Xenon Flash Thermal Diffusivity Measurement System “TD-1 series”

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1. Introduction

Due to increasingly downsized and sophisticated electronic parts and related products, devices mounted on small substrates may generate a large amount of heat during operation and result in unstable circuit operation. To assure stable circuit operation, it is very important to improve the thermal resistance of devices and the heat dissipation performance of devices and mounted on substrates. To improve thermal resistance and heat dissipation performance of devices and parts that compose populated boards, it is essential to evaluate the thermophysical properties of materials of these devices and radiation sheets. By optimizing the thermal design of the materials, it shall be possible to further downsize mounted on substrates.

Figure 1 shows the thermal conductivities of major materials. Generally, thermal conductivity of metals have higher values. On the other hands, polymer materials have lower one. Ceramics have the middle values between metal and polymer materials. Composite materials, such as high-function films made by adding ceramic particles to polymers, have been developed in recent years.

ULVAC-RIKO has developed thermal conductivity measurement systems utilizing the laser flash method. These systems apply high energy to samples and can be used with many materials. However, general polymer materials have low thermal conductivities and their properties vary at low temperatures. There have been concerns that the high energy of laser irradiation may damage polymer materials and thereby affect measurements. ULVAC-RIKO has developed the xenon flash thermal diffusivity measurement system "TD-1 series", by adopting xenon light to reduce damage to samples and allow evaluation of the thermophysical properties of polymer materials such as high-functional films (Figure 2).

Figure 2 Appearance of "TD-1 HTV"

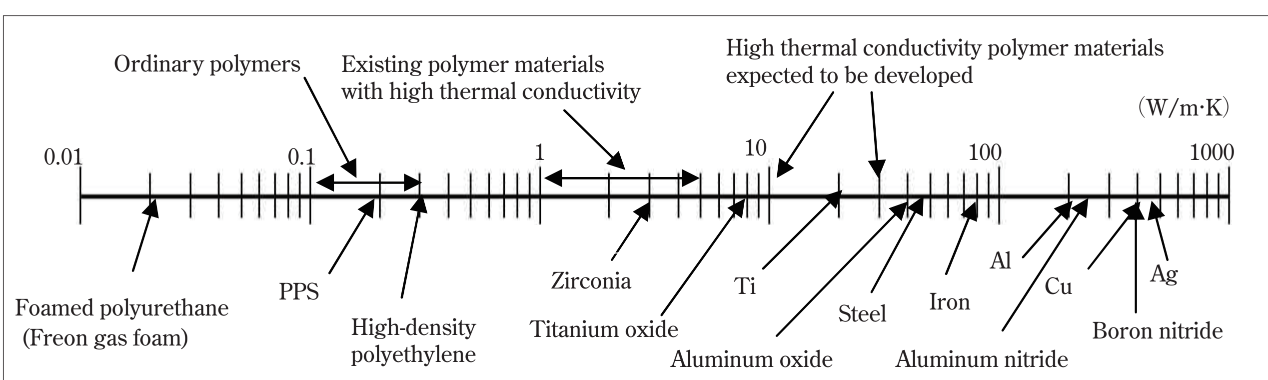

Figure 1 Thermal conductivities of various materials[1)]

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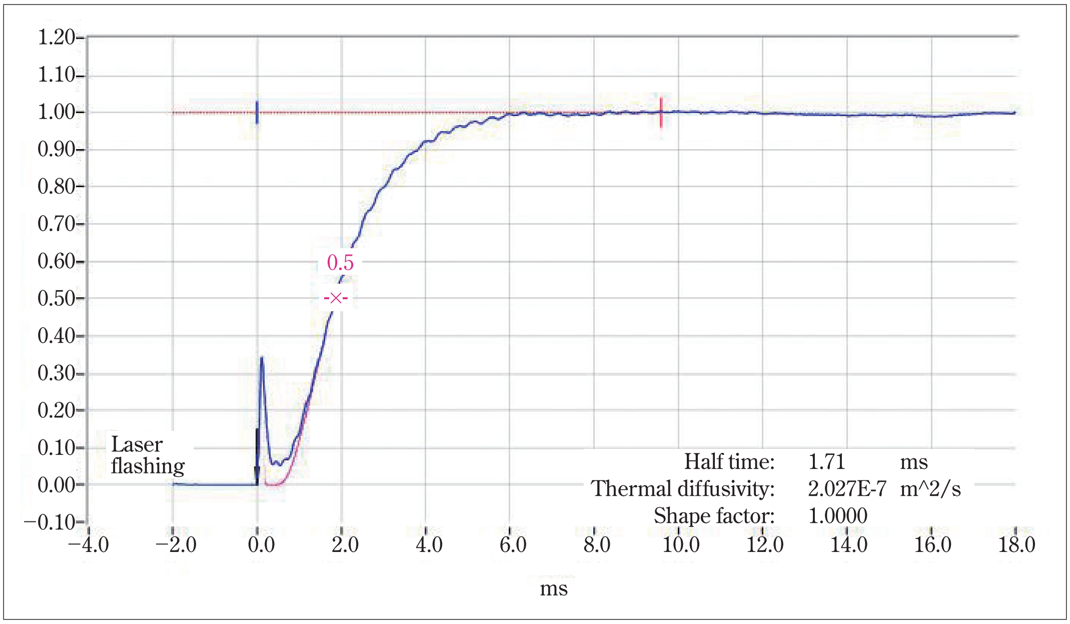

