

[54] **REACTION DEVICE FOR PYROLYTIC DEPOSITION OF SEMICONDUCTOR MATERIAL**[75] Inventors: **Herbert Sandmann**, Vaterstetten; **Wolfgang Dietze**, Munich; **Ulrich Rucha**, Munich; **Gerhard Barowski**, Munich, all of Germany[73] Assignee: **Siemens Aktiengesellschaft**, Berlin & Munich, Germany[22] Filed: **Nov. 20, 1974**[21] Appl. No.: **525,640**[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **118/5; 118/7; 118/10; 118/12; 118/49.1**[51] **Int. Cl.²** **C23C 13/08**[58] **Field of Search** 118/4, 5, 7, 8, 10, 12, 118/48-49.5, 50, 50.1; 117/106-107.2; 148/174, 175[56] **References Cited****UNITED STATES PATENTS**

2,854,226 9/1958 Cone..... 432/48 UX

3,293,074	12/1966	Nickl	156/49.5 X
3,391,270	7/1968	Harris et al.	219/48 X
3,460,816	8/1969	Miller	432/49.1 X
3,492,969	2/1970	Emeis	118/49.1
3,690,290	9/1972	Jarvela et al.	118/48
3,705,567	12/1972	Emels	118/49

Primary Examiner—Morris Kaplan*Attorney, Agent, or Firm*—Hill, Gross, Simpson, Van Santen, Steadman, Chiara & Simpson

[57]

ABSTRACT

A reaction device for the pyrolytic deposition of semiconductor material from a gaseous phase onto heated mandrel surfaces and which comprises a metallic base plate having openings therein for electrodes and gas conduits, a glass-like dome for resting on the base plate, a pressure-resistant housing encompassing the dome and base plate and a pressure-sensitive safety control device interconnected between the interior of the dome and/or the interior of the pressure-resistant housing for controlling the energy input to the electrodes within the dome and controlling the gaseous pressure within the dome and/or the pressure-resistant housing.

