PLASMA SOURCE

FIELD OF THE INVENTION

[0001] The present invention relates to a plasma source and in particular to a plasma source with reactive elements configured to be out of phase with one another so as to provide for controlled wavelength effects within the plasma process.

BACKGROUND

[0002] A plasma is an ionised gas that conducts electricity. In order to generate a plasma, an electrical field is applied to a contained gas, usually contained within a specifically designed chamber. In a vacuum chamber, where ions and electrons have long lifetimes, it is relatively easy to do this. Radio frequency (RF) power in the MHz range can be applied to two metal plates, or electrodes, immersed in the chamber, thereby creating a capacitive discharge. Alternatively, RF power may be deposited into a coil mounted on the chamber walls, thereby producing an inductively coupled plasma.

[0003] In the semiconductor industry, plasmas are used to deposit materials on and etch materials from workpieces that are typically semiconductor, dielectric and metal surfaces. This process is utilised so as to form specific electronic components on the substrate. A gas is introduced into a vacuum plasma processing chamber where the workpiece is located. The gas by undergoing an electrical breakdown forms a plasma in an excitation region using either an inductive source, where the antenna carries a current adjacent to the plasma window or a capacitive source which uses one (or more) electrode(s) with an oscillating voltage. Up until the early 1990's capacitive based systems were the preferred option but in the time period 1991 to 1995, inductive sources became more prevalent, and they continue to dominate in metal etch or poly etch applications. There are however problems with such inductive source plasmas in oxide etch applications. Furthermore, designs of inductive systems for oxide etch that provide the necessary performance and stability for manufacturing criteria results in the cost of an inductive based system being quite high.

[0004] Around 1998 the manufacturers of these systems, companies such as Lam Research Corporation and TEL started to refocus on capacitive systems so as to provide a cheaper and more reliable solution to the problems of plasma etching in this field. Further developments led to the reintroduction of capacitive systems at the expense of inductive systems. It is into this environment that dual frequency capacitive systems re-emerged as the preferred choice for oxide etch applications.

[0005] The reason for this trend towards dual frequency systems is that in a single frequency capacitive reactor, it is possible to increase the RF power to get higher ion bombardment energy, but the plasma density will also increase. These two parameters cannot be changed independently using a single frequency generator. In order to provide an additional degree of flexibility, more than one frequency of excitation of a capacitive plasma can be provided. A typical approach, such as that described in WO03015123, employs two separate power supplies (a high frequency supply and a low frequency supply), each attached to one electrode. Filtering is employed to minimize the interaction between the two signals, for example using an inductor that grounds the top electrode at a KHz signal, while appearing to be a high impedance for a MHz signal. Similarly, a capacitor is used to ground the lower electrode for high frequency signals. Alternative configurations include triode cr confined arrangements where the plasma is confined within a specific radial geometry and a further arrangement where both supplies are connected to the same electrode can also be employed. In all cases the substrate, and therefore necessarily the associated substrate handling components such as pins and lifters, coolants, sensors etc., are RF driven so coupling to the outside world needs to be sympathetic to those environments. This results in added engineering complexity—adding inevitably to cost.

[0006] To a fair approximation, in a dual frequency capacitive system the high frequency power controls the plasma density; due to the higher currents more efficient displacement current increasing the ohmic power into the plasma and sheath heating mechanisms. The low frequency excitation influences the ion bombardment energy. Therefore, the user has some ability to separately adjust the ion bombardment energy and the plasma density, which is not very easy with a single excitation frequency. Reactors of this design have found applications in both PECVD (plasma enhanced chemical vapor deposition) and plasma etching.

[0007] Despite these advances in reactor design a number of problems still exist. These include wavelength effects which introduce currents in the plasma parallel to the electrode surfaces, and under these conditions there is also non-uniform power deposition, which may be expected to produce non-uniform plasma density which degrades the performance of the plasma.

[0008] There is therefore a need to provide a plasma source which is configured to overcome these and other problems.

SUMMARY

[0009] These and other problems are addressed by a plasma source in accordance with the invention. Such a source, according to a first embodiment of the invention provides a plurality of adjacent electrodes, each electrode being out of phase relative to its adjacent neighbour.

[0010] The electrodes can be configured in any one of a plurality of different geometrical configurations including for example planar, hemispheric, dome, convex, concave and/or undulating. The electrodes could be provided so as to be in direct contact with the generated plasma. Using an arrangement in accordance with the present invention it is possible to control the relative centre to edge power deposition by modifying electrode spacings and/or power distribution design and/or the inclusion of active elements such as capacitors and/or inductors.

[0011] The invention therefore provides a plasma source according to claim **1** with advantageous embodiments being detailed in the dependent claims. The invention also provides a method of operating a source in accordance with claim **28** or **29**.

[0012] These and other features of the invention will now be described with reference to exemplary embodiments of the invention.