Figure 3　Example of measurement of a polyimide sample with a thickness of 50 μm

2. Features of xenon flash thermal diffusivity measurement system TD-1 series

2.1 Evaluation of thin samples

This system uses xenon light with its characteristic short heating time. Xenon lamps generate lower energy per pulse compared to the laser used in our TC-9000 laser flash method thermal constant measurement system. This enables measurements of polymer films, adhesives, paints and other materials of lower thermal diffusivity and micrometer-order thickness.

Figure 3 shows the measurement results of a commercially available polyimide film with a thickness of 50 μm. The thermal diffusivity evaluated by using the half time method was 2.0×10^{-7} $m^2 \cdot s^{-1}$. Table 1 shows the results of polyimide films with different thicknesses by using TD-1 series, TC-9000 laser flash method thermal constant measurement system and the FTC-1 periodical heating method thermal diffusivity measurement system. These systems showed similar values for the thermal diffusivity. Figure 4 shows the scope of samples that can be measured by each system. The TD-1 series can measure samples with thinner thicknesses or higher thermal conductivities than those which TC-9000 is able to measure.

Table 1　Measurement results of thermal diffusivity of polyimide samples using different measurement systems

Thermal diffusivity ($\times 10^{-6}$ $m^2 \cdot s^{-1}$)	Thickness (μm)			
	25	50	75	125
TD-1 HTV	0.14	0.20	0.21	0.22
TC-9000		0.19	0.22	0.20
FTC-1	0.15	0.18	0.21	0.21

2.2 Temperature dependence

The TD-1 series use a heating furnace that provides quick temperature response at 350℃ or lower. This en-

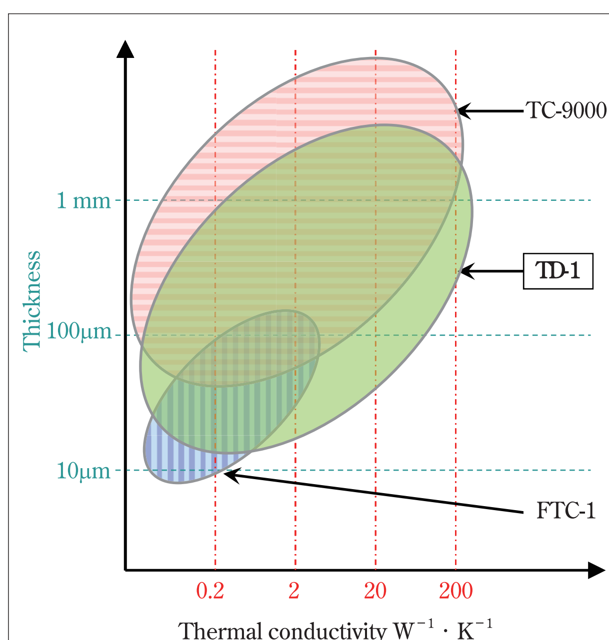

Figure 4　Scopes of application of TD-1 series, TC-9000 and FTC-1

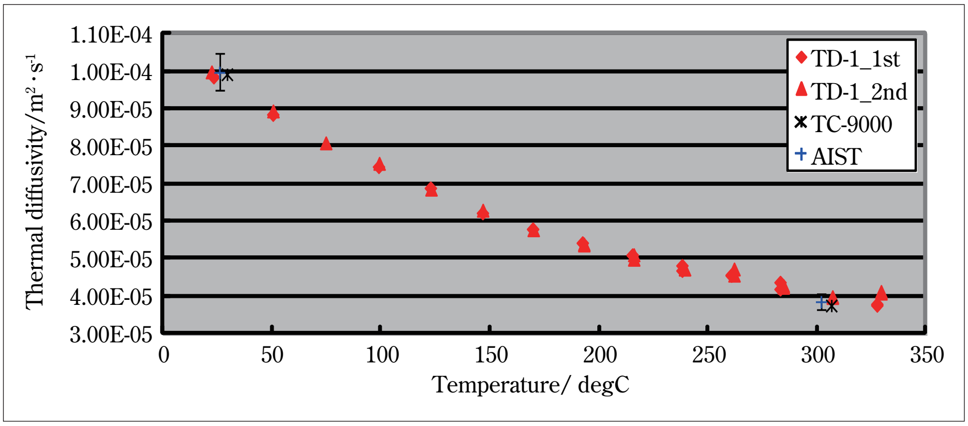

Figure 5 Temperature dependence of thermal diffusivity of isotropic graphite sample

