United States Patent [19]
Sussmann

[11] 3,735,727
[45] May 29, 1973

# [54] DEVICE FOR THE PRECIPITATION OF LAYERS OF SEMICONDUCTOR MATERIAL

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[22] Filed: **Oct. 29, 1971**

[21] Appl. No.: **193,743**

[30] **Foreign Application Priority Data**

Nov. 5, 1970 Germany....................P 20 54 538.4

[52] **U.S. Cl.**....................118/48
[51] **Int. Cl.**....................C23c 13/08
[58] **Field of Search**....................118/48–49.5, 47, 50, 50.1, 326, DIG. 5, 429

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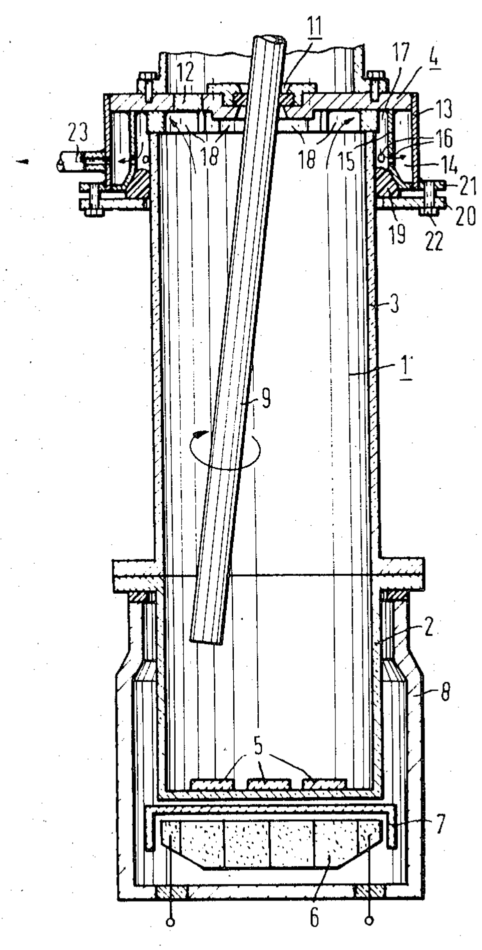
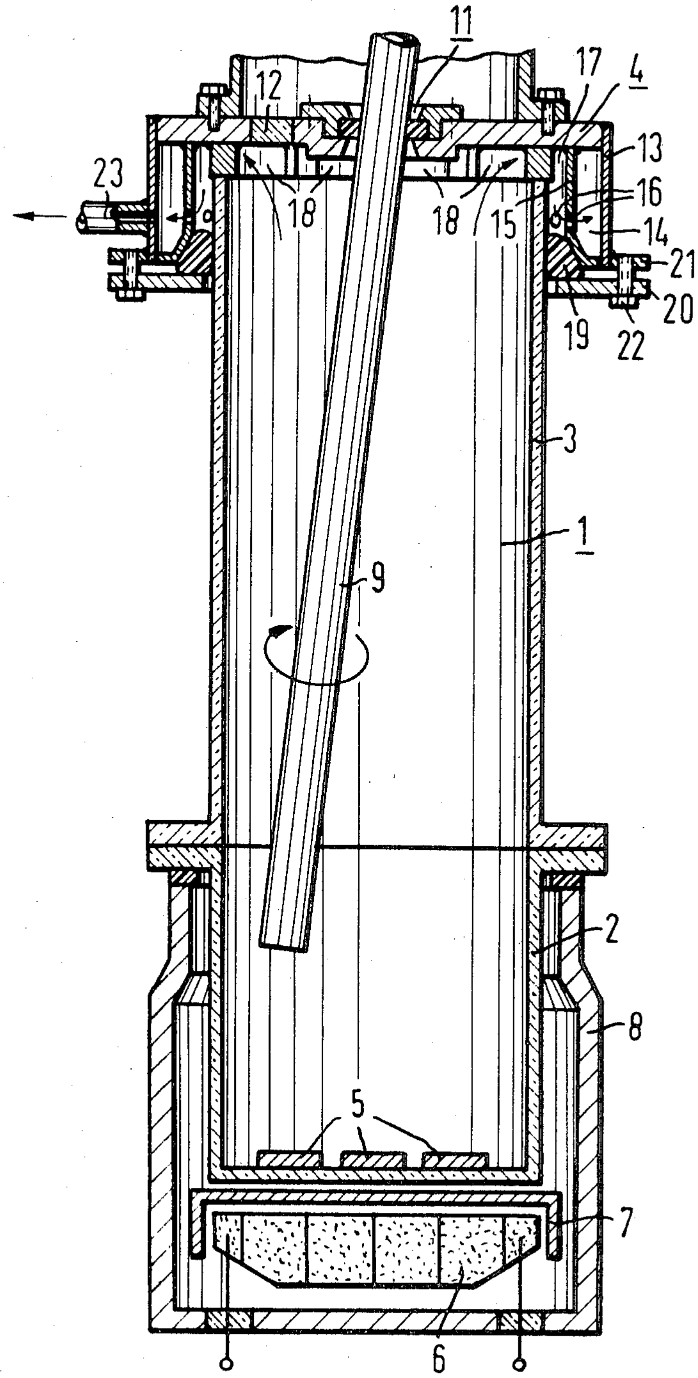
[57] **ABSTRACT**

