US007011711B2

(12) **United States Patent**
Shreter et al.

(10) **Patent No.: US 7,011,711 B2**
(45) **Date of Patent: Mar. 14, 2006**

(54) **CHEMICAL VAPOR DEPOSITION REACTOR**

(76) Inventors: **Yury Georgievich Shreter**, J. Duclos Street, 8/1, app. 13, 194223 St Petersburg (RU); **Yury Toomasovich Rebane**, Kostromskoi prospect 56, app. 22, 194214 St Petersburg (RU); **Ruslan Ivanovich Gorbunov**, 19 line 2/2, app. 39, 197029 St Petersburg (RU); **Sergey Igorevich Stepanov**, Smolnv Prospekt 6, apt 2, 193124 St. Petersburg (RU); **Vladislav Evgenievich Bougrov**, Kondtratievskii Prospekt 64, building 2, app. 7, 195271 St. Petersburg (RU); **Vladimir Nikolaev**, Bogatvrskii prospect 8, app. 86, 197348 St. Petersburg (RU); **Maxim Nikolaevich Blashenkov**, Leni Golikova str. 52-III app. 47, 198255 St. Petersburg (RU); **Alexander Nikolaevich Andreev**, Solidarnisti prospect 9-2, app. 32, 193312 St. Petersburg (RU); **Stephen Sen-Tien Lee**, 2Fl., No. 327 Sung Lund Rd., Taipei (TW) 105

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 231 days.

(21) Appl. No.: **10/445,233**

(22) Filed: **May 23, 2003**

(65) **Prior Publication Data**

US 2004/0129213 A1 Jul. 8, 2004

(30) **Foreign Application Priority Data**

Jan. 7, 2003 (TW) .... 92100278 A

(51) **Int. Cl.**

C23C 16/00	(2006.01)
C23C 16/455	(2006.01)
C23C 16/452	(2006.01)
C23C 16/34	(2006.01)

(52) **U.S. Cl.** **118/715**; 118/724

(58) **Field of Classification Search** 118/715, 118/724, 725

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,574,093 A		3/1986	Cox	
4,760,244 A	*	7/1988	Hokynar	219/390
4,848,273 A	*	7/1989	Mori et al.	118/729
5,146,869 A	*	9/1992	Bohannon et al.	118/724
5,192,370 A	*	3/1993	Oda et al.	118/723 R

(Continued)

FOREIGN PATENT DOCUMENTS

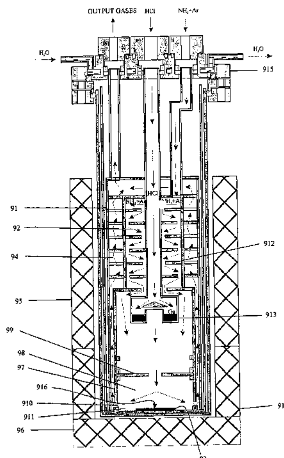
JP 61-251118 * 11/1986

Primary Examiner—Jeffrie R. Lund
(74) *Attorney, Agent, or Firm*—Trojan Law Offices

(57) **ABSTRACT**

A chemical vapor deposition reactor for depositing a thin film on at least a substrate through a reaction between a vertical input reagent gas flow and the at least a substrate is provided, in which a vertical output reagent gas flow is produced after the reaction. The reactor includes a vertical tube, at least a reaction chamber located inside the vertical tube, an input flow baffle located on the at least a reaction chamber, and at least a gas exit installed on the at least a reaction chamber for exhausting the vertical input reagent gas flow and the vertical output reagent gas flow. In addition, the substrate is located at the bottom of the at least a reaction chamber. The provided reactors allow the achievement of more efficient heating process, lower gas consumption and higher growth uniformity than the conventional reactors.

18 Claims, 7 Drawing Sheets



U.S. PATENT DOCUMENTS

5,462,013 A * 10/1995 Punola et al. 118/719
5,498,292 A * 3/1996 Ozaki 118/724
5,520,742 A * 5/1996 Ohkase 118/724
5,578,132 A * 11/1996 Yamaga et al. 118/724
5,580,171 A * 12/1996 Lim et al. 366/336
5,685,914 A * 11/1997 Hills et al. .... 118/723 E
5,980,632 A 11/1999 Lyechika
6,055,927 A * 5/2000 Shang et al. .... 118/723 ME
6,085,689 A * 7/2000 Sandhu et al. .... 118/723 IR
6,086,673 A 7/2000 Molnar
6,144,802 A * 11/2000 Kim 392/479
6,176,925 B1 1/2001 Solomon
6,177,292 B1 1/2001 Hong
6,179,913 B1 1/2001 Solomon
6,207,932 B1 * 3/2001 Yoo 219/444.1
6,267,840 B1 * 7/2001 Vosen 156/345.33
6,328,807 B1 * 12/2001 Boek et al. 118/724
6,332,927 B1 * 12/2001 Inokuchi et al. 118/725
6,350,666 B1 2/2002 Kyliouk
6,352,593 B1 * 3/2002 Brors et al. 118/724
6,514,348 B1 * 2/2003 Miyamoto 118/715
6,537,418 B1 * 3/2003 Muller et al. 156/345.34
6,585,823 B1 * 7/2003 Van Wijck 117/89
2001/0018894 A1 * 9/2001 Chang 118/724
2002/0155713 A1 * 10/2002 Tsvetkov et al. 438/689
2004/0129213 A1 * 7/2004 Shreter et al. 118/715
2005/0056222 A1 * 3/2005 Melnik et al. 118/726

* cited by examiner

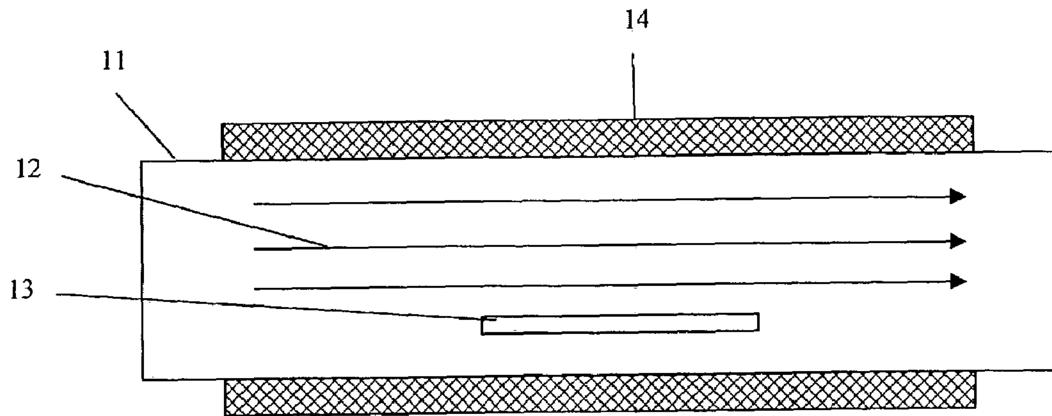


Fig. 1(PRIOR ART)

