United States Patent

Jarvela et al.

[15] **3,690,290**

[45] **Sept. 12, 1972**

[54] **APPARATUS FOR PROVIDING EPITAXIAL LAYERS ON A SUBSTRATE**

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[22] Filed: **April 29, 1971**

[21] Appl. No.: **138,601**

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

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

[58] **Field of Search** 118/48–49.5; 148/175, 174

[56] **References Cited**

UNITED STATES PATENTS

2,789,062	4/1957	Cusano et al.	118/48 UX
3,213,827	10/1965	Jenkin	118/49.5
3,407,783	10/1968	Capita	118/49.5
3,441,000	4/1969	Burd et al.	148/175 X
3,460,510	8/1969	Currin	118/48
3,464,846	9/1969	Mattson	118/48 X
3,492,175	1/1970	Conrad et al.	148/175
3,594,227	7/1971	Oswald	117/201 X
3,635,771	1/1972	Shaw	148/175

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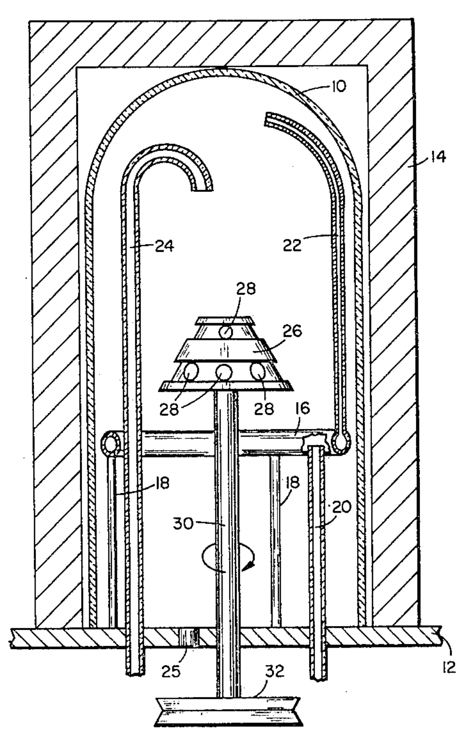
[57] **ABSTRACT**

Epitaxial deposition apparatus includes a bell jar disposed within a furnace and having therein a closed annulus adapted to contain material to be vaporized when heated. First tubular means delivers gaseous reactant to the annulus and second tubular means delivers the reaction product, of the vaporized material and gaseous reactant, to a top portion of the bell jar. Means deliver a second gaseous reactant to said top portion. Means support a substrate at an intermediate portion of the bell jar.

5 Claims, 2 Drawing Figures



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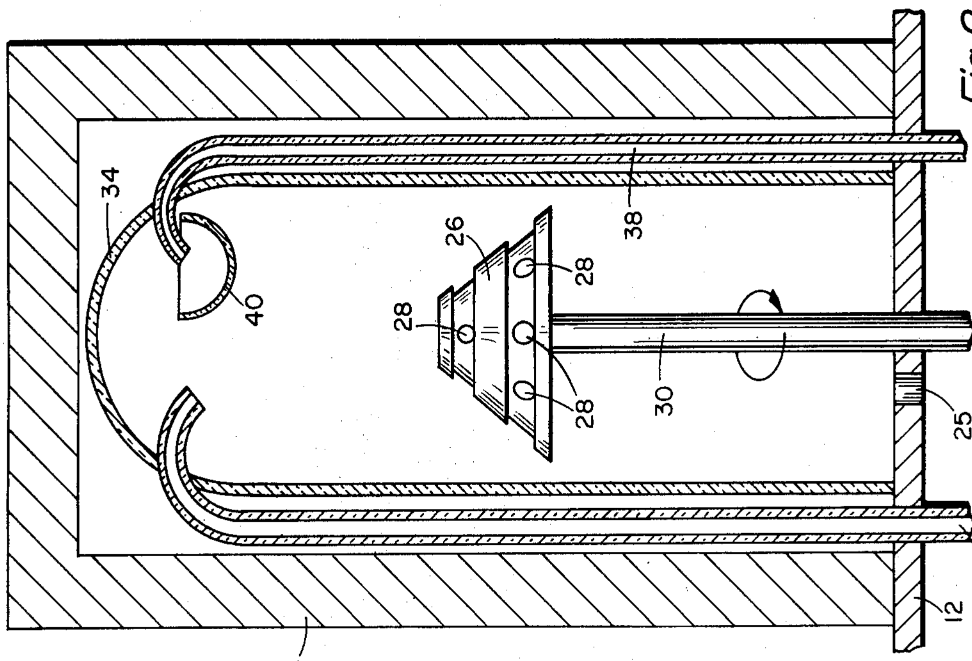

