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GAS DISCHARGE APPARATUS

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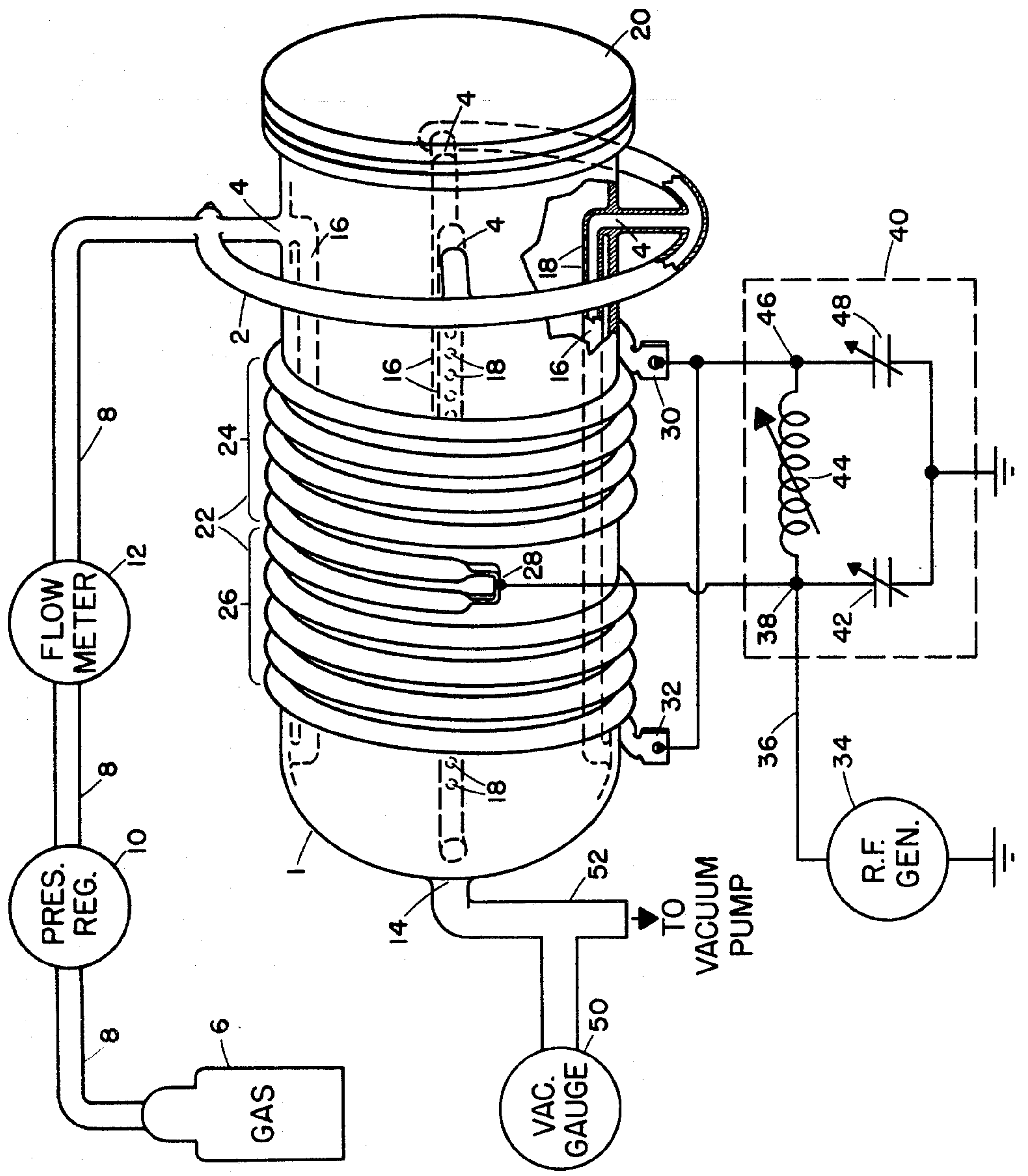


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# GAS DISCHARGE APPARATUS

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## ABSTRACT OF THE DISCLOSURE

The admission of a gas to a reaction chamber which has been previously evacuated, is followed by its activation via a high-frequency electromagnetic field formed by a composite coil surrounding a material-handling zone within the chamber. The activated gas reacts with material introduced into the chamber and is thereafter withdrawn, along with inactive gas and resultant gaseous byproducts, from the system. The construction of the chamber and the composite coil are such as to provide a substantially uniform distribution of gaseous excited species throughout the material-handling volume of the chamber.

