Development of Eddy Current Sensor for End-point Detection in sub-Micron scale during Cu CMP

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INTRODUCTION

Chemical mechanical planarization (CMP) process has been applied to various manufacturing processes like dielectrics, semiconductors or display for substrate's global planarization. Only CMP method can achieve global planarization [1]. Among them, semiconductors have experienced numerous changes over the past 20 years, and this product has mainly led to changes in the industry. As the line width of semiconductor device becomes smaller and the design method of integrated circuits (IC) converts to stacking structure, CMP process's importance is emerging. CMP process aims to decrease roughness and remove steps. CMP process contains various components. Figure 1 shows the schematic of CMP process. As shown in figure 1, wafer mounted reversely under wafer head, and rotates on the pad and makes mechanical friction. Slurry abrasives induces chemical and mechanical planarization between pad and wafer surface [2].

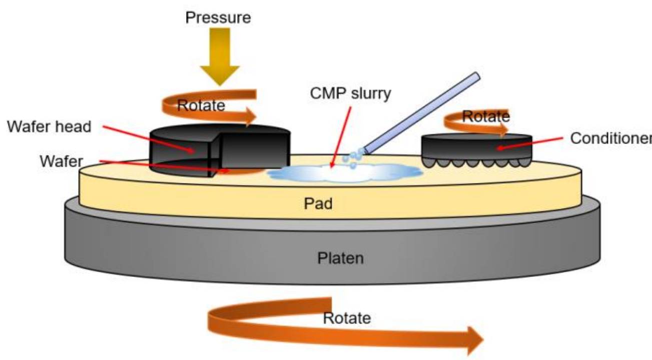

Fig.1 Schematic of CMP process and its consumables

CMP process can be largely divided into metal CMP process and non-metal CMP process. The main material of metal CMP are copper and tungsten. Copper was selected as an important component of large-scale integration circuit with the development of damascene process, due to its superior characteristics such as high electrical conductivity and low resistivity [3]. Copper CMP process is affected by numerous chemical and mechanical variables, such as chemical composition of slurry, process pressure and speed, temperature, slurry flow rate, abrasive shape and so on. Because of this complexity, process prediction is limited, so it is essential to monitor real-time process.

For monitoring CMP process, various methods have been used and the most widely used one is the end point detection (EPD) method [4]. Among various end point detection methods, the eddy current method has some advantages with comparing other methods like optic, friction force or using motor torque. Eddy current method has high repeat reproducibility, inexpensive and since it is non-contact measurement system, it never causes contamination or defect on wafer. In addition, this method can propose the absolute thickness value of metal film. Eddy current EPD method is performed by measuring the amount of eddy current which changes according to the change in thickness of metal films. However, when the thickness of metal film becomes thinner, the signal does not form accurately, and thus the measurement of thickness is limited [5]. This study aims to improve the performance of eddy current sensors and amplify the measurement range for accurate measurement of EPD, a real-time CMP process monitoring technology.

MEASUREMENT SYSTEM

In this study, copper film measurement system based on eddy current method has been developed. System consists of the eddy current sensor, software, signal processing and OP-AMP module. Figure 2 shows the diagram of the configured circuit system. The system was configured to measure the analog data received from the sensor and monitor the data with the local PC in real time. Analog data measured from the sensor goes through OP-AMP for the first time. The data entered the operational amplifier (OP-AMP) amplifies to specific value. The amplified value is then transmitted to analog to digital converter (ADC) and changed to a discrete digital signal. This inverted discrete digital signal undergoes a signal filtering process to increase the signal to noise ratio (SNR). Thereafter, it is encoded as utf-8 language and displayed through a serial receiver which is programmed is local PC.

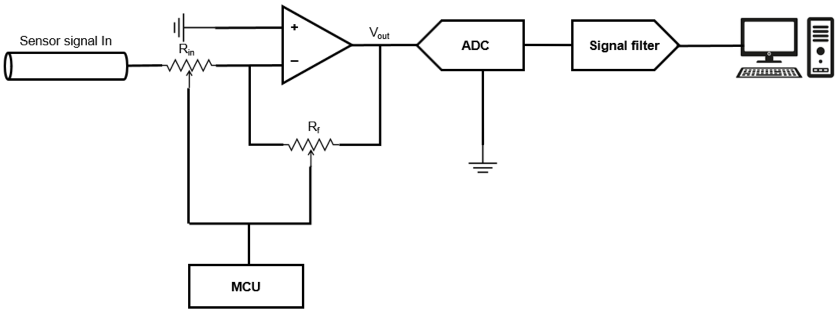

Fig.2 Diagram of the configured circuit system

Serial receiver is designed for real-time serial peripheral interface (SPI) communication between the PC and micro control unit (MCU). SPI communication technique was used for two-way communication of signals. Python language was adopted as a programming language in consideration of more diverse functions of interface, smooth interpretation of utf-8 language, and the versatility of program. Comport or Baud rate is set in the user interface (UI) to facilitate matching with MCU. It can also open, pause, or block communications within the UI. It includes the plotting display window where the data plot is uploaded in real time and the window where the serial text value is displayed. Data uploaded in real time may be converted into a text file and stored. Various functions such as performing Fast Fourier Transform on a data or exporting a graph image were added. Toolbox PyQt ver.5 was used for design UI.UI interface is shown in figure 3. Program was created as an .exe file and ready to be file.