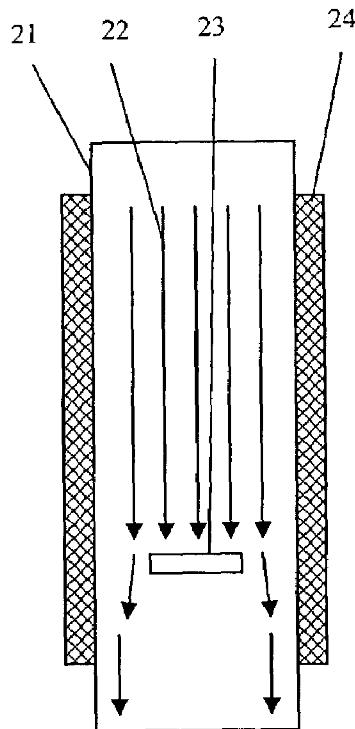


Fig. 2(PRIOR ART)

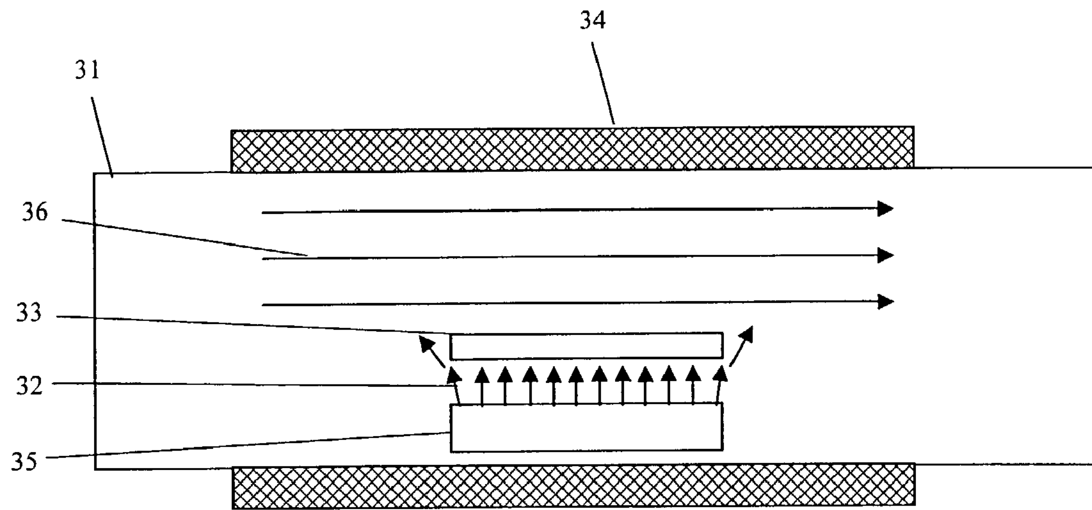


Fig. 3(PRIOR ART)