## BACKGROUND OF THE INVENTION

This invention relates to gas discharge apparatus and, more particularly, it is concerned with an improved means for producing an electromagnetic field facilitating efficient and uniform conversions during heterogeneous (gas-solid) reactions.

In the co-pending application of Georges J. Gorin, Ser. No. 051,275, filed June 30, 1970 and now Pat. No. 3,619,-403, and entitled "Gas Reaction Apparatus," there is disclosed improved apparatus for including reactions between a material and activated (excited) species of a gas. As described therein, a gas is fed into a reaction chamber at a low pressure and is activated by means of an electromagnetic field formed about a conventionally-wound coil which envelops the material-handling zone of the chamber. During reaction with the activated gas stream (plasma) the material decomposes and/or volatilizes. The resultant byproducts together with unreacted species of the gas, are withdrawn from the chamber through an outlet port by means of a mechanical vacuum pump.

Gas reaction systems of the type described above are being used to great advantage in a variety of industrial processes including, for example, the process of manufacturing integrated circuit components from semiconductor substrates. Such systems provide an economical, safe, and rapid means for selectively removing exposed layers of organic material from predetermined areas during the various steps involved in the manufacturing process. However, a basic problem encountered with such systems to date has been their inability to render a sufficiently uinform distribution of reactive chemical conversions throughout a working zone that must accept the production loads of such substrates. Consequently, some of the semiconductor substrates are overexposed to the plasma environment causing failure of material and malfunctioning of the final product.

Accordingly, the general object of the present invention is to provide improved apparatus of the aforementioned character, whereby uniform heterogeneous reactions are accomplished throughout the material-handling zone of a reaction chamber.

## SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a gas discharge apparatus having a composite coil which surrounds the material-handling zone of a reaction chamber. The composite coil consists of two coil sections



whose respective coil turns are wound in opposite directions. A suitable RF energy source is coupled to the composite coil by means of an impedance matching network.

## DESCRIPTION OF PREFERRED EMBODIMENT

The novel features of the present invention, together with further objects and advantages, will become apparent from the following detailed description of a preferred embodiment of the invention and from the accompanying drawing to which the description refers.

The drawing is an illustration in diagrammatic form of a gas discharge system constructed in accordance with the principles of the present invention.

With reference to the drawing, it will be observed that reference numeral **1** designates a reaction chamber having an input manifold **2** whose outlets are coupled to four gas inlet ports **4** which are symmetrically disposed about the circumference of the chamber. A container **6** of molecular gas is coupled to the inlet of manifold **2** by way of a feedline **8** having inserted therein a pressure regulator valve **10** and an adjustable flow meter **12** for monitoring gaseous flow rates throughout the system. Gas is exhausted from the chamber via the gas outlet port **14**.

A portion of the reaction chamber **1** is shown broken away in the drawing to better illustrate one of the four gas diffusion tubes **16** which are fused to the gas inlet ports **4** and are symmetrically disposed along the inner wall of the chamber. Each of the tubes **16** has a plurality of holes **18** along its length which uniformly distribute the non-activated gas within the chamber.

Chamber **1** has an opening at one end for material to be inserted into or removed from its material-handling zone. This material may, for example, consist of a tray of semiconductor slices from which it is desired to etch away exposed portions of a silicon dioxide layer. The chamber's opening is provided with a closure in the form of a cap-like cover **20** which is fitted tightly over the opening after the material is inserted.

