SUMMARY OF Ph.D. DISSERTATION

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Title

Experimental Study on Non-contact and Real-time Sensing Technique for Thermal Diffusivity in Micro-scale Area

Abstract

Thermal diffusivity is one of the important thermophysical properties, and reflects an internal change of structure in a material. It is difficult for conventional measurement techniques of thermal diffusivity to be applied to dynamic measurements of the material during the transient process. Application to an elucidation of a transient mechanism of heat transfer and to a real-time control on heat conduction of a material can be realized by the time-resolved sensing technique for the thermal diffusivity. Since properties of polymer, gel, or liquid crystal, are especially characterized in micro-scale region, it is important to measure the thermal diffusivity in the scale with non-contact manner and in real-time. The purpose of this thesis is to propose and verify a measurement concept of the real-time thermal-diffusivity sensing through the development of a non-contact, real-time sensing technique for the thermal diffusivity in micro-scale area.

Chapter 1 explains significance and potential of the real-time thermal diffusivity measurement. Objective of this study is described through comparisons and theoretical considerations of conventional measurement techniques of thermal diffusivity.

Chapter 2 describes the principle of the forced Rayleigh scattering method, which is based on a transient thermal grating by an interference of laser beams and a diffraction phenomenon. Through several theoretical considerations of systematic uncertainty factors and of certain problems caused in the case of real-time application; i.e., time resolution of real-time sensing, and effect of property change in a timescale of a measurement on analysis result, the applicability of this method for the real-time measurement of thermal diffusivity in micro-scale region is clarified.

Chapter 3 gives the detail explanations about the development of the real-time sensing system for thermal diffusivity. The system utilizes a transient thermal grating with the period of 20~50 μm by an infrared laser and can conduct continual measurements with 10 ms time resolution in non-contact manner. Also, verification of the soundness of this system is also mentioned.

Chapter 4 elaborates on the application of the developed sensing system for structural changes in heat- and light- responsive materials. Dynamic behaviors in thermal diffusivity of a polysaccharide, a thermo-responsive polymer gel, and a light-curing resin during changing process were measured. The results demonstrate the validity of this system to an analytical instrument for the internal structural change and to become an essential tool to develop and design stimuli-responsive intelligent materials.

Chapter 5 describes the application to anisotropy control in thermal diffusivity of a liquid crystal by electric field. Homogeneous alignment of liquid crystalline molecules clearly indicates anisotropic thermal diffusivity, and the anisotropy can be controlled by adjusting the electric field. Potential of microstructure control by feedback scheme using real-time information of thermal diffusivity is illustrated.

Finally, the results of this study are summarized in chapter 6. Validity and potential of the non-contact and real-time sensing for thermal diffusivity in micro-scale area are confirmed.