Epitaxial device in which semiconductor wafers to be coated are disposed at the bottom of a vertical cylindrical reaction vessel and are heated to the high temperature required for precipitation by a heat source arranged underneath the bottom. Fresh reaction gas is fed to the heated semiconductor wafers from above and the spent gas is removed again upwards through holes arranged along an annular zone in the wall of the reaction vessel. The spent gas then passes to two exhaust chambers connected in series. The flow resistance of the gas discharge being essentially determined by the flow resistance between the two exhaust chambers.

**18 Claims, 1 Drawing Figure**

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## DEVICE FOR THE PRECIPITATION OF LAYERS OF SEMICONDUCTOR MATERIAL

The present invention relates to a device for the precipitation of layers of semiconductor material, particularly of monocrystalline material, from an appropriate reaction gas on the surface of semiconductor wafers disposed at the bottom of a vertical cylindrical reaction vessel and heated by a heat source arranged underneath the bottom to the high temperature required for precipitation. Fresh reaction gas is fed to the heated semiconductor wafers via a feed tube which extends into the reaction space of the reaction vessel from above and which, in particular, is swivable. The spent reaction gas upwardly leaves the semiconductor wafers to be doated.

Such devices have been described, for instance, in U.S. Pat. Nos. 3,472,684; 3,486,933. All of these publications describe a method for the preparation of layer of monocrystalline semiconductor material, particularly silicon, wherein an arrangement of the type described above is used. Experience has shown that particularly uniform epitaxial layers are obtained by such devices. In the course of testing such devices and the methods described in the above-cited publications, it has been found, however, that in spite of all the precautions certain nonuniformities of the layers occur. These nonuniformities are caused by a certain unidirectionality of the gas flow. As was recognized according to the invention, these nonuniformities in the gas flow must be attributed to the manner in which the spent reaction gas is removed in the known devices. It is an object of the invention to achieve an improvement also in this respect.

This is achieved, according to the invention, using the above-described device for the precipitation of layers of semiconductor material from an appropriate reaction gas on the surface of semiconductor wafers by providing an exhaust arrangement for the spent reaction gas from the reaction space of the reaction vessel consisting of two annular exhaust chambers which are disposed concentrically with respect to each other and to the vertical cylindrical reaction space. The exhaust chambers with respect to the flow of the spent reaction gas, are connected in series with corresponding openings in the wall between the reaction space and the inner exhaust chamber and the wall betweenthe two exhaust chambers, as well as of a gas venting tube connected to the outer exhaust chamber. The openings leading from the reaction space into the inner exhaust chamber are arranged above the mouth of the feed tube for the fresh reaction gas into the reaction space and above the connecting openings between the two concentric exhaust chambers. The total flow resistance of the openings between the reaction space and the inner exhaust chamber is adjusted to be smaller than the total flow resistance of the openings between the two concentric exhaust chambers.

