We are supporting global environment protection of an enterprise through quality improvement of thermophysical property measurement.

■ Specifications

		TA35 Ultimate	TA33 Professional	TA32 Horizon	TA31 Vertical
Basic function	Measurement object	Thermal diffusivity			
	Measurement range	0.1～1000 [×10^{-6} m^2s^{-1}]			
	Output data	Frequency, Distance, Amplitude, Phase, Thickness [TXT form]			
Measurement mode	In-plane	○	○	–	○
	Out-of-plane	○	○	○	–
	Distribution	○	–	–	–
Accessories	Sample stage heater	Option	Option	–	–
	Focus adjustment	Auto	Auto	Manual	Manual
	Software	○	○	○	○
	PC	○	○	○	○
Measurement environment	Temperature	Room temp	Room temp	Room temp	Room temp
	(Heater installed)	Room temp ～ 300 [℃]	Room temp ～ 300 [℃]	–	–
	Frequency	0.01 [Hz]～100 [kHz]	0.01 [Hz]～100 [kHz]	0.01 [Hz]～100 [kHz]	0.01 [Hz]～100 [kHz]
Laser diode	Wavelength	808 [nm]			
	Maximum output	1.5 [W]			
Radiation thermometer	Element	InSb			
	Cooling method	Liquid nitrogen			
Stage displacement	Detection stage	XY：±5 [mm]	XY：±5 [mm]	XY：±5 [mm]	–
	Sample stage	XY：±10 [mm]	–	–	–
Power supply		AC100/240[V], 10/5 [A], 50/60 [Hz]			
Usage environment	Temperature & Humidity	20～35 [℃], 20～80 [%]			
Repeatability		Less than ± 5%			
Terms of use	Sample	Solid material（Resin・Glass・Ceramics・Metal・Diamond etc...）			
	Shape	Any shape			
	Surface	Sample substrates should be flat and smooth for the best results (Thickness should be measurable).			
	Coating	Blacking processing is required (which may be unnecessary for graphite-based material).			
	Sample size (Max)	100 × 100 × 2 [mm]			
	Sample size (Min)	10 × 10 × 0.015 [mm]			
	Reference sample	Not necessary			
Main boby	Dimensions	W555×D785×H693 [mm]	W555×D785×H693 [mm]	W510×D720×H500 [mm]	W510×D720×H500 [mm]

■ The numbers shown in this catalog are results from our examinations. The same results are not guaranteed in different circumstances.
■ The performance and appearance may be changed for improvement without notice.

Caution for Safety Before using, please read manual and operate correctly for the safety.

CLASS 1 LASER PRODUCT
IEC/EN 60825-1 :2007

Inquiry about products : https://hrd-thermal.jp/en/contact/

<Manufactured and Distributed>

BETHEL Co.,Ltd. Hudson Laboratory

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https://hrd-thermal.jp/en/

<Agent>

Ver.1.05

We wish to contribute to technological innovation and creating the future through our thermal measurement technology.

Periodic heating and radiation thermometry method :
Thermophysical Property Measurement System

Thermowave Analyzer

BETHEL THERMAL Search

Materialization of High Accurate, Precise and Contactless Thermal Diffusivity Measurement.

TA35 Ultimate　**TA33** Professional　**TA32** Horizon　**TA31** Vertical

BETHEL Co., Ltd.

Thermowave Analyzer
TA35/33/32/31

CONCEPT

High Performance and High Accurate Thermophysical Property Measurement System

Concept is “Thermal, Light, Safety, and Security”.
Concentrating the BETHEL’s know-how and technology for Thermophysical Property Measurement by deepening and fusing of the original products based on our original manufacturing prospect.
We wish to contribute to technological innovation and creating the future through our development of high accurate and precise thermophysical property measurement system.

FEATURES

Features of Equipment

◆ Contactless thermal diffusivity measurement.
Adopt periodic heating and radiation thermometry method and contactless thermal diffusivity measurement with the laser.

◆ Wide range measurement. ~Organic films to Diamonds~
This device can measure wide range of samples from organic films to diamond with a single unit.

◆ Continuos measurement of in-plane& out-of-plane. ~Checking of anisotropy~
Continuous measurement can be performed in vertical (Z) and horizontal (XY) directions for same work and same sample.

◆ Mapping measurement is possible. ~Evaluate a defect and nonuniformity of samples~
It is possible to evaluate the distribution by the continuous measurement of thermal properties at plural points in out-of-plane.