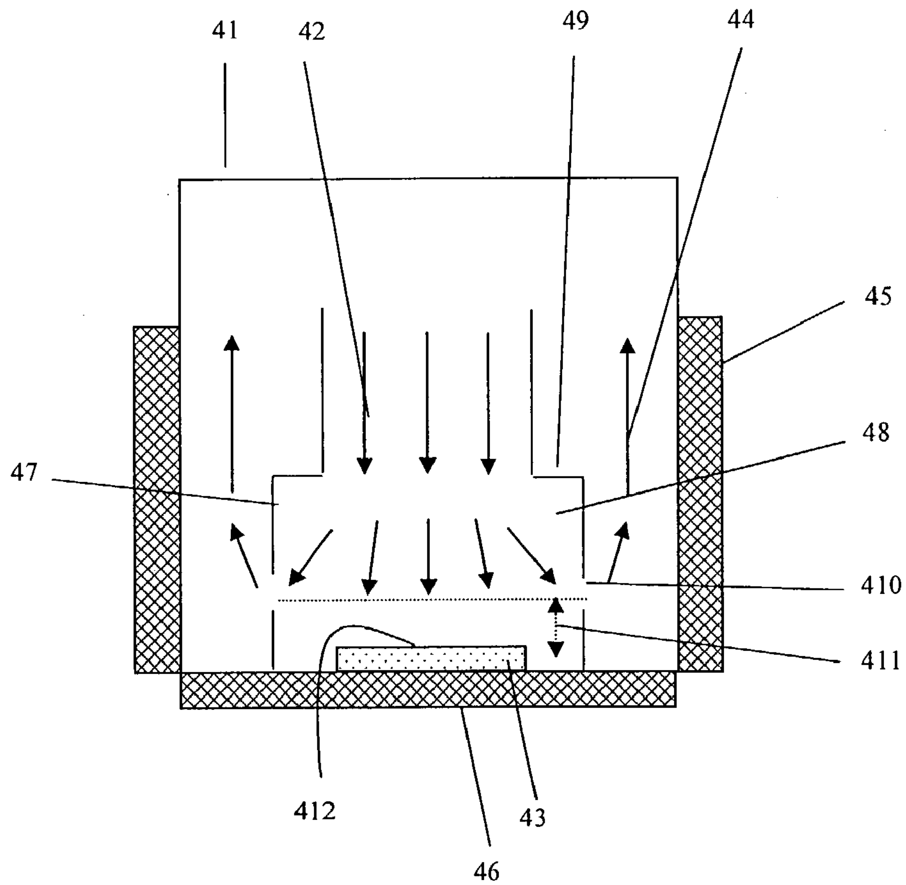


Fig. 4

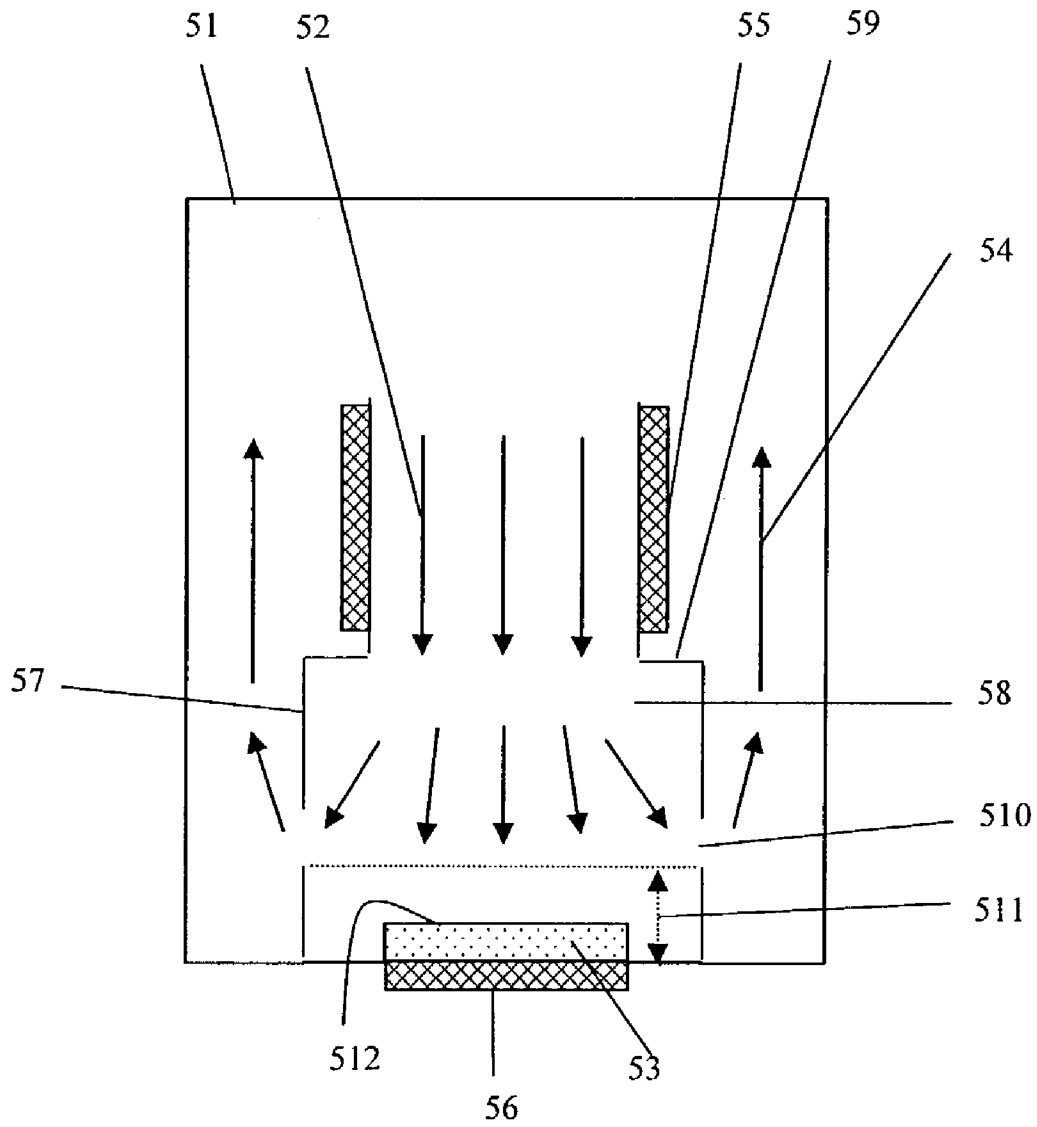


Fig. 5

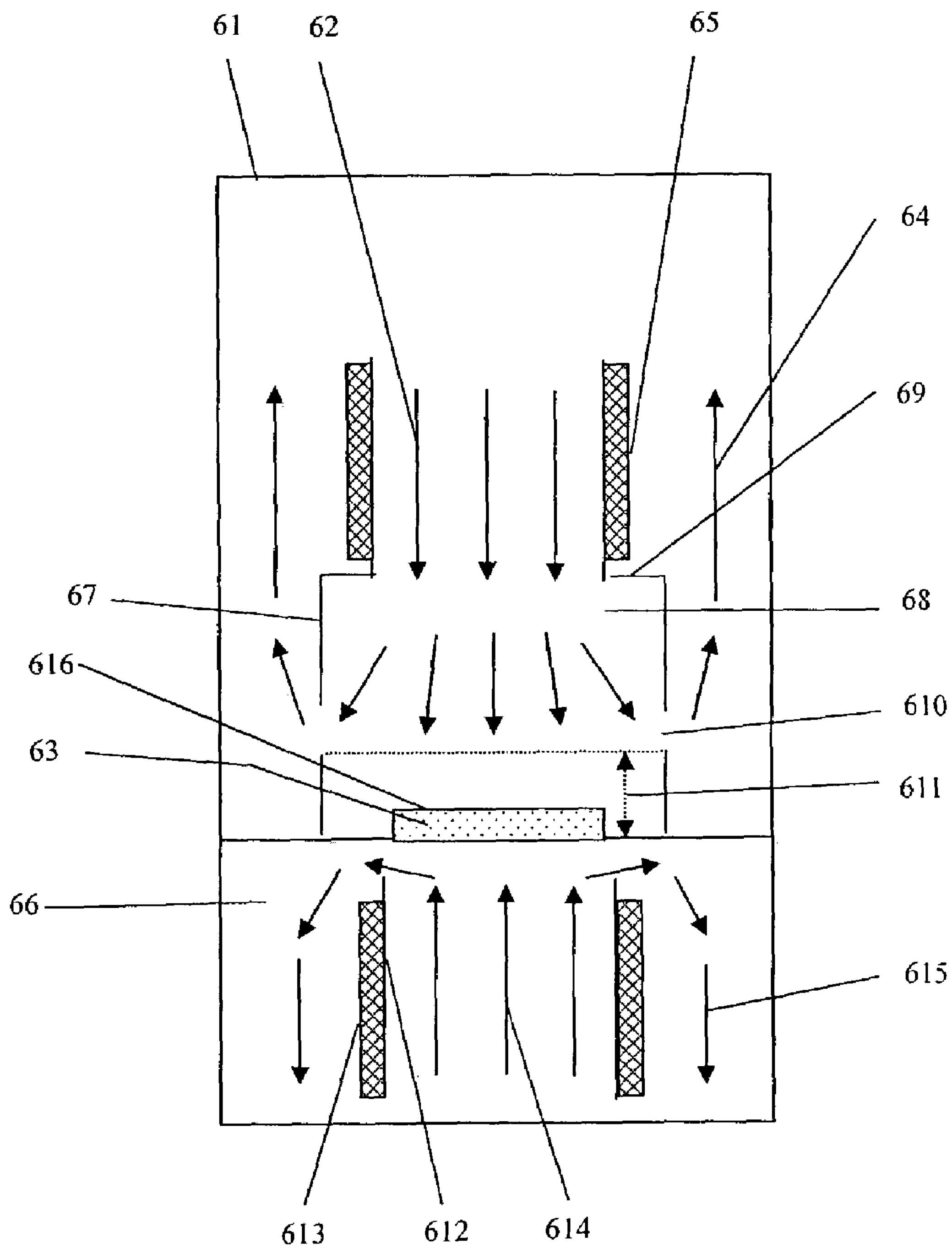


Fig. 6

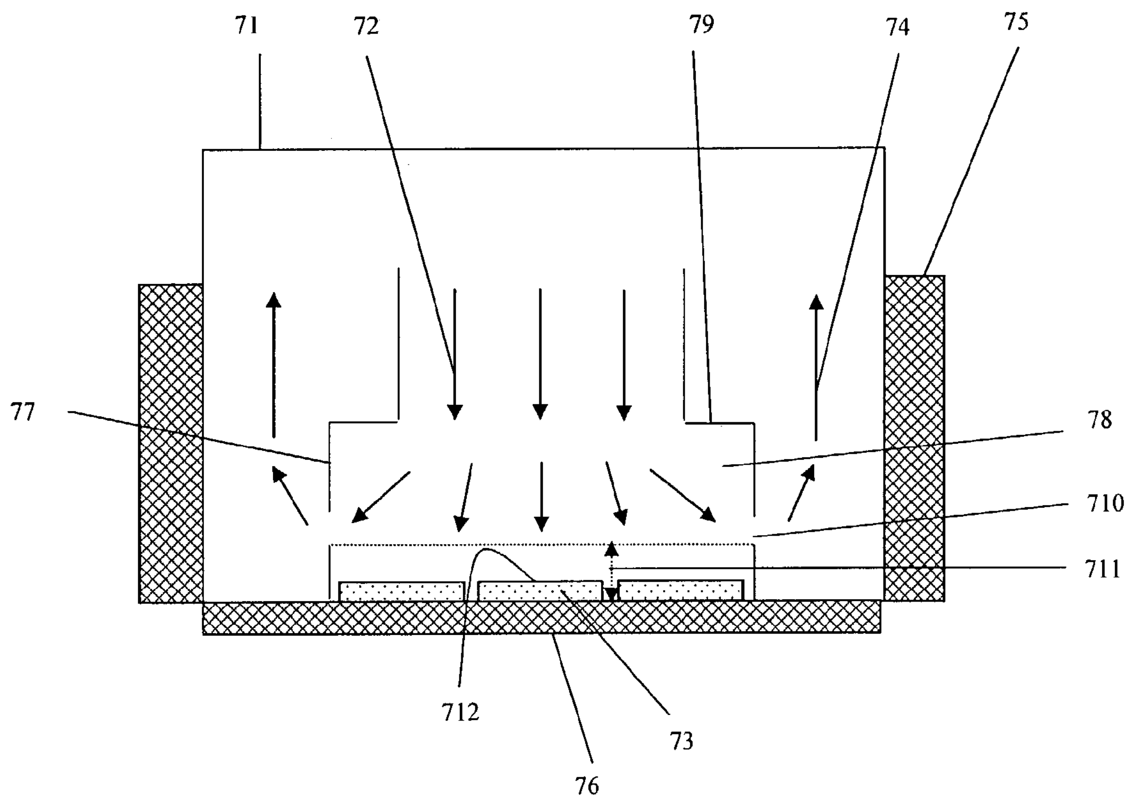


Fig. 7