Surrounding the material-handling zone of the chamber **1** is a composite coil assembly **22** which is adapted to couple an electromagnetic field to the gas within the chamber. The composite coil **22** is a multiturn coil having a section **24** in which the coil turns are wound in a counterclockwise direction, as observed from the front of the chamber, and a section **26** in which the coil turns are wound in a clockwise direction as observed from the front of the chamber. The coil sections **24** and **26** meet at a common junction **28** and have free end terminals **30** and **32**, respectively.

An RF generator **34** has one output lead **36** connected to the input terminal **38** of an impedance matching network **40**, and its other output lead connected to a ground reference terminal. The matching network **40** includes a variable capacitor **42** connected between its input terminal **38** and ground, a variable inductor **44** connected between its input terminal **38** and its output terminal **46**, and a variable capacitor **48** connected between its output terminal **46** and the common ground. The junction **28** of the composite coil is connected to the input terminal **38** of the impedance matching network, while the end terminals **30** and **32** of the composite coil are each connected to the output terminal **46** of the impedance matching network. The outlet port **14** of the reaction chamber **1** is connected to a vacuum gauge **50**, which continually measures the pressure maintained within the chamber, and also to a mechanical vacuum pump (not shown) by way of exhaust line **52**.

In operation, the material to be plasma-treated is introduced into the material-handling zone of chamber **1** and the system is initially pumped down to a preset low-pressure level. The gas is then automatically admitted to the chamber via the diffusion tubes **16**, and the RF generator **34** is then enabled to deliver its energy. The coupling of RF energy into the gas is achieved by means of the matching network **40** and the composite coil **22** that surrounds the material-handling zone of the chamber. The power provided by generator **34** is preferably in the order of a few hundred watts continuous radiation at a frequency of approximately 13.5 mHz. The unique construction of the composite coil **22** is such that the electric fields produced by its coil sections **24** and **26** tend to produce a weak resultant electric field, whereas the associated magnetic fields tend to produce a reinforced resultant magnetic field. As a result, the excited species produced by the electromagnetic breakdown of the gas are uniformly distributed throughout the material-handling zone of the chamber and etching reactions occur more uniformly across the large axis of reaction **1**.

It is believed that moderation of electron energies coupled with a larger number of electrons sharing the same energy throughout the entire volume are the consequences of the resultant electric and magnetic fields. Presumably the electron energy distribution curve has been flattened and fewer electrons deactivate on the walls of the chamber. Volatile components produced by the various reactions, as well as unreacted and undissociated gas, are continuously removed from the chamber by action of the mechanical vacuum pump. The termination of the reaction process is marked by RF energy and gas supply cut off, followed by the evacuation of the chamber and associated flow lines from gaseous residuals prior to their being purged with air.

While there has been shown what is at present considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention.

What is claimed is:

**1.** Apparatus for reacting a gas with a material in the influence of an electromagnetic field comprising:

a reaction chamber adapted to contain said gas and said material,

a composite coil disposed about said reaction chamber, said composite coil having two joined coil sections whose respective coil turns are wound in opposite directions,



an RF source,

and means for coupling said RF source to said composite coil.

**2.** The apparatus of claim **1** wherein said reaction chamber has a generally cylindrical shape, a closure means at one end of said chamber to enable vacuum-tight operation, means for introducing a gas within said chamber, and means for with drawing the gas from said chamber.

**3.** The apparatus of claim **2** wherein said means for coupling said RF source to said composite coil comprises:

an impedance matching network having an input, an output, and a common terminal,

an inductance coupled between said input and said output terminals,

a capacitor connected between said input and said common terminal,

another capacitor connected between said output and said common terminal,

means for coupling said input terminal to the junction of said two coil sections,

means for coupling said output terminal to the free ends of said two coil sections,

and means for coupling said RF source between said input terminal and said common terminal.

**4.** The apparatus of claim **3** wherein said two coil sections have an equal number of coil turns.


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