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FORMATION OF MICROWAVE DISCHARGE

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Annotation. Microwave plasma technology (MPT) is widely used in semiconductor processing. Development of constructions of devices that form microwave discharge leads to make processing more effective.

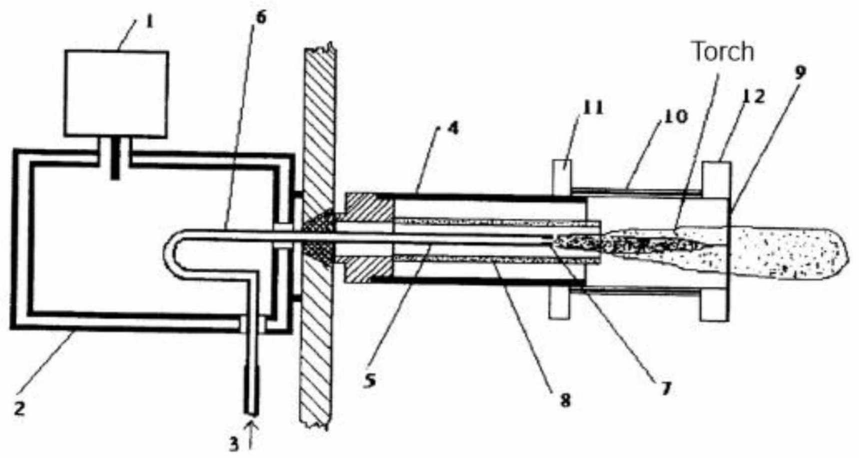
Keywords: microwave discharge, microwave plasma, plasmatron

Introduction. Microwave discharges are used in plasma chemistry, medicine, ecology, analytical chemistry, material processing [1]. In this article there is a description of microwave discharge, its formation and its role in technological process.

The main part. Today different types of microwave devices for generation microwave plasma are designed. Plasma properties depend on way of its formation. Microwave discharge benefits are simplicity of plasma obtaining, high level of plasma energy, wide range of air pressure [1]. In many semiconductor manufacturing processes, a plasma is used. An important point here is that the plasma is not heated. Therefore wafers, which were already metallized, can be processed in plasma processes [2].

There are features of microwave plasma: 1. Higher degree of ionization and decomposition. Higher sensitivity, detection limits down to the ppb level, and superior analytical efficiency for simultaneous measurement of multiple inorganic element concentrations in sample solutions. Microwave plasma atomic emission spectrometers offer superior detection limits compared to flame atomic absorption spectrometers; 2. The ratio of electron temperature and ion temperature to neutral gas temperature is very high, and the carrier gas maintains a suitable temperature. This property, in the case of vapor phase deposition, allows the temperature of the substrate not to be too high; 3. Maintain plasma at high air pressure; 4. There are no internal electrodes. There is no substance other than the working gas inside the plasma vessel. It is clean and free of contamination sources. The plasma generator can maintain a long lifetime; 5. Plasma can be confined in an agreed space using magnetic confinement. Microwave junctions and magnetic circuits can be compatible; 6. High safety factor. The high voltage source and plasma generator are isolated from each other, which is not possible with DC plasma. Microwave leakage is small and radiation safety standards are easily met. This is difficult to achieve with high-frequency induction plasma; 7. Microwave generators are stable and easy to control; 8. Microwave plasma, in many cases, is a relatively quiet plasma, not accompanied by high noise levels like DC discharges; 9. Low cost of use. Automatic operation eliminates the need for flammable or expensive gases, which significantly reduces operating costs; 10. Greater laboratory safety. Eliminates the risks associated with the use of flammable and oxidizing gases, the need to introduce multiple gases into the lab, or the manual handling and handling of cylinders [3].

Microwave plasma is a combination of microwave discharges generated by electromagnetic waves with frequencies exceeding 300 MHz. Plasma generators obtain microwave discharge. These devices are called plasmatrons and supply electromagnetic energy into the discharge volume [4]. The construction of microwave plasmatron is on the Figure 1.



1 – magnetron; 2 – resonator; 3 – gas supply system; 4 – external electrode; 5 – internal electrode; 6 – communication loop; 7 – nozzle; 8 – isolating tube; 9 – conductive cap; 10 – kernel; 11 – quartz tube; 12 – ring

Figure 1 – Construction of microwave plasmatron

Construction of microwave plasmatron consists of magnetron, waveguide resonator with tube filled with working gas. The microwave discharge is obtained in the tube forming the plasma torch. Construction also includes vacuum system and thin air elements [5].