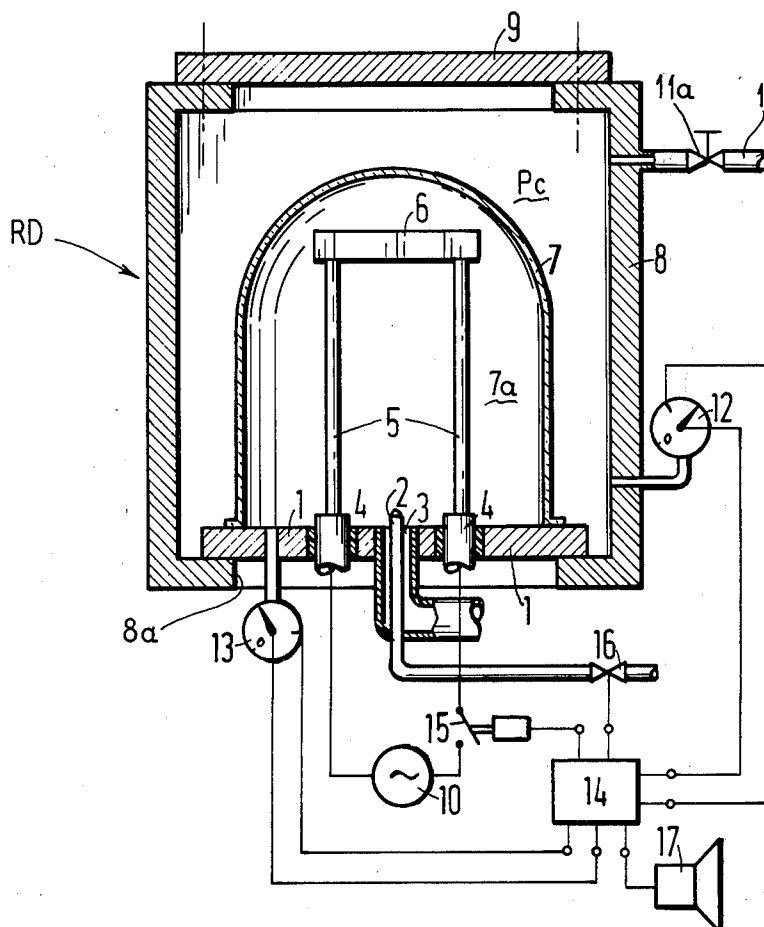
9 Claims, 3 Drawing Figures

Fig.1

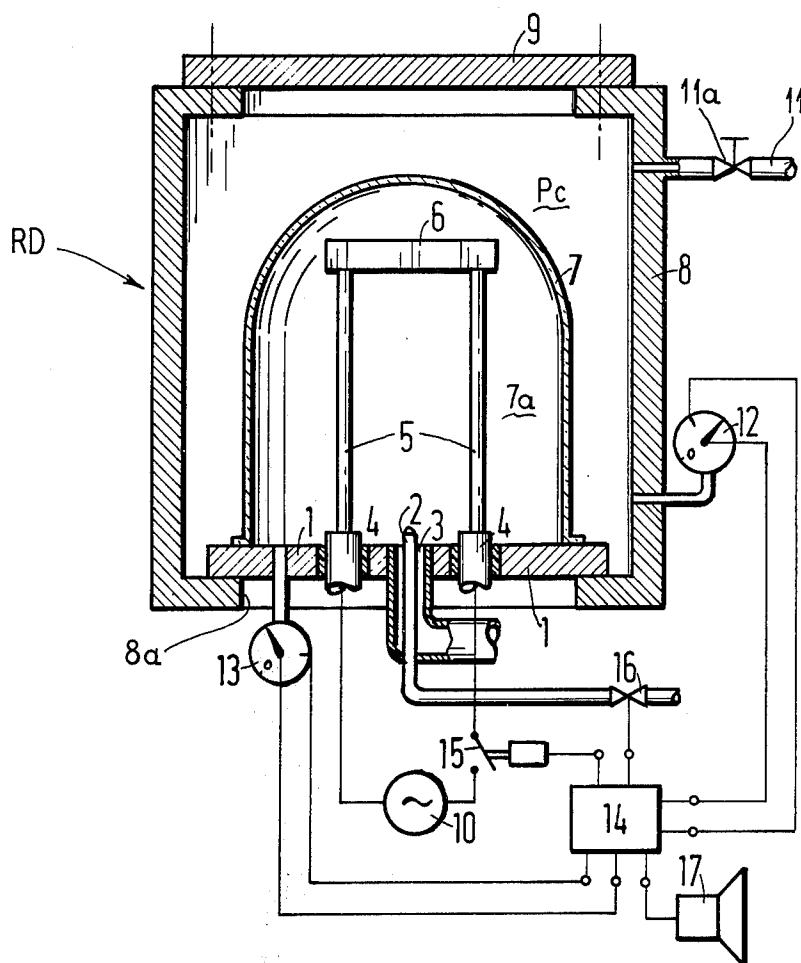


Fig.2

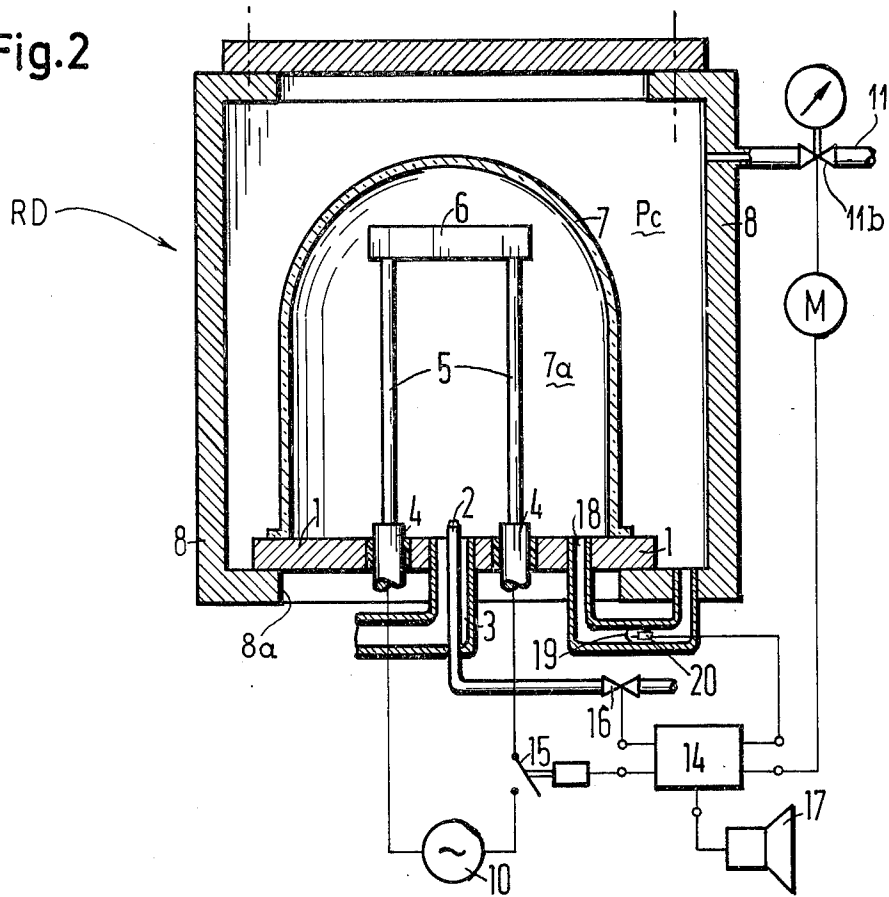
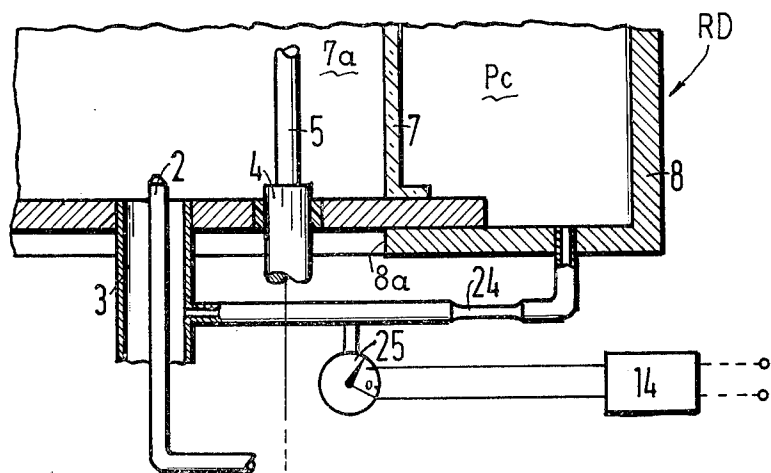


Fig.3



REACTION DEVICE FOR PYROLYTIC DEPOSITION OF SEMICONDUCTOR MATERIAL

CROSS-REFERENCE TO RELATED APPLICATION

Attention is directed to W. Dietze et al. U.S. Ser. No. 447,721, filed Mar. 4, 1974, assigned to the instant assignee and which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to production of semiconductor bodies by pyrolytic decomposition of gaseous semiconductor compounds on heated mandrels within a suitable environment and somewhat more particularly to an improved reaction device for use in such production.

2. Prior Art

Reaction devices for use in the production of semiconductor bodies, such as cylindrical silicon bodies from gaseous silicon compounds are known, for example, from German Pat. No. 1,198,787. Generally, such reaction devices comprise a quartz or glass dome mechanically sealed to an appropriate shaped base plate and include gas inlet and outlet conduits, electrodes and mandrels connected thereto. The electrodes pass through openings in the base plate and are electrically insulated therefrom. The mandrels may comprise parallel silicon or graphite rods mounted on the spaced-apart electrodes so as to extend into the dome. The upper ends of the mandrels are electrically interconnected with one another via a conductive bridge, such as composed of silicon or graphite. An electrical energy source is appropriately connected to the electrodes so that current flows through the electrodes and into the mandrels to heat them to a required reaction temperature. A reaction gas, for example, a mixture of silane and hydrogen, is fed at an appropriate rate into the dome and in contact with the heated mandrel surfaces. A semiconductor material, such as silicon, deposits from the gaseous phase and a shaped body thereof is formed about the mandrels.