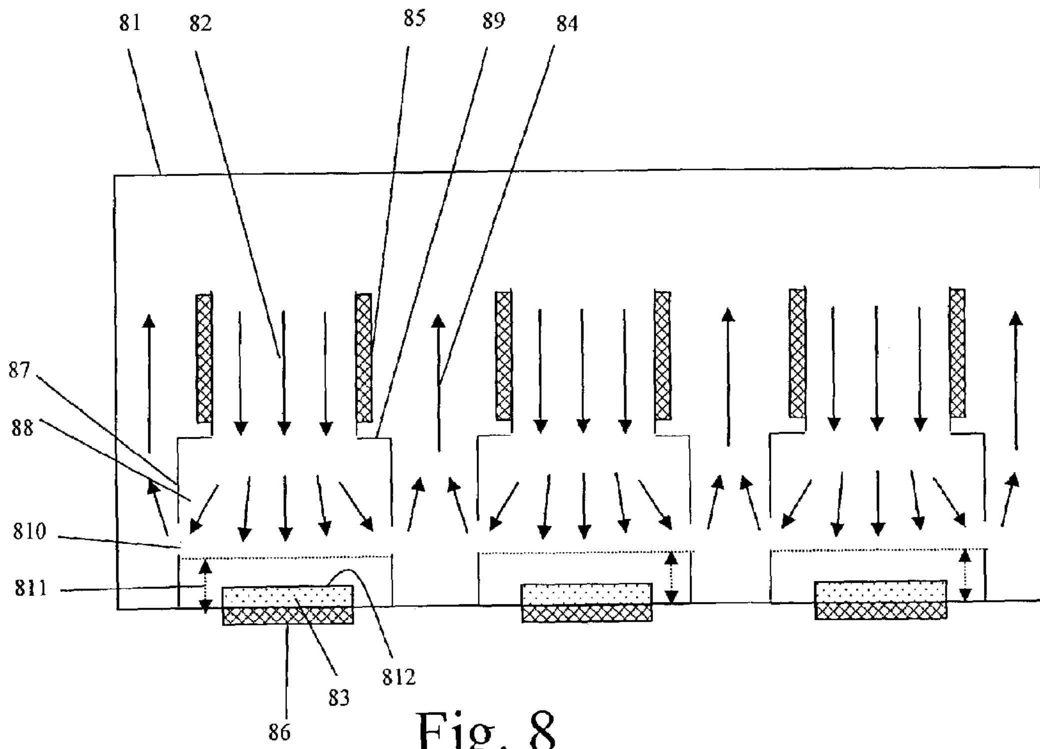


Fig. 8

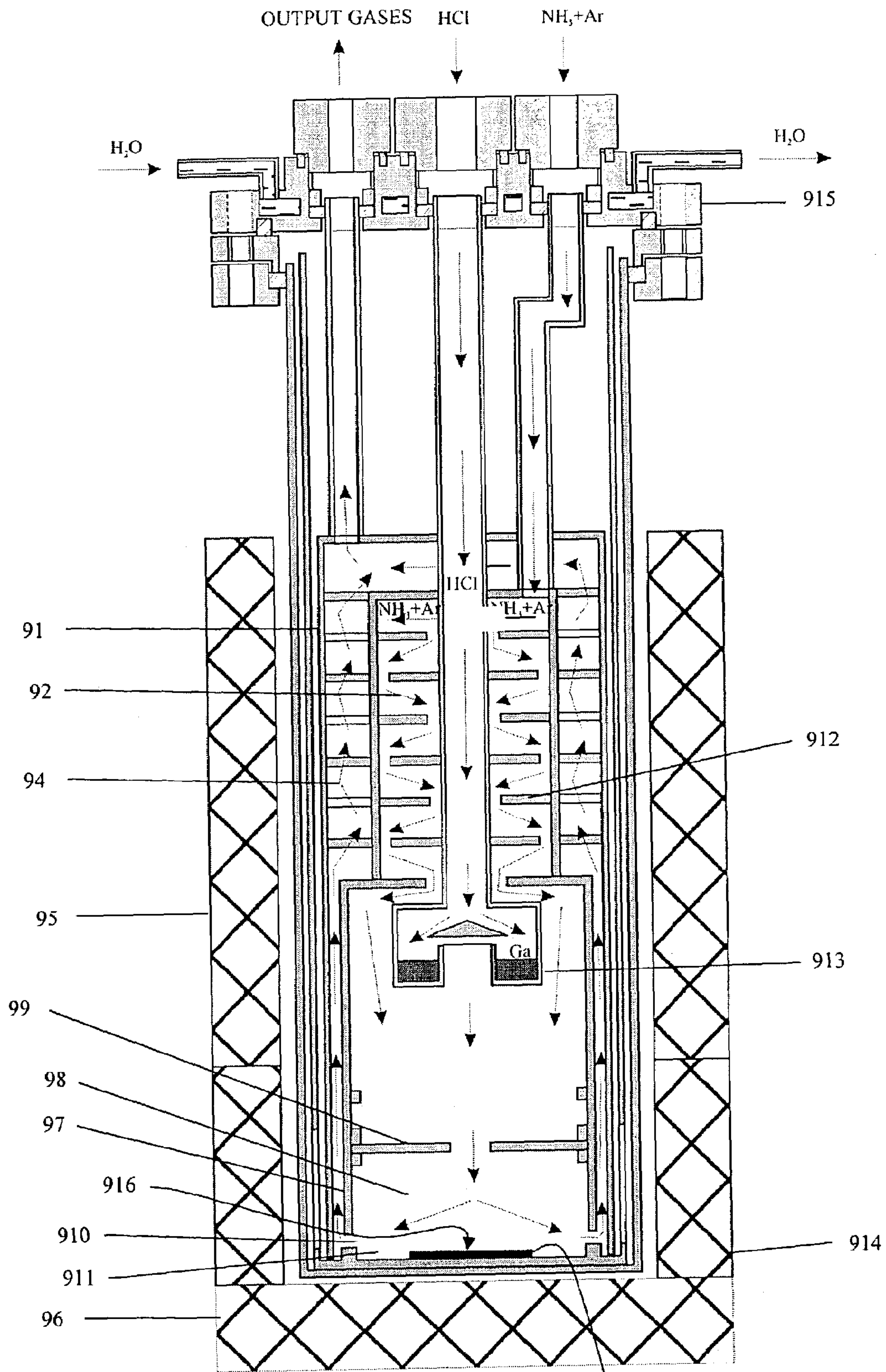


Fig. 9

CHEMICAL VAPOR DEPOSITION REACTOR

This application claims priority to Application No. 092100278 filed in China on Jan. 7, 2003.