One of the most important elements in plasmatron construction is a magnetron. The magnetron is a high-powered vacuum tube that works as a self-excited microwave oscillator. Crossed electron and magnetic fields are used in the magnetron to produce the high-power output required in radar equipment. These multi-cavity devices may be used in radar transmitters as either pulsed or CW oscillators at frequencies ranging from approximately 600 to 95,000 MHz. The relatively simple construction has the disadvantage that the magnetron usually can work only on a constructively fixed frequency [6]. The structure of the magnetron is on the Figure 2.

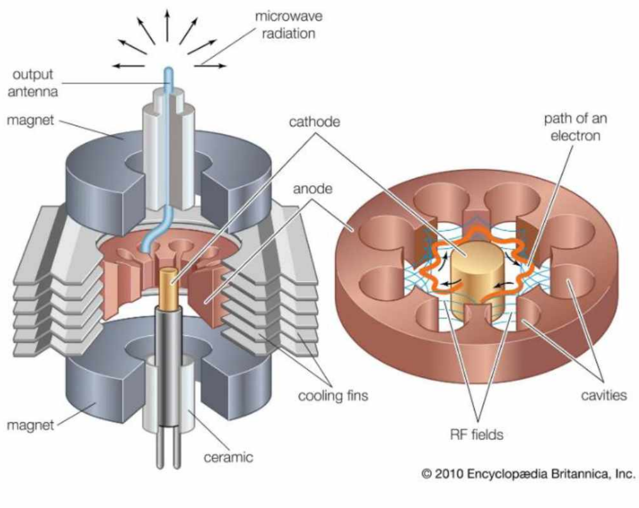


Figure 2 – Structure of magnetron

Microwave discharge is a result of the emergence of breakdown voltage and avalanche ionization of the plasma-forming gas (air, steam, inert gases, hydrogen, oxygen, etc.) as well as the formation of the plasma clot. An area of "plasma combustion" called a plasmoid is given the shape of a torch with the help of an organized flow of plasma-forming gas, which is deduced outside the plasmatron. Thus, a double effect is achieved including protection of the plasmatron from overheating as well as destruction making a powerful tool for application in intensive high-temperature impact on organic and inorganic substances [4].

The high temperature of plasma can provide a high enthalpy working medium to produce materials that cannot be obtained by conventional methods. It has the advantages of a controlled atmosphere, relatively simple equipment, and the ability to significantly shorten the process, so plasma technology has developed considerably.

The most common plasmas are electric arcs, neon, and fluorescent light-emitting gases, as well as lightning and auroras. With the development of science and technology, people have been able to generate plasma artificially by a variety of methods, resulting in widely used plasma technology [3].

A plasma in semiconductor technology is usually generated by high frequency voltage, for example, argon serves as a gas. The gas is located in a high-frequency field between two charged plates (electrodes) and here it is ionized. Electrons are necessary to strike out electrons from the argon atom's outer shells.

These initial electrons can be generated in different ways: 1. Electrons are emitted from a thermionic cathode; 2. By a very high voltage electrons can be pulled out from the negative electrode; 3. In each gas there always are temporarily free electrons by collisions of the particles.

Since the electrons are much lighter than the ions, they are immediately attracted to the positively charged electrode, and the heavy ions moving slowly to the negative electrode. Before they will achieve it, however, the polarity of the electrodes is reversed, the electrons are drawn to the other electrode and on their trajectory they will strike out more electrons from the atoms due to collisions. Typical frequencies for the plasma generation process is 13.56 MHz and 2.45 GHz, so the voltage across the electrodes will be reversed 13.56 million or 2.45 billion times per second.

The electrons are located mainly on the electrodes, while in between the positively charged ions, the plasma, oscillate back and forth, because they can not follow the rapid voltage changes.

The plasma production takes place under vacuum, the produced plasma is not heated, which is important for many processes. The plasma can be used in deposition, sputtering, etching or ion implantation. Due to the rapid oscillations of the positive ions in the high-frequency field they are very energetic. There are not only positive ions and free electrons in the plasma, as other particles are created by collisions: the condition of the plasma changes constantly. Electrons are captured by the ions partially and ejected again, these additional particles, however, do not play a matter in the further use of the plasma. The degree of ionization is 0.001-10%, depending on the particle density in the process chamber (10^8-10^{12} particles per cm^3); so the majority of the particles is unloaded [2].

Conclusion. Microwave discharge formation creates microwave plasma which has a number of features. These features are important for microelectronics production because taking into account these features the plasma chemistry equipment is being designed. Example of such equipment is microwave plasmatron which is meant to form plasma. The working principle of such appliance is described in this article. Thus, in the future by analyzing known constructional solutions of plasmatrons they will be modified in order to increase productivity and efficiency of semiconductor processing in production of microelectronics.

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