Fig. 2

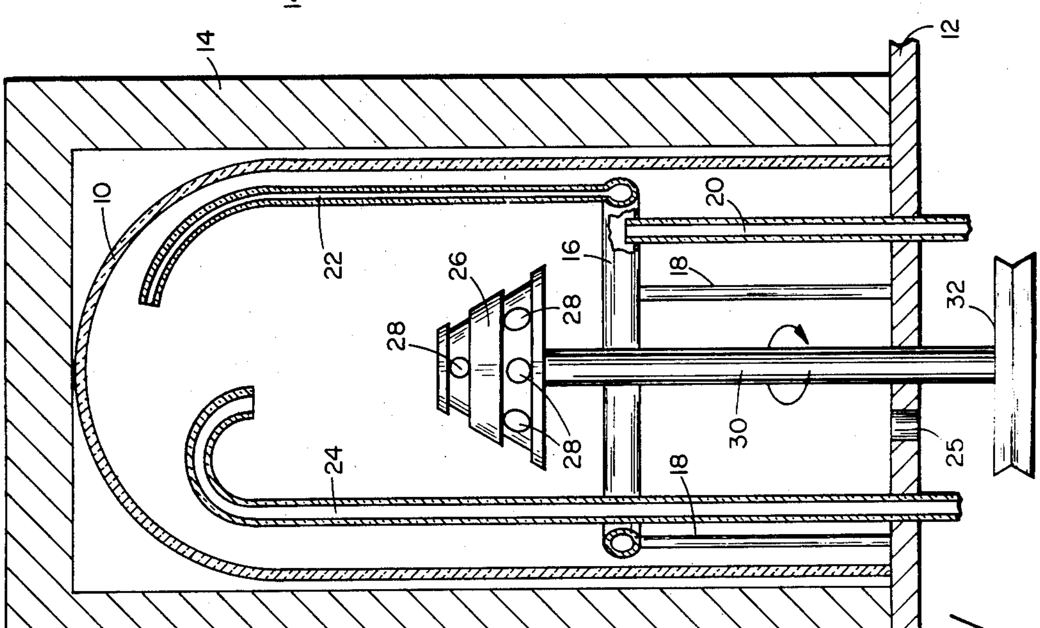

Fig. 1

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APPARATUS FOR PROVIDING EPITAXIAL LAYERS ON A SUBSTRATE

BACKGROUND

This invention relates to apparatus for depositing an epitaxial layer of Group III – Group V or II–VI intermetallic compounds on a substrate.

In the making of certain solid state devices such as light emitting diodes, in the process of producing the PN junction of the diode, an epitaxial layer of gallium arsenide (GaAs) or gallium arsenide phosphide ($GaAs_xP_{1b-x}$) or gallium phosphide (GaP) is deposited on a suitable substrate. The substrate may be monocrystalline material of the same composition as the epitaxial layer or it may be of a different material having a suitable crystalline form and a lattice distance the same as or very close to the lattice distance of the material being deposited. In known methods of depositing the epitaxial layer, a vertical quartz tube about 6 feet long is used and a heater or furnace, which is also about 6 feet long surrounds the tube. In charging or cleaning the tube and the parts of the apparatus that are in the tube, the furnace must be taken away from around the tube. If the furnace is vertically disposed it must be raised to clear the tube and a very high ceiling is needed, if the furnace is opened as by hinging along a plane through the axis of the tube, the heating provided by the furnace to the tube and its contents is not uniform around the circumference of the tube. Furthermore, the tube being 6 feet long is expensive and due to its size, is hard to work with. A horizontal reactor of similar size is also complex and cumbersome in operation. An inherent difficulty of the horizontal reactor is obtaining deposition uniformity over a multiplicity of substrates.

It is an object of this invention to provide an improved apparatus for depositing an epitaxial layer of a Group III – Group V or II–VI compound on a suitable substrate.

It is another object of this invention to provide an apparatus of the type mentioned of convenient size.

It is still another object of this invention to provide an apparatus of the type mentioned in which the heater provides uniform heating and yet may conveniently be removed from the quartz part of the apparatus that it heats.