ables quick evaluation, even at different temperatures, of materials that suddenly change in thermal diffusivity in the temperature range between room temperature and 350℃, although it was difficult to evaluate thermal diffusivity at such temperatures range by using our laser flash thermal constant measurement systems.

Using the TD-1 series and the TC-9000 laser flash method thermal constant measurement system, we measured the thermal diffusivity along the thickness direction of a certified reference material (isotropic graphite with a thickness of 1.993 mm) available from the National Institute of Advanced Industrial Science and Technology (AIST). The measurement results and calibration data provided by AIST are shown in Figure 5. As AIST calibration data and measurement results obtained by using TC-9000 show only the results at room temperature and 300℃, we cannot evaluate how the thermal diffusivity decreases in the temperature range from room temperature to 300℃. In this test, we measured the thermal diffusivity in about 25℃ interval from room temperature to 350℃, and found that the decrease in thermal diffusivity becomes smaller as the temperature rises. At about 300℃, the measured thermal diffusivity differs by only about 5% from the AIST calibration data. This test proves that the TD-1 series can evaluate thermal diffusivities at temperatures up to 350℃.

2.3 Multi-layer analysis software

This system comes standard with software developed on the basis of the multilayer analytical model developed by Araki[2] as well as the multilayer analytical model developed by Baba[3], which is adopted in JIS H 8453. The software can calculate thermal diffusivities of polymer film layers on substrates, paints and adhesive applied between substrates.

2.4 Substrate method (option)

This system adopts the substrate method for evaluation of in-plane thermal diffusivity, and can be used for measurements of materials with different thermal diffusivity values along the thickness direction and the in-plane direction. By rotating sample holder, the system can evaluate the thermal diffusivity in different directions of anisotropic materials, such as liquid crystal polymers.

2.5 Hardware features

① Compact desktop unit containing a sample system, a detection system, a control circuit and other components

② Energy efficient system with a maximum power consumption of 1.5 kVA

③ Temperature control from room temperature to 350℃ (HTV type), optimal for evaluation of the thermal conductivities of polymer materials

④ Maximum of 4 samples simultaneously set on a multi sample holder

⑤ Measurements in atmosphere, in vacuum and in inert gases (HTV and RTV types)

3. Specifications of the TD-1 series

Table 2 shows the specifications for the TD-1 series xenon flash thermal diffusivity measurement system.

Table 2 Specifications for TD-1 series xenon flash thermal diffusivity measurement system

TD-1 series	HTV type	RTV type	RTA type
Measurement property	Thermal diffusivity, Specific heat capacity ※ Thermal conductivity is obtained by multiplying thermal diffusivity, specific heat capacity, and density.		
Sample size	ϕ10 mm (Circular disc sample, one dimensional measurement)		
Sample thickness	25 μm～2 mm (in case of a polyimide sample)		
Measurement range	Thermal diffusivity : 1×10^{-7}～1×10^{-4} $m^2 \cdot s^{-1}$		
Number of samples	4 samples with an electric transfer mechanism	4 samples with an electric transfer mechanism	1 sample
Temperature range	Room temperature to max. 350℃	Only room temperature	Only room temperature
Measurement atmosphere	In air, vacuum and inert gases	In air, vacuum and inert gases	Only in air
Pulse heat source	Xenon flash lamp		
Radiation thermometer	Infrared detector (light receiving element : InSb)		

4. Conclusion

ULVAC-RIKO has developed "TD-1 series" thermal diffusivity measurement system, which can be used for evaluation of the thermophysical properties of high function films and other polymer materials difficult to measure using the laser flash method. This has enhanced the lineup of our thermal conductivity evaluation systems applicable to various kinds of materials. We will continue to further expand the lineup of evaluation systems.

References

1) "General guidance for high-thermal-conductivity realization of polymer materials and new method using low melting point metal", Chapter 2 [2] of "Control and measurement/evaluation methods of thermal diffusivity, thermal conductivity", Science & technology Co., Ltd., p30 (in Japanese)
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