reaches a diametrically opposite side of the susceptor plate. No attempt is therefore made to simultaneously coat all portions of the susceptor plate at once. Although the mechanism of the uniform film which results from the offset nozzle is not clearly understood, it is a finding of this invention that it is not only not necessary to simultaneously deposit material on all portions of the susceptor plate in order to produce a uniform layer but also it is not desirable. It will be further appreciated that because the nozzle is not supported by the

bell jar it makes very little difference what type or what size bell jar shown here diagrammatically at **35** is utilized to cover the susceptor plate so as to provide a uniform atmosphere for the deposition. It will be apparent that since the ejectant is downwardly directed that less of the ejectant is likely to coat the sides or the interior walls of the bell jar and thus the bell jar is cleaned less frequently than prior art bell jars. In one prior art configuration, as shown in FIG. **1**, there is nothing to limit the upward travel of the ejectant other than the surface of the bell jar. In FIG. **2**, an extremely large conical nozzle is used at the top of the bell jar and no attempt is made to keep the ejectant from the sides of the bell jar. Thus a great deal of the ejectant adheres to the side walls of the bell jar which when heated causes flaking and therefore contamination of the surface layer deposited on the susceptor plate **10**.

Referring again to FIG. **3**, gas containers **36** and **37** are coupled through the central support member **25** to the nozzle **30**. In one configuration when silicon dioxide is to be deposited the chamber is heated to 400°–450° C and a mixture of silane, phosphene and nitrogen from the container **36** is fed into the outer of the concentric conduits **26** while oxygen from the container **37** is fed into the central conduit **27**. In this particular reaction and in general for uniformity of the layer deposited, the central gas is ejected into the nozzle **30** at a point beneath the open end of the conduit **26**. In a typical configuration, this distance is shown by the arrows **31** to be on the order of a quarter of an inch. As mentioned hereinbefore, the face plate of the nozzle **30** is provided with series of apertures. One arrangement of these apertures is shown in FIG. **4**. In FIG. **4**, the nozzle **30** is provided with a first ring of apertures **41** and an interior ring of apertures **42** which leave the center of the face **40** of the nozzle **30** devoid of apertures. The reason for this is to provide adequate mixing of the gas carried by the central conduit **27** with that carried by the outside conduit **26**. The gas in the central conduit **27** is directed towards the occluded portion of the nozzle face **40** such that this gas is bounced back towards the gas carried by the conduit **26** to effect a mixing action. Thereafter, the gas thus mixed is ejected from the orifices **41** and **42** in a homogeneous manner reacting in the deposition chamber on the way down to the susceptor. The layer deposited on the susceptor plate **10** is thus chemically uniform as well as being uniform in thickness. It will be appreciated that layers other than silicon dioxide may be deposited in the above manner. Amongst these are the pre-emitter glass layers which are in general of a two layer configuration with the first layer being silicon dioxide which is undoped and the second layer being silicon dioxide which is doped with phosphene. The subject technique may also be used in any multi-layer insulation glass configuration in which two to three layers of metallization are insulated by layers of glass therebetween. In addition, silicon nitride and any of the other dielectrics may be deposited by vapor deposition in this manner.

Referring again to FIG. **3**, it has been found that an acceptable angle θ is 40° and that the inter-orifice spacing on the face **40** of the nozzle **30** as shown in FIG. **4** is on the order of one-fourth inch. It will be further appreciated that the rotary member **19** is in a sealing fit with the bell jar support member **22** such that a seal can be made between the lip **38** of the bell jar **35** and the top surface of the member **22**. There is usually a sump or drain (not shown) in the member **22** so that a gas flow can be established.

Referring now to FIG. **5**, a comparison of the uniformity of film or layer thickness with respect to distance from the center of the susceptor plate is shown. In either of the two configurations shown in FIGS. **1** and **2**, it can be seen from FIG. **5** that the thickness tapers off towards the periphery of the susceptor plate. Again although the reasons are not clear, this is in general not true when an offset nozzle of the configuration shown is utilized. As shown by the dotted line **50**, the thickness of the film or layer deposited on the susceptor plate is substantially uniform throughout its extent, tapering very quickly to zero near the center of the susceptor plate. Apparently the flatness of the curve **50** occurs priarily because only a portion of the susceptor plate is subjected to deposition at any given time. This flatness permits a substantial area to be coated thus enabling an increase in size for the susceptor plate and an increase in yield. It will be appreciated that heretofore it was extremely difficult in a rotary system to provide that the material deposited not taper at the periphery of the susceptor. Because of the offset system shown by the subject offset nozzle, a substantial area of material can be deposited at one time on top of the susceptor plate without substantial variation in thickness across the plate.

Thus, a considerable number of wafers can be coated in one operation due to the increase in the area upon which can be provided a uniform thickness film. By use of the offset nozzle, the output of a deposition chamber can be trebled without a decrease in the quality, homogeneity or thickness of the films deposited. Further, flow problems, heat distribution problems and problems associated with flaking are eliminated.

What is claimed is:

1. Apparatus for vapor deposition of a layer of material on a plurality of substrates comprising:

a sealed chamber;

a rotatable support in said sealed chamber;

a susceptor having a central opening and connected to said rotatable support for carrying the plurality of substrates;

a frusto-conical ejection nozzle;

feed means extending through said opening and connected to said frusto-conical ejection nozzle and to said sealed chamber for supporting and feeding a plurality of gaseous vapors into said frusto-conical ejection nozzle, said frusto-conical ejection nozzle being offset with respect to the center of said susceptor and being directed at said susceptor; and

said feed means including an outer conduit connected to the smaller end of the frusto-conical ejection nozzle and an inner conduit concentrically arranged with respect to said outer conduit and extending further into said frusto-conical ejection nozzle than said outer conduit by a predetermined distance selected to prevent formation of particles wherein vapor of a first type ejected from said inner conduit is reflected from the occluded portion of said face plate and is mixed with vapor of a second type ejected from said outer conduit; and

a face plate connected to said frusto-conical ejection nozzle at the larger end thereof, said face plate having a plurality of apertures therein, a central portion of said face plate being occluded.

2. The apparatus as recited in claim **1** wherein said apertures in said face plate are arranged to form an outer ring of apertures and an inner ring of apertures.

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