Reactive Ion Etching에서 Optical Emission Spectroscopy의 투과율과 강도를 이용한 에러 감지 기술 제안

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Relative Transmittance and Emission Intensity of Optical Emission Spectroscopy for Fault Detection Application of Reactive Ion Etching

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Abstract : This paper proposes that the relative transmittance and emission intensity measured via optical emission spectroscopy (OES) is a useful for fault detection of reactive ion etch process. With the increased requests for non-invasive as well as real-time plasma process monitoring for fault detection and classification (FDC), OES is suggested as a useful diagnostic tool that satisfies both of the requirements. Relative optical transmittance and emission intensity of oxygen plasma acquired from various process conditions are directly compared with the process variables, such as RF power, oxygen flow and chamber pressure. The changes of RF power and Pressure are linearly proportional to the emission intensity while the change of gas flow can be detected with the relative transmittance.

Key Words : Plasma, FDC, OES

1. Introduction

Plasma processing is an integral part of manufacturing, not only for the semiconductor industry, but also the microelectronics packaging industry [1]. As the oxygen plasma plays an important role in the etching, ashing and cleaning processes, oxygen plasma has been widely used in semiconductor manufacturing [2]. In the etch process using CHF_3,for example, the additive oxygen enhances the dissociation of fluorine atoms in CHF_3 plasma, resulting in increased etch rate for the substrate [3].

Among a number of efforts for closer investigation of plasma process, OES is recommended as one of the diagnostics tool for plasma process. OES has been applied to continuous monitoring of plasma condition [4]. *In-situ* plasma monitoring using OES has advantages of non-intrusive and real-time; however, it has been known that OES can only provide direct information of the concentration of exited species. Despite the known limitation, OES diagnostics also makes use of the fact that the radical density changes sharply on interface have been crossed during etching [5]. It is also capable to detect suspicious or shifted process by correlating the OES data and process condition [6]. In this research, OES is also proposed as a process diagnostic tool that may contribute to process fault detection and classification (FDC)by correlate the relative transmittance and emission intensity with process parameters.

2. Experiments

ICP-RIE, (*Miniplasma*™, manufactured by Plasmart, Korea) was employed in this experiment. The system consists of ICP plasma source (13.56 MHz, 1000 W) on both top module and CCP-RIE plasma source (13.56 MHz, 600 W) at bottom module. While the capacitively coupled plasma- reactive ion etch (CCP-RIE) was generated, optical emission spectroscopy system, mounted outside the view port, collected emission spectra.UV/VIS spectrometer was used for the acquisition of plasma optical emission spectra. The CCD detector based OES system provides the spectra range from 200nm to 1100nm, thus even outside the visible spectral range was detectable.UV/VIS spectrometer was used for the acquisition of plasma optical emission spectra. Plasma emission spectra scanned by OES was automatically stored in a local computer. (Figure 1.)

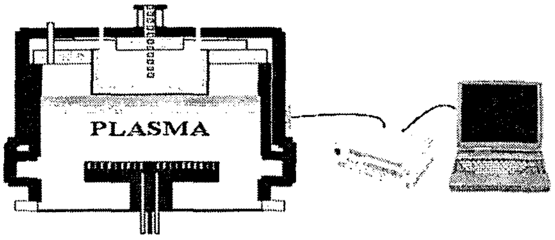

Figure 1. Plasma monitoring system

First of all, reference for the relative transmittance and emission intensity calculation was defined with the baseline. Once the plasma was turned on, we have waited for 5 seconds until the plasma state to be settled down, and spectrum measurement was continuously performed. No wafer was loaded in the chamber, but it was valuable to detect the change of the transmittance and intensity according to the pre-determined process shifts from the baseline. Three process parameters, O_2 flow rate, RF power, and Chamber pressure, were considered to change its value to see the sensitivity of the transmittance and intensity along the modification. The transmittance at pixel n is determined using the initially defined reference and dart data sets in the following equation:

$$T_n = 100 \times \left(\frac{\text{sample}_n - \text{dark}_n}{\text{ref}_n - \text{dark}_n} \right)$$

We have performed 9 to 11 experiments for each parameter, in total 30 experiments, and the baseline and the ranges of the modification is shown in Table 1.

3. Results

With the acquired OES data, we, first of all, performed statistical hypothesis testing for normality since the normality holds for further statistical analysis. From the Shapiro-Wilk test, the relative Transmittance clearly indicated the normality, but the emission intensity was unclear; however, we continued the graphical analysis for the relationships between the two parameters and process variables.

Figure 2 (a) and (b) clearly indicates that the emission intensity is linearly proportional to the change of RF power and Chamber pressure. This is not surprising sincethe increased intensity can be explained by delivered power and amount of collision. When more RF power is delivered to the system, it increases the number free radicals, so the photon counts can also be increased. In the same manner, with the increased process chamber pressure, molecular and/or atomic collisions are increased, so more photon counts are expected. What interesting fact in this experiment is that the average emission intensity collected over a period clearly shows the linear trend for both RF power and Chamber pressure. This is a good indicative that the average emission intensity can be readily utilized for detecting shifted process due to RF power and chamber pressure.

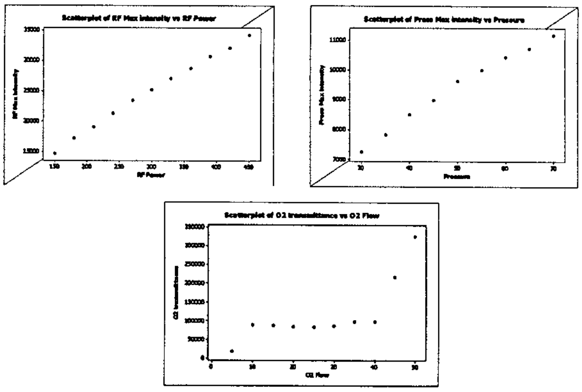

Figure 2. (a) Intensity of changed RF power (b) changed pressure (c) transmittance of changed oxygen flow

4. Summary

For the ultimate application to fault detection and classification (FDC) of reactive ion etch using optical emission spectroscopy in non-invasive and real-time fashion, the potential of relative transmittance and emission intensity have been primarily investigated. It is noticed that the RF power and chamber pressure is strongly showed the linear relationship with the averaged emission intensityover a period of time, and the amount of injected gas (oxygen) shows the positively proportional tendency to the relative transmittance. Further investigations with mixture gases, different type of plasma etch system, and even simultaneous change of process variables are required to draw a meaningful conclusion for the FDC application; however, we believe that the preliminary result is positive indication for the successful achievement of FDC for semiconductor industry.

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