U.S. Ser. No. 447,721, referred to earlier, describes an improved reaction device of this type wherein the dome and base plate are encompassed by a pressure-resistant housing having a pressurized inert gas therein for holding the dome onto the base plate without mechanical clamping or mounting means since such mechanical means tend to damage and/or break the dome. However, this type of reaction device fails to provide for any gas leakage between the interior dome and the interior of the pressure-resistant housing. Such gas leakage tends to damage the semiconductor bodies being produced and/or damage the heated mandrels.

SUMMARY OF THE INVENTION

The invention provides a reaction device which adequately holds a dome onto a base plate without mechanical means and includes a pressure-sensitive safety control device operationally interconnected therewith so as to shut off electrical current to the electrodes and regulate the gas pressure within the interior of the pressure-resistant housing and/or within the interior of the dome thereby preventing damage to the reaction device and/or the components therein.

In accordance with the principles of the invention, the pressure-sensing control means comprise a gas-pressure-sensing device in communication with the in-

terior of the dome and/or the interior of the pressure-resistant housing and is operationally coupled to a control means which receives an appropriate signal from the sensing device and regulates a supply of current to the electrodes and regulates a supply of reaction gas to the interior of the dome and/or the supply of inert gas to the interior of the pressure-resistant housing. An audio or visual alarm system may also be operationally coupled with the control means for activation upon receipt of the appropriate signal.

In certain embodiments of the invention, the gas-pressure-sensing device produces a signal to the control means when the pressure within one of the pressurized chambers in the reaction device decreases below a predetermined minimum value or increases above a predetermined maximum value for blocking the current to the electrodes and/or for blocking the supply of reaction gas to the interior of the dome and/or for activating the alarm system coupled to the control means.

In other embodiments of the invention, the gas-pressure-sensing device produces a signal to the control means when the difference between the pressure within the interior dome and the pressure within the pressure-resistant housing is outside a predetermined range for appropriately regulating the current and gas supplies and/or the alarm system as set forth above.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevated schematic view of an embodiment of a reaction device constructed and operable in accordance with the principles of the invention;

FIG. 2 is a somewhat similar view of another embodiment of the invention; and

FIG. 3 is a partial schematic view of yet another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, identical reference numerals are utilized throughout the various FIGURES to designate identical elements therein.

As shown in the drawings, a reaction device RD constructed and operable in accordance with the principles of the invention comprises a base plate 1, preferably composed of a metal such as silver, having a plurality of apertures therein for accommodation of a gas inlet conduit 2, a gas outlet conduit 3 (which in the embodiment shown are coaxially mounted so that the outlet conduit surrounds the inlet conduit), a pair of spaced-apart electrodes 4 which are insulated from one another and from the base plate 1. In the embodiment shown in FIG. 1, the base plate 1 also includes an aperture for a gas conduit of a manometer 12. Appropriate seals are provided at the various base plate apertures for rendering the base plate gas impermeable.

Two or more vertically extending substantially identical relatively thin mandrels 5, such as composed of silicon, are respectively mounted at their lower ends on the electrodes 4 in an electrically conductive relation therewith. A conductive bridge 6, composed of an electrically conductive and substantially inert material, such as graphite or silicon, is attached to the upper ends of the mandrels 5 so that electrical current can pass through the various mandrels and heat them to a select temperature. An operating current source 10 is electrically connected to the electrodes 4 via suitable electrical conduits with a switch means 15 therein for selectively shutting off the current to the electrodes.

When the current source is operating, current flows from one electrode through the mandrel mounted thereon via the bridge to the other mandrel and to the other electrode so as to heat the mandrels to a desired temperature.

A dome 7, composed of glass-like material such as quartz or glass, is positioned on the base plate 1 so as to encompass a reaction chamber 7a, which includes mandrels 5 therein.

In order to provide a safe reaction housing and to seal dome 7 to plate 1 in a gas impermeable manner, a pressure-resistant housing 8, such as a steel box, is positioned to encompass the reaction chamber 7a. The housing 8 has an apertured bottom 8a so that the various connections between the energy and gas conduits within the reaction chamber 7a can be appropriately connected to their respective supply sources. As shown, the base plate 1 partially overlaps the peripheral edges of the apertured bottom 8a of housing 8 so as to provide a gas-tight seal between the pressure chamber Pc inside the housing 8 and the exterior thereof. The upper area of housing 8 may be sealed with a gas impermeable closure member 9. The housing 8 is also provided with a gas conduit 11 having a valve means 11a, which may be electrically or manually activated for directing pressurized inert gas, such as nitrogen, argon, etc. from a source thereof (not shown) to the pressure chamber Pc.