FIELD OF THE INVENTION

This invention relates to a reactor, and more particularly to a chemical vapor deposition reactor.

BACKGROUND OF THE INVENTION

Chemical vapor deposition is a thin film deposition technique about using a method of depositing a solid product onto a chip surface from reactants by a chemical reaction in a reactor. The reactants are usually gas reactants. After decades of developments, the chemical vapor deposition has become the most important and the main deposition method in the semiconductor manufacturing process for depositing a thin film on the semiconductor elements, such as conductors, semiconductors, and dielectric materials.

The key equipment of the facilities for the chemical vapor deposition is the reactor, and a thin film is deposed onto a substrate therein. However, according to the relevant application, scopes, the designs for chemical vapor deposition reactors might be various. A Hydrogen Vapor Phase Epitaxy reactor, HVPE reactor, is one of the popular chemical vapor decomposition reactors.

The conventional HVPE reactors for growing the compound semiconductors of IV and III–V groups of the periodical table and their alloys are well-known in the industry. These reactors can be divided into three main groups according to their geometrical features. The three main groups are respectively HVPE reactors with horizontal geometry of gas flow (HG HVPE reactors), HVPE reactors with vertical geometry of gas flow (VG HVPE reactors), and HVPE reactors with closed shower head (SH HVPE reactors).

Please refer to FIG. **1**, which shows a structural diagram of a prior HG HVPE reactor. As shown in FIG. **1**, the HG HVPE reactor includes a horizontal tube **11**, a horizontal reagent gas flow **12**, a substrate **13**, and a gas heater **14**. A hydride thin film is deposited on the substrate **13** through a reaction of the horizontal reagent gas flow **12** in the HG HVPE reactor. The relevant structures and features of HG HVPE reactors are disclosed in U.S. Pat. Nos. 6,176,925, 6,177,292, 6,179,913 and 6,350,666.

The disadvantages of above-mentioned HG HVPE reactors include: 1. It's difficult to obtain a high efficiency of gas utilization and high growth uniformity of the thin film simultaneously. 2. In order to avoid the temperature gradients inside the horizontal tube **11**, a big gas heater **14** with high power consumption is always necessary. 3. Because it is difficult to control the temperature difference between the inside walls of the horizontal tube **11** and the substrate **13**, a deposition material is always formed on the inside walls of the HG HVPE reactor. 4. Because of the long thermal relaxation time and the changes of the gas flow rate, a Quantum Well structure, QW structure, is unable grown. 5. It is difficult to control and model the growth processes of the thin film due to the low symmetry of the HG HVPE reactor.

Please refer to FIG. **2**, which shows a structural diagram of a prior VG HVPE reactor. As shown in FIG. **2**, the VG HVPE reactor includes a vertical tube **21**, a vertical reagent gas flow **22**, a substrate **23**, and a gas heater **24**. A hydride thin film is deposited on the substrate **23** through a reaction of the vertical reagent gas flow **22** in the VG HVPE reactor. The relevant structures and features of VG HVPE reactors are disclosed in U.S. Pat. Nos. 5,980,632 and 6,086,673.

The disadvantages of above-mentioned VG HVPE reactors include: 1. The growth uniformity of the thin film is not yet ideal enough. 2. In order to avoid the temperature gradients inside the vertical tube **21**, a big gas heater **24** with high power consumption is still necessary. 3. Because it is still difficult to control the temperature difference between the inside walls of the vertical tube **21** and the substrate **23**, a deposition material is always formed on the inside walls of the VG HVPE reactor. 4. Because of the long thermal relaxation time and the changes of the gas flow rate, a Quantum Well structure, QW structure, is either unable grown.

Please refer to FIG. **3**, which shows a structural diagram of a prior SH HVPE reactor. As shown in FIG. **3**, the SH HVPE reactor includes a horizontal tube **31**, a vertical reagent gas flow **32**, a substrate **33**, a gas heater **34**, and a shower-type head **35**. A hydride thin film is deposited on the substrate **33** through a reaction of the vertical reagent gas flow **32** in the SH HVPE reactor. The SR HVPE reactor further includes a horizontal gas flow **36** as a buffer gas. The relevant structures and features of SH HVPE reactors are disclosed in U.S. Pat. No. 4,574,093.

The disadvantages of above-mentioned SH HVPE reactors include: 1. The shower-type head **35** is a non-technological design, so that the shower-type head **35** is difficultly fabricated. 2. Because it is difficult to control the temperature difference between the inside walls of horizontal tube **31** and the substrate **33**, deposition materials are always formed on the inside walls of the SH HVPE reactor and the shower-type head **35**.

As above-mentioned, a HVPE reactor with the abilities of high efficiency of gas utilization and high growth uniformity of thin film being able to avoid the erroneous deposition is worthy for the relevant industries.

Because of the technical defects described above, the applicant keeps on carving unflaggingly to develop a "CHEMICAL VAPOR DEPOSITION REACTOR".

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, a reactor is provided for depositing a thin film on a substrate through a reaction between an input gas and the substrate. A output gas is produced after the reaction. The reactor includes a vertical tube, at least a reaction chamber located inside the vertical tube, a plurality of baffles staggeredly arranged along the inside walls of the vertical tube, a plurality of heaters connected to the vertical tube for controlling a temperature difference between the substrate and walls of the reactor and improving a distribution of the input gas, a gas exit installed on the at least a reaction chamber for exhausting the reacted gas and an extended diffusion layer formed from a bottom of the reaction chamber to the gas exit. In addition, the substrate is located at the bottom of the at least a reaction chamber.

Preferably, the reactor is a hydride vapor deposition reactor.

Preferably, the gas exit is installed on a side wall of the at least a reaction chamber.

Preferably, the reactor is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics.

Preferably, the input gas is a mixture of HCl, GaCl, NH_3, and Ar gases.

Preferably, the substrate is a sapphire substrate.

Preferably, the thin film is one compound semiconductor selected from a group consisting of IV group and their alloys, III–V groups and their alloys, and GaN.

Preferably, the reacted gas is a mixture of HCl, GaCl, Cl_2 NH_3, and H_2 gases.

Preferably, the extended diffusion layer is used for increasing a utility rate of the input gas and a deposition unity.