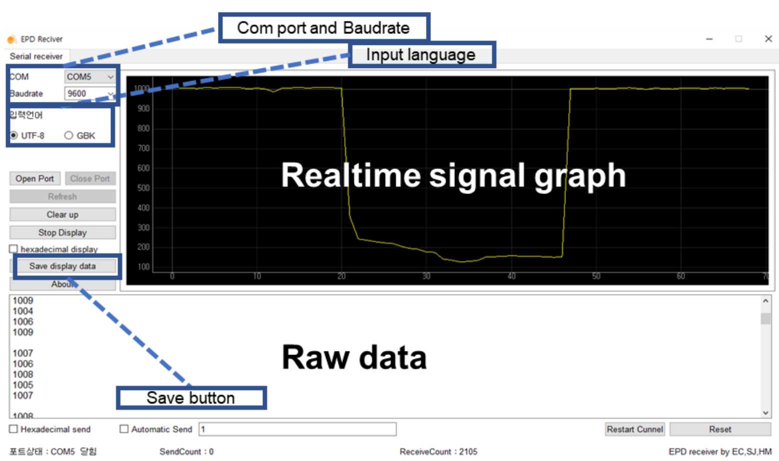

Fig.3 Real-time serial receiving measurement program UI

RESULTS & DISCUSSIONS

Two major problems were found in the designed system. the first was that the resolution of the signal was very poor, and the second one was short measurement range, about 3000Å. To solve this problem, two solutions were introduced.

First, a digital signal processing technique was used to increase the resolution of the signal. Digital signal processing is the most representative method for improve the signal to noise ratio (SNR) [6]. Digital signal processing basically increase the resolution of the system, but a time delay inevitably follows. Various filters were tested and applied to achieve high resolution and low time delay at the same time. Since raw data's quality was too poor, the first data rinse was performed with a moving average filter optimized with low number of windows, and then signal processing was performed through 1-D Kalman filter. In the case of the Kalman filter, since the quality of the initial signal greatly affects the output data, this process has been performed. The results of the filtered data and the results using the single signal processing technique are shown in figure 4.

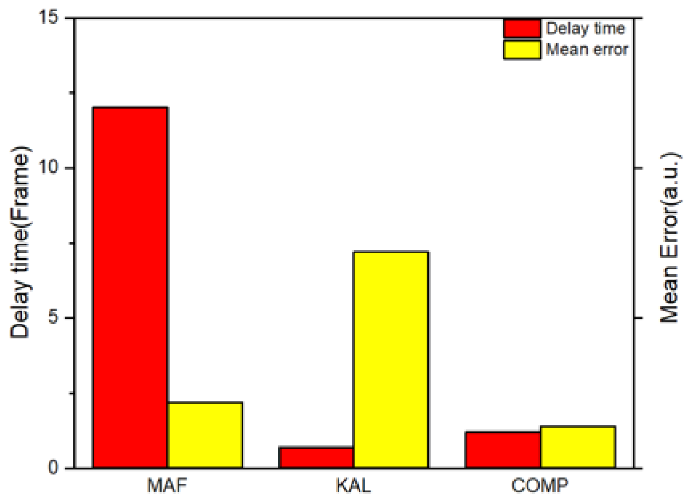

Fig.4 Comparison of filtered signal's delay time and mean error value

Second, a voltage amplification method was used to amplify the measurement range of the signal. According to Lorentz's law, the magnitude of the signal is proportional to the magnitude of the magnetic field, current, and length of conductor. Because the type of sensor is fixed and the length is clearly limited due to the EPD window, the current is changed. It was found that when the current is changed, the measured measurement range is shifted. Based on this phenomenon, we manufactured a module containing a digital potentiometer capable of arbitrarily changing the amplification value of OP-AMP. Through this, we changed the current to expand the measurement range, and such a system can be controlled by local pc. Through these results, we have improved the resolution by 20 times. The measuring range was amplified in the range of 7000Å ~ 550Å. Figure 5 shows the final measurement range to which the optimal system is applied.

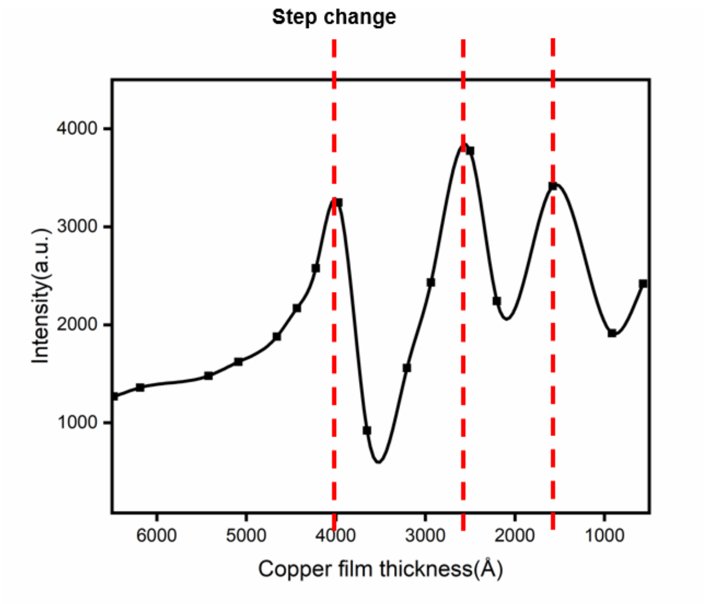

Fig.5 Optimized measurement range by EPD system

CONCLUSIONS

The measurement accuracy of the sensor was improved by about 18 times compared to that of the existing sensor, and through this, we were able to measure the thin film quality at a highly reliable level. In addition, the measurement range was also improved to 7000Å ~ 550Å. We developed a new filter that combines Kalman filter and moving average filter for digital signal processing. Through this, the time delay due to signal processing was minimized, and the measurement accuracy was significantly improved. In addition, an automation system that continuously changes the measurement range using the OP-AMP system and digital variable resistance was constructed. All measurements were taken based on the thickness of the EPD window used in the industry, 1.5mm.

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