According to a further feature of the invention, an important feature of this device consists in the fact that the openings between the reaction space and the inner exhaust chamber, as well as the openings between the two exhaust chambers, are made in the corresponding walls along the azimuthal ring zone respectively and are arranged within the individual ring zones at equal spacings from each other.

Experience leading to the invention has shown that the danger of an undesired precipitation of semiconductor material at the feed lines and at the wall of the reaction vessel increases with increases in flow velocity of the reaction gas. The danger is particularly great at the constrictions of the gas exhaust openings. For this reason, the acute danger of undesirable precipitation leading to disturbing nuclei exists at the exit points if the latter are arranged, as for instance, in the arrangement according to the aforementioned patents or U. S. Pat. Nos. 3,505,499; 3,519,798 and 3,536,892, in the lid of the cylindrical reaction vessel. The attempt, apparent in the U.S. Pat. No. 3,486,933, to prevent this by a screen has been found to be unsatisfactory as to the gas flow in the reaction space and therefore as the uniformity of the supply and removal of the reaction gas with occurrence of unstable back phenomena.

According to the invention, the exhaust gas, upon leaving the reaction space, encounters at first no appreciable flow resistance. The latter occurs rather only inthe transition from the inner exhaust chamber to the outer exhaust chamber. There the danger of undesired precipitation is greatest. However, this point is located outside of the reaction space proper, so that disturbing or defect nuclei produced there cannot fall on the semiconductor wafers to be coated, which are situated at the bottom of the reaction vessel. A uniform distribution of the discharge openings from the reaction space, especially their design as an azimuthal horizontal annular slot, interrupted by at most a few equidistant spacers, results in a uniform exhaust of the spent gas into the inner exhaust chamber. It is important for uniform exhaust that also the openings, between the two exhaust chambers, having the higher flow resistance are uniformly distributed along a annular or ring shaped zone in the wall between the two exhaust chambers. The gas venting tube opening into the outer exhaust chamber, however, is not critical. An adjustable valve arranged in it permits more or less flow of the discharged gases, as required. The total flow resistance of the discharge point for the spent reaction gas should be such that the gas between the two exhaust chambers encounters a substantially larger, about 20 to 100 times larger, flow resistance than in the transition from the reaction space to the inner exhaust chamber. However, it depends in each case on the desired reaction conditions, particularly also on the desired dwell time of the reaction gas in the reaction space, whether the total flow resistance of the gas discharge is adjusted to be large or small. The already mentioned valve for adjusting the discharge resistance in the gas venting tube, which is suitably made wide, from the outer exhaust chamber represents a simple adjustment means, so that it is recommended to make the flow resistance from the reaction space to the outer exhaust chamber not too large.

The arrangement is appropriately operated observing the considerations that have already been set forth in U. S. Pat. Nos. 3,505499; 3,519,798 and 3,536,892. The pressure of the inflowing reaction gas is chosen in the feed tube in such a manner that the reaction gas reaches the semiconductor wafers disposed at the bottom of the reaction vessel with certainty in spite of the resistance of the exhaust gas. Accordingly, it is reccommend here that the fresh reaction gas enter the reaction space with a Reynolds number of at most 50, or in particular, at most 40. It is further recommended that the gas feeding tube is swivable so that the point of entry of the fresh reaction gas is along a path running above the semiconductor wafers to be coated and which is adapted to the periphery of the total precipitation area given by the totality of the semiconductor wafers present, exhibiting radial symmetry with respect to its center, in such a manner that the image generated by orthogonal projection of the point of entry on the total precipitation area along a path on the total precipitation area becomes slower the further the respective point of the trajectory is removed from the center of the total precipitation area. Furthermore, points of the image path having the same radial distance from the center of the total precipitation area, are traversed by the image with equal frequency, as counted over the the total precipitation time.

