（様式乙 1-3-2）

# THE SUMMARY OF Ph.D. DISSERTATION

| | | |
|---|---|---|
| School of Integrated Design Engineering | Doctor Identification Number | TAKETOSHI, Naoyuki |

Title

## Thermophysical Property Measurements of Thin Films Using a Picosecond Thermoreflectance Technique

**Abstract**

Thermal design is important in advanced industries such as optical disks or semiconductor devices. In order to do the thermal design, reliable thermophysical properties of submicrometer thin films are necessary. However, there are few quantitative data of thin film thermophysical properties because thermophysical property measurements of thin films are more difficult than those of bulk materials. In order to measure thermal diffusivities of submicrometer thin films, a picosecond thermoreflectance measurement system has been developed.

Chapter 1 summarizes the background and the previous studies.

Chapter 2 describes principles of the picosecond thermoreflectance method. A thin film is heated by picosecond pump laser pulses and the temperature change of the film surface is detected by the other picosecond probe laser pulses reflected by the thin film. In the previous studies, both the pump laser pulses and the probe laser pulses were focused on the same area of the film surface and the thermal diffusivity of the thin film was calculated from the time constant of the temperature decrease after the pulse heating (Front heating Front detection (FF) method). Instead of the FF method, the Rear heating Front detection (RF) method is proposed. The pump laser pulses are focused on a film surface of a transparent substrate side and the temperature change on the film surface opposite to the heat area is detected by the probe laser pulses. This RF type configuration is similar to the configuration of the laser flash method for bulk materials. The thermal diffusivity of the thin film is calculated from the heat diffusion time across the thin film.

Chapter 3 describes the measurement system.

Chapter 4 describes the thermoreflectance signals of metal thin films. Thickness dependence of the thermoreflectance signals for aluminum thin films on glass substrates were observed with the “FF” method. Thermoreflectance signals of metal thin films of nominal 100 nm thick on glass substrates were observed with the “RF” method for the first time in the world. The thermal energy transfer across the thin films at room temperature is dominated by diffusion process.

Chapter 5 describes a new detection technique using signal phase instead of signal amplitude synchronized with the modulation frequency of the heating beam. The change of the signal phase is proportional to the temperature rise by pulse heating and free from intensity fluctuation of both the pump beam and the probe beam. The principles of this detection technique can be explained from spontaneously generated reference signal by the repetitive pump laser pulses.

Chapter 6 describes a new picosecond thermoreflectance measurement system. In this system, temperature history curve of the film surface is obtained by changing the delay of the probe pulse to the pump pulse electrically. The observable time scale is much larger than the repetition period of the picosecond pulse laser.

Chapter 7 describes factors of uncertainties for thermal diffusivity measurements by the developed picosecond thermoreflectance measurement system.

Chapter 8 describes thermal diffusivities of molybdenum thin films synthesized by different sputtering condition. Thermal diffusivity measurements of the Mo thin films and observation of their structure by XRD, SEM, and TEM reveal that the nano-scale heat transfer depends on crystal size of the thin films.

Chapter 9 summarizes the results of this study.