PLASMA DEPOSITION AND ETCHING REACTORS FOR SEMICONDUCTOR APPLICATIONS

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EXTENDED ABSTRACT

Numerous reactors for plasma deposition of inorganic (1) and organic (2) films and for plasma etching to clean substrates or delineate patterns (3) have been described in the literature. From the standpoint of the reactor itself, the only significant differences among these processes are the thermal treatment of the substrate, the nature of the gases used, and the vacuum pumping system required to accommodate the process gases safely and with adequate throughput.

In general there are two types of reactor used for semiconductor applications: tunnel and parallel-plate. Because of well-known problems with uniformity of etching or deposition in tunnel reactors(1,3), these devices are mainly employed for removal of organic resist materials.

In most parallel-plate reactors, the substrates upon which films are to be deposited or from which they are to be etched, are located on the electrode facing the powered electrode. However, for some etching processes (known variously as "reactive sputter etching" or "reactive ion etching") the substrates are attached to the powered electrode. Recently it has been shown that both configurations are essentially the same (4). Most commercial reactors are designed and operated in such a way as to cause the formation of very high plasma potential, leading to substantial ion bombardment of both electrodes and all other surfaces in contact with the discharge. These designs lead to some irreducible minimum substrate bombardment potential which is often higher than necessary for anisotropic etching or conformal coverage during deposition. These high levels of bombardment can lead to contamination and/or radiation damage during the processing of semiconductor devices. Electrically, the preferred reactor is designed much the same as a bias sputtering system; i.e., with relatively small electrodes that are independently powered.

The physical limit to scaling a parallel-plate reactor to very large sizes is the axial magnetic field generated by the current flowing in the discharge. This field leads to a pinching of the discharge toward the center of the electrode. However, this effect can be used to balance the consumption of reactive gas if the gas flow is radial (5) such that it is introduced about the perimeter of the electrodes and exhausted at the center. Gas flow and flow ratio controllers appear to be essential to achieve reproducible results.

Special attention must be given the vacuum pumping system used for these processes not only to ensure process quality, but also low maintenance and operator safety. Many of the gases involved are flammable, explosive, toxic, corrosive, poisonous, carcinogenic or some combination of these. To ensure minimum background gas contamination during processing and to prevent operator contact with these gases upon venting, a diffusion pump or some other kind of high vacuum pump should be employed to exhaust the system thoroughly both before processing and before venting.

Normally, rough vacuum pumps are used during the processing. The optimum combination of pumps appears to be a Roots blower (for high throughput) backed with a rotary mechanical pump and oil filter(6). In some deposition systems in which large quantities of particles can be generated it is sometimes necessary to include a porous filter between the blower and the process chamber. In all cases, the pump fluid should be chemically inert to all process gases, fragments thereof and to gases generated in the process. The most stable fluids appear to fluorochlorocarbons and perfluoro-polyethers. In general, hydrocarbon fluids do not stand up well and pose an explosion hazard when pumping strong oxidants.

When toxic or corrosive gases are pumped, the exhaust from the mechanical pump should be scrubbed. When flammable materials that produce colloidal dust upon burning (e.g., SiH_4) are pumped, adequate space must be provided in the exhaust to collect the dust, and provision made for safe removal of it from the exhaust to prevent cleaning personnel from contracting silicosis.

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