Preferably, the plurality of heaters include a first gas heater and a second gas heater.

Preferably, the first gas heater is one of an external side wall gas heater and an internal side wall gas heater.

Preferably, the second gas heater is an external bottom gas heater.

Preferably, the second gas heater includes an input gas tube and a heater.

Preferably, the reaction chamber is a cylindrical chamber.

Preferably, the extended diffusion layer is used for transmitting the input gas to the substrate.

In accordance with another aspect of the present invention, a hydride vapor deposition reactor is provided for depositing a thin film on a substrate through a reaction between an input gas and the substrate. A reacted gas is produced after the reaction. The reactor includes a vertical tube with two side wall gas heaters and a bottom gas heater, a baffle staggeredly located on an inside wall of the vertical tube for extending routes of the input gas, a reaction chamber located inside the vertical tube a second baffie located on a top of the reaction chamber, and a gas exit installed on a side wall of the reaction chamber for exhausting the reacted gas.

Preferably, the thin film is one compound semiconductor selected from a group consisting of III–V groups and their alloys, IV groups and their alloys, and GaN.

Preferably, the two side wall gas heaters are a first gas heater and a second gas heater respectively located on external side walls of the vertical tube.

Preferably, the vertical tube further includes a Ga tank.

The above contents and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed descriptions and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a structural diagram of a prior HG HVPE reactor;

FIG. **2** shows a structural diagram of a prior VG HVPE reactor;

FIG. **3** shows a structural diagram of a prior SH HVPE reactor;

FIG. **4** shows a structural diagram of the HVPE reactor according to a preferred embodiment I of the present invention;

FIG. **5** shows a structural diagram of the HVPE reactor according to a preferred embodiment II of the present invention;

FIG. **6** shows a structural diagram of the HVPE reactor according to a preferred embodiment III of the present invention;

FIG. **7** shows a structural diagram of the HVPE reactor according to a preferred embodiment IV of the present invention;

FIG. **8** shows a structural diagram of the HVPE reactor according to a preferred embodiment V of the present invention; and

FIG. **9** shows a structural diagram of the HVPE reactor according to a preferred embodiment VI of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only; it is not intended to be exhaustive or to be limited to the precise form disclosed.

The present invention provides HVPE reactors with opposite direction flow geometries and extended diffusion layers. A quantum well structure can be formed on a semiconductor material in the HVPE reactor of the present invention.

Please refer to FIG. **4**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment I of the present invention. As shown in FIG. **4**, the HVPE reactor includes a vertical tube **41**, a first gas heater **45**, a second gas heater **46**, a reaction chamber **47**, the diaphragm **49**, and the gas exist slit **410**. The reaction chamber **47** has a containing portion **48**. And, a substrate **43** for being deposited thereon is positioned at the lower part of the containing portion **48**.

The first gas heater **45** is positioned on the external side wall of the vertical tube **41**, and the second gas heater **46** is positioned at the external bottom wall of the vertical tube **41**. The reaction chamber **47** is located inside the vertical tube **41** and is a cylindrical reaction chamber. The diaphragm **49** is positioned on the top of the reaction chamber **47**, and the gas exist slit **410** is located on the internal side wail of the reaction chamber **47** with a particular distance from the substrate **43**. An extended diffusion layer **411** is formed between the gas exist slit **410** and the bottom of the reaction chamber **47**. The reaction chamber **47** is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrate **43** is a sapphire substrate.

The HVPE reactor of the preferred embodiment I of the present invention is used for depositing the thin film **412** on the substrate **43** by a reaction between the input reagent gas **42** and the substrate **43**. And, a reacted gas **44** is produced after the reaction. The reacted gas **44** can be exhausted through the gas exist slit **410**.

The input reagent gas **42** is a mixture of HCl, GaCl, NH_3, and Ar gases. The thin film **412** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The reacted gas **44** is a mixture of HCl, GaCl, NH_3, Ar, and H_2 gases. And, the second gas heater **46** is used for controlling the temperature difference between the substrate **43** and the internal side walls of the HVPE reactor.

On the other hand, the substrate **43** is not directly reacted with the input reagent gas **42**. The reaction is performed during the diffusion process of the input reagent gas **42** in the extended diffusion layer **411**. Meanwhile, the input reagent gas **42** is still in a gas state during the diffusion process. Because the second gas heater **46** can be used to control the temperature difference between the internal side walls of the HVPE reactor and the substrate **43**, no deposition will be formed on the internal side walls of the HVPE reactor.

Therefore, the advantages of the reactor according to the preferred embodiment I includes that it is not necessary to seal up the first gas heater **45** and the second gas heater **46**, because they are not directly exposed to the input reagent

gas **42** and the reacted gas **44**. As above, the HVPE reactor of the present invention has a significantly smaller volume than those of the prior reactors.

Please refer to FIG. **5**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment II of the present invention. As shown in FIG. **5**, the HVPE reactor includes a vertical tube **51**, a first gas heater **55**, a second gas heater **56**, a reaction chamber **57**, the diaphragm **59**, and the gas exist slit **510**. The reaction chamber **57** includes a containing portion **58**. And, a substrate **53** for being deposited thereon is positioned at the lower part of the containing portion **58**.

The first gas heater **55** is positioned in the vertical tube **51**. The second gas heater **56** is positioned at the external bottom wall of the vertical tube **51**. The reaction chamber **57** is located inside the vertical tube **51** and is a cylindrical reaction chamber. The diaphragm **59** is positioned on the top of the reaction chamber **57**, and the gas exist slit **510** is located on the side wall of the reaction chamber **57** with a particular distance from the substrate **53**. An extended diffusion layer **511** is formed from the gas exist slit **510** to the bottom of the reaction chamber **57**. The reaction chamber **57** is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrate **53** is a sapphire substrate.

The HVPE reactor of the preferred embodiment II is used for depositing a thin film **512** on the substrate **53** by a reaction between the input reagent gas **52** and the substrate **53**. And, the reacted gas **54** is produced after the reaction. The reacted gas **54** can be exhausted through the gas exist slit **510**.

The input reagent gas **52** is a mixture of HCl, GaCl, NH_3, and Ar gases. The thin film **512** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The reacted gas **54** is a mixture of HCl, GaCl, NH_3, Ar, and H_2 gases. And, the second gas heater **56** is used for controlling the temperature difference between the substrate **53** and the side walls of the HVPE reactor.

On the other hand, the substrate **53** is not directly reacted with the input reagent gas **52**. The reaction is performed during the diffusion process of the input reagent gas **52** in the extended diffusion layer **511**. Meanwhile, the input reagent gas **52** is still in a gas state during the diffusion process. Because the second gas heater **56** can be used to control the temperature difference between the side walls of the HVPE reactor and the substrate **53**, no deposition will be formed on the internal side walls of the HVPE reactor.

The first gas heater **55** is directly exposed to the reacted gas **54**, so that it is necessary to seal up the first gas heater **55** of the HVPE reactor of the preferred embodiment II of the present invention. Furthermore, the HVPE reactor according to the preferred embodiment II is more sensitive to the temperature change than the HVPE reactor of the preferred embodiment I.

