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Non-contact monitoring of wafer temperature in plasma processing by using optical interferometer
光干渉計を用いたプラズマプロセス中の非接触ウエハ温度モニタリング

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In order to control the processing such as plasma etching and plasma enhanced chemical vapor deposition precisely, the temperature of Si substrate was monitored with non-contact by optical low coherence interferometry. We demonstrated the real-time monitoring of the temperatures of a Si wafer in capacitively coupled plasmas. The response of the low-coherence interferometry was faster than that of a fluorescence temperature sensor, and the low-coherence interferometry enabled the monitoring of the actual temperature during plasma processing.

1. Introduction

Various plasma processing technologies such as the plasma etching and plasma enhanced chemical vapor deposition (PECVD) have been used for the fabrication of semiconductor devices. Control of the temperature of the wafer in various plasma processing technologies is important to process with high-preciseness [1, 2]. However, contact measurements such as thermo-couples and fluorescent temperature sensor cannot measure the accurate temperature in low pressure due to poor thermal conductance. To solve this problem, we have performed non-contact temperature and thickness measurement of substrate by using time domain low coherence interferometer [3, 4]. This system has been experimentally performed to measure an accurate wafer temperature in plasma processing [5]. However, the measurement time depends the scan time of the reference mirror. Moreover the vibration noise of the scanning reference mirror reduces the accuracy of temperature measurement. In order to achieve the real-time monitoring of the temperature, it is required that the measurement speed improve to be about 1 msec. We focused on frequency domain low coherence interferometer to improve more accuracy and simplify the interferometer of optical sysytem [6]. The Cross-Correlation Type (CCT) using frequency domain low coherence interferometer measures the optical path length of wafer from cross-correlation terms which shows interferences between the reference arm and the sample arm by the inverse Fourier transform of spectral interferogram. On the other hand, the Auto-Correlation Type (ACT) without a reference

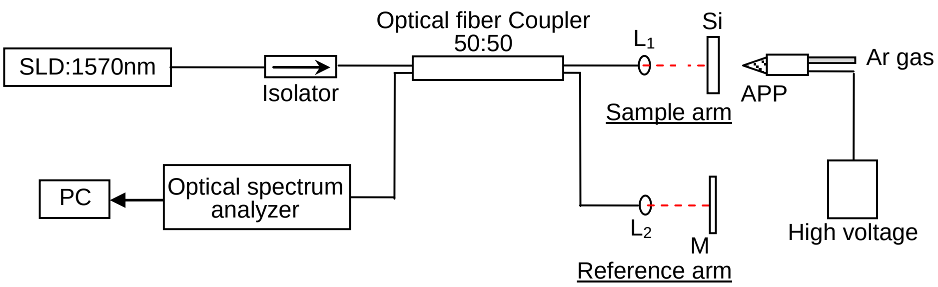

Fig. 1. Optical system for temperature measurement.
APP:Atmospheric Pressure Plasma. M:Mirror. L:Lens

mirror can be used for Si wafer which has high reflectivity of the surface and is expected to improve the measurement accuracy and time. We report the temperature measurement of Si wafer using ACT. We have demonstrated the temperature measurement of Si wafer during the treatment of atmospheric pressure plasma by ACT.

2. Experimental

The setup for the measurement system of frequency domain low coherence interferometer is shown in Figure 1. Temperature measurement using ACT was performed without the reference arm. SLD (Super luminescent diode; center wavelength: 1570 nm, spectral width: 38 nm) was used as the low coherence light source. This system can monitor the temperature by measuring optical path length of Si wafer that depends on temperature. The optical path length of Si wafer was deduced from the position of interferences which were obtained by the inverse Fourier transform of the spectral interferogram. The spectral interferogram was measured by the optical spectrum analyzer which spectral range and wavelength resolution were 1520~1620 nm and 0.065 nm, respectively.

3. Results

Figure 2 shows the spectral interferogram of CCT at room temperature. Figure 3 shows the inverse Fourier transform of the spectral interferogram of Figure 2. The correlation signals of ACT appeared at optical path length of 0 and 5593 μm and those of the CCT appeared at 484 μm and 6077 μm, which are interferences at the top and the bottom of Si wafer, respectively. The optical path length of Si wafer is equivalent to be the interval of the peaks of CCT [Fig.3. (a)] or ACT [Fig.3. (b)]. The relation between the temperature of Si (780μm) and the optical path length was derived from the experiment using furnace and described as follows

$$T = -1.6\times10^{-2}L^{2} + 9.4\times10L - 1.4\times10^{5} \quad (1)$$

were T (°C) and L (μm) is the temperature and the optical path length, respectively. The standard deviations of the optical path length of CCT and ACT were 92 nm and 7 nm at room temperature, which were equivalent to be 0.52 °C and 0.04 °C in temperature. It is found that ACT improved the measurement accuracy in addition to simplify the optical system.

The temperature measurement of Si wafer by ACT was performed during the plasma treatment by using atmospheric pressure plasma. Argon gas was flowed with 3 L/min between the two electrodes and the plasma was generated by applying a high voltage. Figure 4 shows time evolution of Si wafer temperature measured by ACT and thermocouple. The temperature was successfully measured by using ACT during plasma processing.

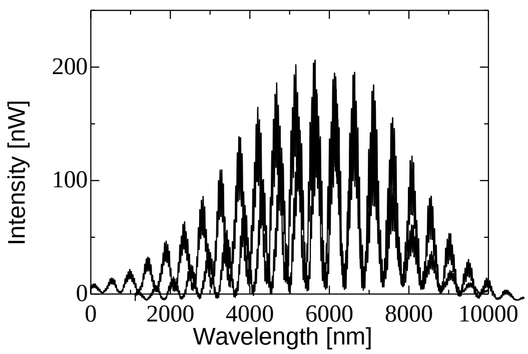

Fig. 2. the spectral interferograms(CCT).

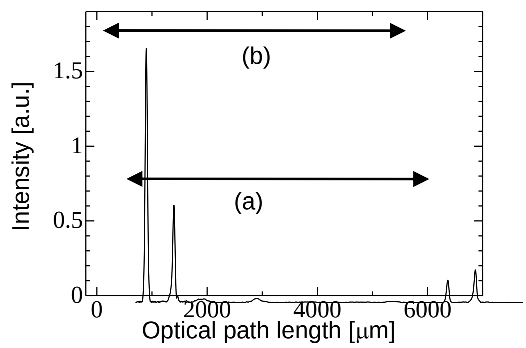

Fig. 3. the inverse fourier transforms of the spectral interferograms. Optical path length of Si for CCT(a) and ACT(b).

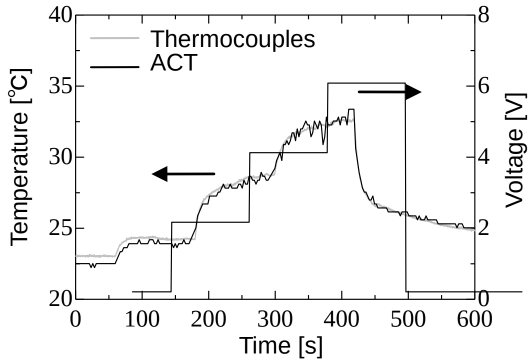

Fig. 4. time evolution of Si wafer temperature measured by ACT and thermocouple

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