Reaction gas inlet conduit 2 is provided with a valve means 16, which is preferably electrically activated for controlling the amount of a pressurized reaction gas, such as SiHCl_3 , SiCl_4 or SiH_4 mixed with a reduction gas such as H_2 being fed from a source thereof (not shown) to the reaction chamber 7a.

During operation, the mandrels 5 are heated in a reduction gas atmosphere supplied via conduit 2 by the electrical current from the operational current source 10 to the high temperature required (i.e. about 1100° to 1400° C.) for deposition of silicon or other semiconductor material and the actual reaction gas is then supplied to the incandescent mandrels.

The embodiment of the invention illustrated at FIG. 1 may include two manometers 12 and 13 which, in addition to sensing gas pressure, also function as electrical contacts. The contact manometer 12 monitors the pressure within the pressure chamber Pc of housing 8 and the contact manometer 13 monitors the pressure within the reaction chamber 7a. The contact manometer 12 is constructed so as to generate a signal for closing an electrical circuit that activates an automatic control means 14 when the pressure within chamber Pc decreases below a predetermined minimum value. The contact manometer 13 is similarly constructed so that it generates a signal activating the control means 14 when the pressure within the chamber 7a exceeds a predetermined maximum value.

Upon receipt of a signal from either manometer 12 or manometer 13, the automatic control means 14 is activated and performs the following functions:

- a. disconnects the operating current source 10 from the mandrels 5 by opening a switch means 15 in the electrical circuit between the current source and the mandrels;
- b. decreases and/or shuts off the supply of fresh reaction gas to the reaction chamber 7a by actuating the valve means 16, which may comprise a magnetically operable valve mechanism, within the gas

conduit between the reaction gas source and the chamber 7a; and

- c. actuates an alarm system 17 which may be an optical and/or an acoustical alarm system.

In another embodiment of the invention, an electrical contact-difference manometer which senses a difference between the pressure in chamber 7a and chamber Pc may be utilized to activate the automatic control means 14. An exemplary form of this embodiment is shown at FIG. 2. As shown, the reaction chamber 7a is in communication with the pressure chamber Pc via a bridging conduit 18. The bridging conduit 18 is provided with a gas impermeable elastic membrane 19 and a pressure-sensitive electronic element 20, such as a semiconductor element having a pn-junction, in operational relation with membrane 19 and in electrical communication with the automatic control means 14. Due to the elasticity of membrane 19, a change of pressure, for example, a decrease of pressure within chamber Pc below a predetermined minimum value, causes the membrane to press against the pressure-sensitive electronic element 20 with a sufficient force to produce a signal for activating the control means 14. A motor M may be operationally coupled to a suitable pressure regulating valve 11b and to the control means 14 so that upon activation of control means 14, the motor M is energized and adjusts the valve means 11b to increase the infeed of the pressure gas into chamber Pc.

Strictly speaking, the automatic control means 14 is activated in this embodiment as soon as the pressure difference between the chambers 7a and Pc drops below a predetermined minimum value.

In another embodiment of the invention (partially illustrated at FIG. 3), a connecting capillary conduit 24 is provided between the interior of dome 7 and the interior of housing 8. A sensitive gas flow member 25 is coupled with the capillary conduit 24 for controlling the flow of gas therethrough and is in electrical communication with control means 14. The flow member 15 not only controls the flow of gas but also functions as an electrical contact maker, i.e. it generates an electrical signal when the speed of gas flow through the capillary 24 exceeds a value beyond a predetermined absolute value. The signal generated activates the control means 14 to initiate corrective measures as explained hereinbefore. Since the speed of gas flow through the capillary is determined by the pressure difference between the two chambers, this embodiment of the invention becomes immediately understandable by those skilled in the art.