It is another object of this invention to provide an apparatus for depositing layers epitaxially and with uniformity on a multitude of substrates.

SUMMARY

In accordance with the invention, a bell jar is provided which includes a container or reservior for melting and reacting gallium and a holder which may be rotational for supporting the substrates. The bell jar is positioned with the closed end up and means are provided for passing the required chemicals in gaseous or vapor phase along the length of the bell jar and into the upper part of the jar. The Group III and Group V reactants are formed in the top part of the bell jar in gaseous form and in flowing countercurrently to the lower temperature of the substrate react to form the compound which is deposited in solid form on the substrates. The furnace, which may be in the shape of a cylinder, having the top thereof closed, is put over the bell jar with the closed end up and provides the desired temperatures in the bell jar, that is the highest temperatures in the region of the top of the jar, and the lowest temperatures at the bottom of the bell jar. The bell jar may be about 3 feet tall whereby the furnace need be but a little taller than 3 feet and the furnace can be removed in a room having normal headroom. Also, the furnace and the quartz bell jar being about 3 feet long are much less expensive than the prior art quartz tube which is about 6 feet long and the furnace which is comparably long and also, the apparatus of this invention is easier to charge and to clean than the prior art apparatus. This apparatus results in a much lower reactor enclosure surface to volume ratio for given number of substrates. This reduces purge times, and contamination of the epitaxial deposits from the walls of the reactor. If desired, the tubes feeding the gases to the bell jar may be inside of the furnace but outside the bell jar and feed into the top of the bell jar, whereby a larger diameter support for the substrates supporting more substrates, may be used in the jar than when the tubes that feed gases to the top of the bell jar are in the bell jar.

DESCRIPTION

The invention will be better understood upon reading the following description in connection with the accompanying drawing in which

FIG. 1 illustrates an epitaxial layer producing apparatus according to this invention and

FIG. 2 illustrates another embodiment of the epitaxial layer producing apparatus according to this invention.

Turning first to FIG. 1, a bell jar 10, which may be of quartz, is sealed to a baseplate 12 fitted with gas inlets and outlet(s) to provide an isolated reaction environment within. The height of the bell jar may be about one-half or less of the height of the prior art tube (not shown), this prior art tube being open at both ends and fitted with suitable sealing devices. A furnace 14 is positioned over the bell jar surrounding the bell jar, on top and sides. The furnace 14, may be composed of resistance elements which are heated by passing current therethrough in a known manner or, in proper circumstances, the furnace 14 may be of the induction heating type. This furnace may be of one piece, whereby it can easily be designed to provide uniform heating around the circumference of the bell jar but with increased heating in the upper portion of the bell jar as compared to the lower portion thereof. The furnace (not shown) used with the long tube cause greater heating in the middle of the length thereof, the heating at the end thereof being symmetrically decreased at points further away from the longitudinal center thereof. It is noted that the heating profile of the prior art long tube is folded over in the present invention, the hottest portion being nearer the upper end rather than in the longitudinal center as with a long tube. A chamber 16, which may be in the form of a hollow annulus is provided for holding the Group III element to be volatized and is supported on the base plate 12 in the bell jar 10 by the legs 18, only two of the three legs being shown. A tube 20 goes up through the base plate 12 and into the chamber 16, a portion of the chamber 16 being broken away to show the top of the tube 20. Another tube 22 extends from the top of the chamber 16 and extends to the top of the bell jar 10 and has an open end which is directed towards the middle of the bell jar at the top thereof. Another tube **24** extends into the bell jar **10** through the base plate **12**. The end of the tube **24** terminates near the top, center of the bell jar **10**. An exhaust outlet **25** is provided in the table **12** for the jar **10**. A support **26** with substrates **28** in niches in the surface thereof is rotatably mounted on a shaft **30** to be rotated, as by a pulley **32**, which is fixed to the bottom end of the shaft **30**.

FIG. **2** differs from FIG. **1** generally in that the gas tubes are outside the bell jar, and the Group III element chamber **40** is located above the support **26** and in this case near the top of the bell jar **34**. The support **26** for the substrates **28** may be larger in diameter, whereby the number of substrates **28** that are processed at one time can be greater in FIG. **2** than in FIG. **1**. Due to this similarity, similar elements in FIGS. **1** and **2** have been given similar reference characters. The bell jar **34** of FIG. **2** must include ports for the entry of the tubes **36** and **38** thereinto. Tubes **36** and **38** are analogous to tubes **24** and **20** in FIG. **1**. The tube **36** extends up through the base plate **12** but outside the bell jar **34** and the upper end of the tube **36** enters the bell jar **34** near the top thereof and the end of the tube **36** is in the bell jar **34**. The tube **38** goes up through the base plate **12** outside of the bell jar **34** and the upper end thereof goes into the bell jar **34** and turns to project a gas that is carried thereby into a container **40** which is also in the bell jar and which contains the material to be melted. The container **40** may hang from the top of the bell jar **34** or from the end of the tube **38**.