◆ Measurement method of absolute values for easy condition setting.
It is possible to get absolute values of thermal diffusivity.
And by “Easy Measurement” function, the setting of measurement condition is easily performed.

◆ A High degree of freedom of sample preparation can specify measurement point.
It is possible to choose closely measuring point and to measure the required points individually.
And because being able to measure regardless of sample shape, the preparation of the sample is very easy which provides a capability to measure a sample with an irregular shape such as a circle and a triangle.

◆ Easy operation as being able to perform up to an analysis by PC, after placing samples on the stage.
After placing measurement sample on the test stand, it operates all of procedures up to the analysis by PC.

LINEUP

Four lineups with much attention meeting user’s needs

The first class model “TA35-Ultimate” that combines full functions from the measurement of the XYZ axis to the mapping measurement, High performance model “TA-33-Professional” that enables the anisotropy evaluation by the measurement of XYZ axis, Basic models “TA32-Horizon”and “TA31-Vertical” that are limited to a necessary function.
Please select favorite grade from four lineups according to the purpose of use at customers.

PREMIUM

For user needs for the professional measurement that “desiring to evaluate difficult thermophysical property by own company”.

Exerting great power to composite materials.
Fully loaded with function and marvelous premium model.

TA35 Ultimate

In-plane / Out-of-plane / Distribution / Focus adjustment / Heater installed ※option

STANDARD

It’s best to evaluate the anisotropic materials. The high performance model with all necessary functions.

Analyze the anisotropy by continuous measurement of three axis, standard model high performance function.

TA33 Professional

In-plane / Out-of-plane / Distribution / Focus adjustment / Heater installed ※option

BASIC

For casual user, that “we have decided to limited function, and wish to use simply and easily.”

The basic model with cheap edition which narrowed-down a necessary function at a pin point.

TA32 Horizon

In-plane / Out-of-plane / Distribution / Focus adjustment / Heater installed ※option

TA31 Vertical

In-plane / Out-of-plane / Distribution / Focus adjustment / Heater installed ※option

Function List

Out-of-plane
Thermophysical propety of Z axis measure.

In-palne
Thermophysical property of XY axis measure.

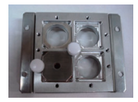
Mapping measurement
It is possible to evaluate the distribution by the continuous measurement at plural points.

Focus adjustment
When measuring sample with different thickness, focus adjustment can be autmatically by moving Z stage.

Heater installed
By heater installed , thermophysical property measurement in changing temperature from room temperature at 300℃ can do.

Option

◇ Various test stage



Plural sample stage
for continuous measurement.

Sample stage for pressure measurement.

◇ etc...

SCENE

Utilization scene

To a new stage by thermophsical property measurement

In development electronic device miniaturized evey year, solution of thermal problem is one of very important issues. It’s essential to grasp exactly thermophysical property of parts and materials.
“Thermowave Analyzer TA35, 33, 32, 31” are widely used in verious scenes that grasp of thermophysical property need.
For example, preformance confirmation of new matelials developments, thermal desigh at product development, quality control of manufacturing site, and inspection device of defect and nonuniformity of samples.

THEORY

Measurement Principle

Thermowave Analyzer TA Series measures thermal diffusivity with Periodical heating radiation-temperature measuring method.

■Measurement Principle

Irradiate the sample surface with a thermal diffusivity α with periodic heat source $P_0 e^{i\omega t}$. Alternate current component of temperature at the hot spot is expressed as $T_{ac} = T_0 e^{i\omega t}$. The temperature diffusion induced around sample stage by periodic heat source $P_0 e^{i\omega t}$, which is expressed by the following formula:

$$T_{ac} = \frac{P_0}{4\pi\alpha rc} \cdot e^{-kr+i(\omega t-kr)}$$

C is the heat capacity, r is distance from the heat so and k is

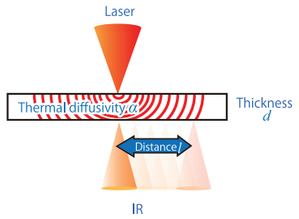
$$k = \sqrt{\frac{\omega}{2\alpha}} = \sqrt{\frac{\pi f}{\alpha}} = \frac{1}{\mu}$$

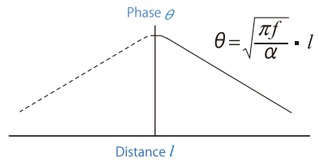
μ is the thermal diffusion length.
Therefore, the phase lag could be derived

$$\theta = -\sqrt{\frac{\pi f}{\alpha}} \cdot r \quad \cdots\cdots\cdots\cdots\cdots\cdots ①$$