The invention is illustrated and described hereinbelow. It is not intended to be limited to the details shown, since various modifications may be made therein within the scope and the range of the claims. The invention, however, together with additional objects and advantages will be best understood from the following desciption and in connection with the accompanying Drawing, in which:

The Drawing shows a preferred embodiment of the invention.

The cylindrical reaction space 1 is closed off at the bottom by a cup-shaped lower part 2, and by a cylindrical upper part 3. These parts consist practically of quartz. The reaction space is closed at the top by a lid 4, for instance, of alloy steel. The feed tube 9, for the fresh reaction gas, is brought through this lid. A viewing window 12, for pyrometrically measuring the temperature at the semiconductor wafers to be coated, is also fitted into lid 4.

The wafers to be coated 5, are disposed at the bottom of the cup-shaped lower part 2. The wafers are heated from below via heat equalizing plate 7, the heat being supplied by a heating element 6, through which current flows. The lower part 2 of the reaction space 1 and the heating device 6, 7 are appropriately located in a cooled casing metal 8.

The fresh reaction gas is supplied via the gas feeding tube 9 which penetrates the metal lid 4. It is desirable that the tube is swivable in the lid. The appropriate seals 11, which prevent the reaction gas from escaping at the feed through point, of course, must be chemically and thermally resistant, resilient material. Reference can be made to the above-mentioned patents, regarding the detailed design of the gas entry point 9.

As will be seen from the Figure, the lid 4 extends all around beyond the wall 3 of the cylindrical reaction vessel. From its periphery an annular wall 13 extends downward, which forms the outer boundary of the outer annular exhaust chamber 14. Gas discharge tube 23 is in this wall 13. A second annular wall 15 extends further inward and is tightly connected, on the one hand, with the lid 4, and on the other hand, at its lower edge, with the already mentioned wall 13. In this manner the outer exhaust chamber 14 is formed. The wall 15 contains a number of evenly spaced holes 16, which form the connection between the interior of the outer exhaust chamber 14 and the inner exhaust chamber 17 which is arranged between the wall 15 and the wall 3 of the reaction space 1. It is also hermetically sealed against the outer space by appropriate wall parts and has only one connection to the outer exhaust chamber 14 and the reaction space 1.

The connection between the reaction space 1 and the inner, annular exhaust chamber 17 is situated directly below the lid 4. It consists of one or several azimuthal slots 18, the total flow resistance of which is considerably smaller compared to that of the openings 16, at least by a factor of one-fifth and preferably one-twentieth or one-hundredth. All of the openings 18 and the openings 16, respectively, have the same shape and dimensions.

The larger flow resistance between the two exhaust chambers, as compared to that between the inner exhaust chamber and the reaction space can be achieved, on the one hand, by making the openings 18 correspondingly larger than the openings 16 and/or by providing correspondingly more openings 18 as compared to the openings 16. The arrangement of the openings 18 immediately below the lid 4 ensures the no dead spaces are formed in the reaction space with respect to the gas flow. In any event, the openings 18 must be arranged above the entry point for the fresh reaction gas, i.e., the mouth of the gas feeding tube 9. Similarly, the openings 18 must be arranged above the openings 16, so that the spent reaction gas flowing in the chamber 17 must flow somewhat downward.