In one use of the apparatus of FIGS. **1** and **2**, gallium is put into the containers **16** or **40** and substrates **28** are put on the supports **26** in the niches therein as shown and the supports **26** are caused to turn continuously. The furnace **14** is positioned over the bell jar **10** or over the bell jar **34** and the tubes **36** and **38** and the furnace **14** is heated in a known manner. When the gallium in the containers **16** or **40** is melted and is at a suitable temperature of about 600° to 800°C, purified HCl is passed up through the tube **20** of FIG. **1** and **38** of FIG. **2** and passed over the molten gallium in the chambers **16** and **40** respectively. Arsine AsH_3 alone or a mixture of AsH_3 and hydrogen gas is passed up through the tube **24** in FIG. **1** or **36** in FIG. **2**. The HCl and the molten gallium react to produce GaCl at the temperature of over 830°C at the top of the bell jar **10** or **34**. The temperature goes down to about 800°C in the region of support **26**, and the GaCl which is unstable at temperatures below 800°C becomes gallium and $GaCl_3$. The gallium reacts with the arsine and becomes GaAs. The GaAs is deposited on the substrates **28** which are about 780°C, in an epitaxial manner. The chemical reactions are well known and need not be further described. Furthermore, by proper selection of chemicals such as causing the flow of phosphine instead of arsine in the tubes **24** and **36** and using suitable temperatures and flow rates GaP will be deposited on the substrate **28** in an epitaxial manner. Similarly, if phosphine and arsine are passed simultaneously with hydrogen in the tubes **24** and **36** the epitaxial layer will be $GaAs_xP_{1-x}$. It is known that the condition of the surface of the substrate and the composition thereof are important in the production of good epitaxial layers.

It will be noted that the gases flowing up in the tubes **20**, **22** and **24** in FIG. **1** and **36** and **38** in FIG. **2** are brought up to the required temperatures for the chemical reactions to take place. Furthermore, the flow downwardly in the bell jars **10** and **34** of the reacting gases causes the reactions to take place and the epitaxial substrate to be deposited in their own temperature zones. Therefore, the gases in the reaction products flowing in opposite directions as described makes it possible to have a shorter furnace **14** and a shorter reaction chamber, the bell jars **10** and **34**, than the long furnace and the long tubular reaction chamber of the prior art. Furthermore, the vertical positioning of the bell jars, in combination with the rotation imparted to the substrates **28** by rotation of the holders **26** causes more uniform deposition of the epitaxial layer on the substrates **28** than if a horizontal reactor with horizontal flow of gases were used. Therefore, the disclosed apparatus will cause the deposition of epitaxial layers on substrates and yet it is more compact, it is less expensive, is easier to charge and to clean and to operate and to maintain than prior art devices.

What is claimed is:

1. Apparatus for depositing on substrates comprising
   a vertically positioned bell jar, sealed to a base plate fitted with suitable gas inlets and outlets,
   a furnace positioned over said bell jar and arranged to heat said bell jar to its highest temperature in a region of the top of said bell jar,
   first tubular means for leading a first gas into said bell jar adjacent a top portion thereof,
   a horizontally disposed chamber for holding an element to be volatilized in said bell jar and comprising a closed annulus,
   second tubular means for introducing a second gas into said annulus for causing a reaction between said element, when heated by said furnace, and said second gas,
   third tubular means for leading the gaseous product of said reaction into said top portion of said bell jar in the vicinity of said first gas,
   and means for supporting substrate wafer elements in said bell jar intermediate said top portion and said base plate.

2. The invention of claim **1** in which said bell jar is substantially surrounded top and sides by said heater.

3. The invention of claim **1** in which said tubes extend inside said bell jars from the open end thereof.

4. The invention of claim **1** in which said tubes extend along the outside of said bell jar and between said bell jar and said furnace for the major portion of their length.

5. The invention of claim **1** in which said support for wafers is rotatable.

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