Please refer to FIG. **6**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment III of the present invention. As shown in FIG. **6**, the HVPE reactor includes a vertical tube **61**, a first gas heater **65**, a second gas heater **66**, a reaction chamber **67**, the diaphragm **69**, and the gas exist slit **610**. The reaction chamber **67** includes a containing portion **68**. And, a substrate **63** for being deposited thereon is positioned at the lower part of the containing portion **68**.

The first gas heater **65** is positioned on the internal side wall of the vertical tube **61**. The second gas heater **66** is positioned at the external bottom wall of the vertical tube **61**. The reaction chamber **67** is located inside the vertical tube **61** and is a cylindrical reaction chamber. The diaphragm **69** is positioned on the top of the reaction chamber **67**, and the gas exist slit **610** is located on the side wall of the reaction chamber **67** with a particular distance from the substrate **63**. An extended diffusion layer **611** is formed from the gas exist slit **610** to the bottom of the reaction chamber **67**. The reaction chamber **67** is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrate **63** is a sapphire substrate.

Particularly, the second gas heater **66** includes an input gas tube **612** and an internal heater **613**. The input reagent gas **614** is heated by the internal heater **613** while being flown through the input gas tube **612**. A reacted gas **615** is formed after the heated input reagent gas flow **614** reacts with the substrate **63**. The input reagent gas **614** and the reacted gas **615** are oppositely directed and thermally coupled. Because the temperature of the substrate **63** directly depends on the heated input reagent gas **614**, the temperature of the substrate **63** can be changed quickly.

In addition, the HVPE reactor of the preferred embodiment III of the present invention is used for depositing a thin film **616** on the substrate **63** by a reaction between the input reagent gas **62** and the substrate **63**. A reacted gas **64** is produced after the reaction. The reacted gas flow **64** can be exhausted through the gas exist slit **610**.

The input reagent gas **62** is a mixture of HCl, GaCl, NH_3, and Ar gases. The thin film **616** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The reacted gas **64** is a mixture of HCl, GaCl, NH_3, Ar, and H_2 gases.

In the preferred embodiment III, the substrate **63** is not directly reacted with the input reagent gas **62**. The reaction is performed during the diffusion process of the input reagent gas **62** in the extended diffusion layer **611**. The input reagent gas **62** is still in a gas state during the diffusion process. The second gas heater **66** is used for controlling the temperature difference between the substrate **63** and the side walls of the reactor, so that no deposition will be formed on the internal side walls of the HVPE reactor.

The reactors of the preferred embodiments I, II, and III of the present invention are used for depositing a thin film on single substrate, so that they are not suitable for the mass production. On the other hand, the following reactors of the preferred embodiments IV and V of the present invention are suitable for the mass production of the substrates with thin films.

Please refer to FIG. **7**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment IV of the present invention. As shown in FIG. **7**, the HVPE reactor includes a vertical tube **71**, a first gas heater **75**, a second gas heater **76**, a reaction chamber **77**, the diaphragm **79**, and the gas exist slit **710**. The reaction chamber **77** includes a containing portion **78**. And, the substrates **73** for being deposited thereon are positioned at the lower part of the containing portion **78**.

The first gas heater **75** is positioned at the external side wall of the vertical tube **71**, and the second gas heater **76** is positioned on the external bottom wall of the vertical tube **71**. The reaction chamber **77** is located inside the vertical tube **71** and is a cylindrical reaction chamber. The diaphragm **79** is positioned on the top of the reaction chamber **77**, and the gas exist slit **710** is located on the side wall of the reaction chamber **77** with a particular distance from the substrates **73**. An extended diffusion layer **711** is formed from the gas exist slit **710** to the bottom of the reaction chamber **77**. The reaction chamber **77** is made of a material

selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrates **73** are sapphire substrates.

The HVPE reactor of the preferred embodiment IV is used for depositing the thin film **712** on each of the substrates **73** by reactions between the input reagent gas **72** and the substrates **73**. A reacted gas **74** is produced after the reaction. The reacted gas **74** can be exhausted through the gas exist slit **710**.

The input reagent gas **72** is a mixture of HCl, GaCl, NH_3, and Ar gases. The thin film **712** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The reacted gas **74** is a mixture of HCl, GaCl, NH_3, Ar, and H_2 gases.

In the preferred embodiment IV, the substrates **73** are not directly reacted with the blowing of the input reagent gas **72**. The reactions are performed during the diffusion process of the input reagent gas **72** in the extended diffusion layer **711**. The input reagent gas **72** is still in a gas state during the diffusion process. The second gas heater **76** is used for controlling the temperature difference between the substrates **73** and the side walls of the HVPE reactor, so that no deposition will be formed on the internal side walls of the HVPE reactor.

Please refer to FIG. **8**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment V of the present invention. As shown in FIG. **8**, the HVPE reactor includes a vertical tube **81**, a plurality of first gas heaters **85**, a plurality of second gas heaters **86**, a plurality of reaction chambers **87**, the diaphragms **89**, and the gas exist slits **810**. Each of the reaction chambers **87** includes a containing portion **88**. And, each of the substrates **83** for being deposited thereon is positioned at the lower part of each containing portion **88**.

The first gas heaters **85** are positioned on the external side walls of the vertical tubes **81** respectively, and the second gas heaters **86** are positioned at the external bottom walls of the vertical tubes **81**. The reaction chambers **87** are respectively located inside the vertical tubes **81** and are cylindrical reaction chambers. The diaphragm **89** is positioned on a top of the reaction chamber **87**, and each gas exist slit **810** is located on the internal side wall of the reaction chamber **87** with a particular distance from the substrate **83**. A plurality of extended diffusion layers **811** are respectively formed from the gas exist slits **810** to the bottoms of the reaction chambers **87**. The reaction chambers **87** are made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrates **83** are sapphire substrates.

The HVPE reactor of the preferred embodiment V of the present invention is used for respectively depositing the thin film **812** on the substrate **83** by a reaction between the input reagent gas **82** and the substrate **83**, and, the reacted gas **84** is produced after the reaction. The reacted gas **84** can be exhausted through the gas exist slit **810**.

The input reagent gas **82** is a mixture of HCl, GaCl, NH_3, and Ar gases. The thin film **812** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The output reagent gas **84** is a mixture of HCl, GaCl, NH_3, Ar, and H_2 gases.

In the preferred embodiment V, the substrates **83** are not directly reacted with the input reagent gas **82**. The reaction is performed during the diffusion process of the input reagent gas **82** in the extended diffusion layers **811**. And, the input reagent gas **82** is still in a gas state during the diffusion process. The second gas heater **86** is used for controlling the temperature difference between the substrate **83** and the side walls of the HVPE reactor, so that no deposition will be formed on the internal side walls of the HVPE reactor.

The reactors of the preferred embodiments I, II, III, IV, and V are the main designs of the HVPE reactors in the present invention. The following reactor of the preferred embodiment VI is an extended reactor of the preferred embodiment I.