It is pointed out that the input opening of the capillary into the actual reaction chamber, i.e. the interior of dome 7, is advantageously located in or near the gas discharge conduit 3 so that the pressure gas, which may be nitrogen, cannot adversely affect the deposited semiconductor material within the reaction chamber. The diameter of the capillary 24 is of a sufficiently small size to allow a sensitive flow meter to control the leakage of gas through the capillary and yet minimize the loss of pressurized gas or reaction gas through such a capillary. Various flow rates or speed indicators may be substituted for the flow meter shown, for example, sensitive hot conductor elements (i.e. PTC resistor elements) or sensitive cold conductor elements which have a self-heating rate that changes in response to changes in the gas flow rates may be used. In instances where such temperature-sensitive conductor elements are utilized, it is advisable to periodically or continu-

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ously compensate for the leakage losses of the pressure gas over the capillary.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

We claim as our invention:

1. In a reaction device for the deposition of a semiconductor material onto a heated surface from a reaction gas having a gaseous compound of said semiconductor material therein, including a base plate having means for supporting at least one pair of spaced-apart mandrels which are electrically interconnected with an operational current source capable of heating said mandrels to a select temperature, a dome composed of a glass-like material and positioned in contact with said base plate so as to enclose a reaction chamber about said mandrels, means for supplying a pressurized reaction gas from a source thereof to said reaction chamber, a pressure-resistant container having a pressure chamber therein surrounding said dome and at least a portion of said base plate and a means for supplying a pressurized inert gas from a source thereof to said pressure chamber for applying a gas pressure onto said dome to hold said dome in a gas impermeable relation with said base plate; the improvement comprising:

a pressure-sensing control means operationally interconnected between said operational current source and said mandrels and between said pressure chamber and said means for supplying a pressurized reaction gas from a source thereof to said reaction chamber so that when the pressure within said pressure chamber drops below a predetermined minimum value said control means generate a signal to block the current flow to said mandrels and generate a signal to block the reaction gas flow to said reaction chamber.

2. In a reaction device as defined in claim 1 including an alarm system operationally interconnected with said control means, said alarm system being activated by a pressure-responsive signal generated by said control means.

3. In a reaction device as defined in claim 1 wherein said pressure-sensing control means includes a contact manometer which senses the gas pressure within said pressure chamber and generates an electronic signal in response thereto.

4. In a reaction device as defined in claim 1 wherein said pressure-sensing control means is also operationally interconnected between said reaction chamber and said means for supplying a pressurized reaction gas

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from a source thereof to said reaction chamber so that when the pressure within said reaction chamber increases above the predetermined maximum value said control means generates a signal to block the current flow to said mandrels and generates a signal to block the reaction gas flow to said reaction chamber.

5. In a reaction device as defined in claim 4 wherein said pressure-sensing control means includes a contact manometer which senses the gas pressure within said reaction chamber and generates an electronic signal in response thereto.

6. In a reaction device as defined in claim 1 wherein said pressure-sensing control means is also operationally interconnected between said pressure chamber and said reaction chamber so that when the difference in pressure between said chambers drops below a predetermined minimum value said control means generates a signal to block the current flow to said mandrels and generates a signal to block the reaction gas flow to said reaction chamber.

7. In a reaction device as defined in claim 6 including an elastic gas impermeable membrane and positioned in communication with said pressure chamber and said reaction chamber and a pressure-sensitive electronic signal generating element operationally coupled to said membrane and said pressure-sensing control means so that when the difference in pressure between said chambers drops below a predetermined minimum value said membrane exerts a pressure on said pressure-sensitive electronic signal generating element which generates a signal actuating said control means to block the current flow to said mandrels and to block the reaction gas flow to said reaction chamber.

8. In a reaction device as defined in claim 7 wherein said pressure-sensing control means is also operationally interconnected between said pressure chamber and said means for supplying a pressurized inert gas from a source thereof to said pressure chamber so that when the difference in pressure between said chambers exceeds a predetermined maximum value said membrane exerts a pressure on said pressure-sensitive electronic signal generating element which produces a signal actuating said control means to increase the inert gas flow to said pressure chamber.

9. In a reaction device as defined in claim 6 including a capillary interconnection between said reaction chamber and said pressure chamber and a flow meter operationally interconnected between said capillary and said control means capable of generating a signal when the speed of gas flow past said flow meter drops below a predetermined minimum value for activating said control means to block the current flow to said mandrels and to block the reaction gas flow to said reaction chamber.

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