What is claimed is:

1. In a device for the precipitation of layers of semiconductor material from an appropriate reaction gas on the surface of semiconductor wafers which are disposed at the bottom of a vertical cylindrical reaction vessel and are heated to the high temperature required for precipitation by a heat source arranged underneath the bottom, in which the fresh reaction gas is fed to the heated semiconductor wafers via swivable feed tube which extends into the reaction space of the reaction vessel from above and the spent reaction gas leaves the semiconductor wafers to be coated in an upward direction, the improvement which comprises an exhaust system for the spent reaction gas from the reaction space consisting of two annular exhaust chambers which are disposed concentrically with respect to each other and to the vertical cylindrical reaction space with a common wall between the inner of said two annular exhaust chambers and said reaction space and a common wall between the outer of said two exhaust chambers and said inner exhaust chamber, said exhaust chambers are connected in series as to the flow of the spent reaction gas via openings in the wall between the reaction space and the inner exhaust chamber and the wall between the two exhaust chambers and a gas venting tube connected to the outer exhaust chamber, the openings leading from the reaction space to the inner exhaust chamber are arranged above the mouth of the tube feeding fresh reaction gas into the reaction space and above the connecting openings between the two concentric exhaust chambers, the total flow resistance of the openings between the reaction space and the inner exhaust chamber is less than the total flow resistance of the openings between the two concentric exhaust chambers.

2. The device of claim 1, wherein the openings between the reaction space and the inner exhaust chamber and the openings between the two exhaust chambers are arranged in the corresponding walls along a respective azimuthal ring zone.

3. The device of claim 1, wherein the openings between the reaction space and the inner exhaust chamber and the openings from the inner exhaust chamber

each have the same dimensions and are arranged at equal spacings with respect to each other.

4. The device of claim 1, wherein the number of the openings between the reaction space and the inner exhaust chamber is larger than the number of openings between the two exhaust chambers.

5. The device of claim 3, wherein the individual openings between the reaction space and the inner exhaust chamber are larger than the individual openings between the two exhaust chambers.

6. The device of claim 1, wherein the total flow resistance for the spent reaction gas between the two exhaust chambers is adjusted to be larger by a factor of at least 5, than the flow resistance between the reaction space and the inner exhaust chamber.

7. The device of claim 1, wherein the total flow resistance for the spent reaction gas between the two exhaust chambers is adjusted to be larger by a factor of at least 20 to 100, than the flow resistance between the reaction space and the inner exhaust chamber.

8. The device of claim 1, wherein the flow resistance in the gas venting tube for gas leaving the outer exhaust chamber is controllable by a valve and that the flow resitance with the valve open is so small that the total flow resistance is practically set by the flow resistance between the two exhaust chambers.

9. The device of claim 1, wherein the openings between the reaction space and the inner exhaust chamber are horizontal slots which complement each other to form a horizontal annular slot interrupted only by local spacers between a lid of the reaction vessel and the upper edge of the cylindrical wall of the reaction space.

10. The device of claim 9, wherein the openings between the reaction space and the inner exhaust chamber are arranged directly at the upper end of the reaction space.

11. The device of claim 9, wherein both concentric and annular exhaust chambers are closed on top by a lid on the reaction vessel, said lid extending radially beyond the wall of the reaction vessel.

12. The device of claim 11, wherein the outer exhaust chamber is formed by two annular walls which extend downward from the lid of the reaction vessel and are arranged concentrically with respect to each other and to the reaction space, said walls being hermetically connected with each other, a gas venting tube attached at the outer wall and connecting openings in the inner wall connecting to the inner exhaust chamber.

13. The device of claim 12, wherein the wall of the reaction space consists of quartz and the lid of the reaction vessel consists of metal.

14. The device of claim 12, wherein the wall of the reaction space consists of glass and the lid of the reaction vessel consists of alloy steel.

15. The device of claim 12, wherein the walls of the outer exhaust chamber consists of the same material as the lid of the reaction vessle.

16. The device of claim 12, wherein the inner exhaust chamber formed by the inner wall of the outer exhaust chamber and the wall of the reaction space is sealed toward the bottom by a sealing ring of thermally and chamically resistant, resilient material.

17. The device of claim 16 wherein the sealing ring is pressed by means of a metal washer from the outside against the wall of the reaction space and against the inner wall of the outer exhaust chamber, said washer being tightened against the lower edge of the wall of the outer exhaust chamber by means of a mounting and clamping device.

18. The device of claim 1, wherein a quartz glass viewing window is disposed in the lid of the reaction vessel.

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