Please refer to FIG. **9**, which shows a structural diagram of a HVPE reactor according to the preferred embodiment VI of the present invention. As shown in FIG. **9**, the HVPE reactor includes a vertical tube **91**, a first gas heater **95**, a second gas heater **914**, a third gas heater **96**, a reaction chamber **97**, the second diaphragm **99**, the first diaphragms **912**, the gas exist slit **910**, the Ga tank **913**, and the water cooled flange **915**. The reaction chamber **97** includes a containing portion **98**. And, the substrate **93** for being deposited thereon is positioned at the lower part of the containing portion **98**.

The first gas heater **95** is positioned on one external side wall of the vertical tube **91**, the second gas heater **914** is positioned on another external side wall of the vertical tube **91**, and the third gas heater **96** is positioned at the external bottom wall of the vertical tube **91**. The reaction chamber **97** is located inside the vertical tube **91** and is a cylindrical reaction chamber. The second diaphragm **99** is positioned on the top of the reaction chamber **97** and upon the first diaphragms **912** staggeredly arranged along the side wall of the vertical tube **91**. The gas exist slit **910** is located on the internal side wall of the reaction chamber **97** with a particular distance from the substrate **93**. An extended diffusion layer **911** is formed from the gas exist slit **910** to the bottom of the reaction chamber **97**. The reaction chamber **97** is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics. The substrate **93** is a sapphire substrate.

The HVPE reactor of the preferred embodiment VI of the present invention is used for depositing the thin film **916** on the substrate **93** by a reaction between the input reagent gas and the substrate **93**. The reacted gas **94** is produced after the reaction. The reacted gas **94** can be exhausted through the gas exit slit **910**.

The input reagent gas is a mixture of a first gas containing NH_3 and Ar gases and a second gas containing HCl and GaCl gases. The thin film **916** is a compound semiconductor selected from a group consisting of III–V groups and their alloys, IV group and their alloys, and GaN. The reacted gas **94** is a mixture of HCl, GaCl, NH_3, Ar, and Ha gases. The first diaphragm **912** is for extending the flowing routes of the first gas **92** and the reacted gas **94**, and enhancing the thermal interaction between the first gas **92** and the reacted gas **94**. Furthermore, it is possible that the volume of the reactor can be effectively reduced by the design of first diaphragms **912**.

In the preferred embodiment VI, the substrate **93** is not directly reacted with the input reagent gas. The reaction is performed during the diffusion process of the input reagent gas in the extended diffusion layer **911**. The input reagent gas is still in a gas state during the diffusion process. The third gas heater **96** is used for controlling the temperature difference between the substrate **93** and the side walls of the HVPE reactor, so that no deposition will be formed on the internal side walls of the HVPE reactor.

As above-mentioned, the features of the HVPE reactors provided by the present invention include:

1. The reactor has a design of an input reagent gas flow and a reacted gas flow being oppositely directed and thermally coupled. The design makes the effect of the

gas heating improved effectively and allows a reactor with a smaller volume. Besides, with the ability of quick responding to the changes of the temperature and the reagent gas flowing rate, the HVPE reactors are potentially suitable for the growth of quantum well structures.
2. With the design of an extended diffusion layer, the input reagent gas flow can be reacted with the substrate in a gas state during the diffusion process, so that it is possible to enhance the utilization efficiency of the reagents and obtain a good growth uniformity of the thin film.
3. The external bottom gas heater of the HVPE reactors according to the present invention allows the control of the temperature difference between the substrate and the internal side wall of the reactor, so that no deposition is formed on the internal side walls of the HVPE reactor.
4. The reaction chamber of the present invention is a cylindrical chamber with high symmetry, so that it is easy to control the model of the deposition processes.

Thus, the advantages of the HVPE reactors provided by the present invention can be summarized as follows:

1. Good deposition uniformity.
2. High efficiency of gas reagent utilization.
3. Compact design.
4. Easily controlling and modeling the deposition processes due to the high symmetry.
5. Possibility of using low power heater.
6. Possibility of growing a QW structure.
7. Possibility of suppressing the deposition on side walls of the reactor.

While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention needs not be limited to the disclosed embodiment. On the contrary, it is intended, to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A reactor for depositing a thin film on a substrate through a reaction between an input gas and said substrate, wherein a reacted gas is produced after said reaction, comprising:

a vertical tube;

a reaction chamber located inside said vertical tube, wherein said substrate is located at a bottom of said reaction chamber;

a plurality of baffles staggeredly arranged along an inside wall of said vertical tube;

a plurality of heaters connected to side walls of said vertical tube for controlling a temperature difference between said substrate and walls of said reactor and improving a distribution of said input gas; and

a gas exit installed on said reaction chamber for exhausting said reacted gas; wherein an extended diffusion layer is formed from a bottom of said reaction chamber to said gas exit.

2. The reactor as claimed in claim **1**, wherein said reactor is a hydride vapor deposition reactor.

3. The reactor as claimed in claim **1**, wherein said gas exit is installed on a side wall of said reaction chamber.

4. The reactor as claimed in claim **1**, wherein said reactor is made of a material selected from a group consisting of steel, quartz, sapphire, and ceramics.

5. The reactor as claimed in claim **1**, wherein said input gas is a mixture of HCl, GaCl, NH_3, and Ar gases.

6. The reactor as claimed in claim **1**, wherein said substrate is a sapphire substrate.

7. The reactor as claimed in claim **1**, wherein said thin film is one compound selected from a group consisting of IV group and their alloys, III–V groups and their alloys, and GaN.

8. The reactor as claimed in claim **1**, wherein said reacted gas is a mixture of HCl, GaCl, Cl_2, NH_3, and H_2 gases.

9. The reactor as claimed in claim **1**, wherein further said extended diffusion layer is used for increasing a utility rate of said input gas and a deposition unity.

10. The reactor as claimed in claim **1**, wherein said plurality of heaters comprise a first gas heater and a second gas heater.

11. The reactor as claimed in claim **10**, wherein said first gas heater is one of an external side wall gas heater and an internal side wall gas heater.

12. The reactor as claimed in claim **10**, wherein said second gas heater is an external bottom gas heater.

13. The reactor as claimed in claim **10**, wherein said second gas heater comprises an input gas tube and a heater.

14. The reactor as claimed in claim **1**, wherein said reaction chamber is a cylindrical chamber.

15. The reactor as claimed in claim **1**, wherein said extended diffusion layer is used for transmitting said input gas to said substrate.

16. A hydride vapor deposition reactor for depositing a thin film on a substrate through a reaction between an input gas and said substrate, wherein a reacted gas is produced after said reaction, comprising:

a vertical tube with two side wall gas heaters and a bottom gas heater;

first baffles staggeredly located on an inside wall of said vertical tube for extending routes of a first gas and said reacted gas;

a reaction chamber located inside said vertical tube;

a second baffle located on a top of said reaction chamber;

a Ga tank located in said vertical tube and connected to a second gas;

wherein said first gas and second gas are mixed to form said input gas before passing through said second baffie; and

a gas exit installed on a side wall of said reaction chamber for exhausting said reacted gas.

17. The hydride vapor deposition reactor as claimed in claim **16**, wherein said thin film is one compound selected from a group consisting of III–V groups and their alloys, IV groups and their alloys, and GaN.

18. The hydride vapor deposition reactor as claimed in claim **16**, wherein said two side wall gas heaters are a first gas heater and a second gas heater respectively located on external side walls of said vertical tube.

* * * * *