■Schematic of Thermowave Analyzer

In-plane (Distance)

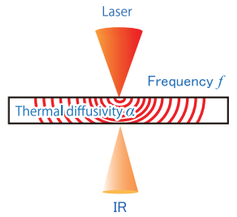


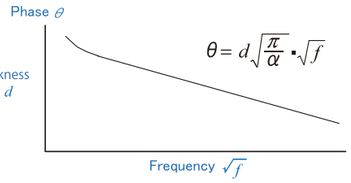


Measure the In-plane thermal diffusivity of the sample by getting the phase per the moving distance of heat radiation respect to the laser after varying the temperature measuring position of heat radiation.

Replace r in Eq. ① with l and plot the phase lag θ respect to l.

Out-of-plane (Frequency)



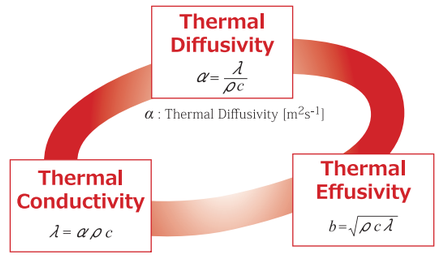


Measure the vertical thermal diffusivity of the sample by getting the phase per the frequency after varying the heating frequency of the laser.

Replace r in Eq. ① with d and plot the phase lag θ respect to $\sqrt{f}$.

Thermophysical property values are convertible to others

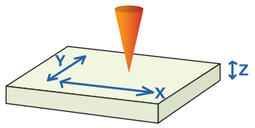
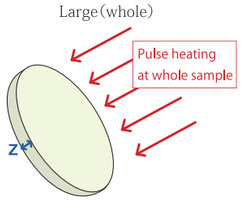
The thermal diffusivity can be converted to thermal conductivity and thermal effusivity by applying of specific heat and density.



λ : Thermal Conductivity [$Wm^{-1}K^{-1}$]
ρ: Density [kgm^{-3}]
b : Thermal Effusivity [$Js^{-0.5}m^{-2}K^{-1}$]
c : Heat capacity [$Jkg^{-1}K^{-1}$]

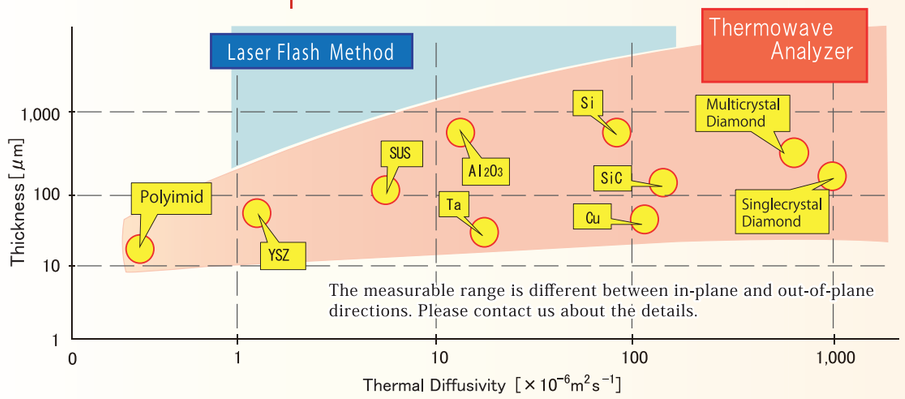
The reason why BETHEL adheres to periodical heating radiation-temperature measuring method.

～ comparison with laser flash method ～

Periodical heating radiation-temperature measuring method		Laser flash method
Periodical heating by beam	Heating method	Pulse heating by beam
Small（ϕ 100~150 μm） Periodical heating at pinpoint 	Laser diameter	Large（whole） 
Z：Changing of phase for distance. XY：Changing of phase for distance.	Measuring axis and receving signal	Z：Curve of increase in temperature with time
Measure a point aimed at pinpoint （Measuring area by one point：ϕ 500 μm）	Range	Calculate the mean value of the physical property of whole samples.
By continuously measuring of Z axis, evaluate nonuniformity of distribution.	Distribution evaluation	Impossible
No restriction of external form of sample with φ20mm or more	Shape	Depend on testing device
Cu：300 μm or more A thin sample can be measured.	Thickness	Cu：1000 μm or more
Not necessary	Sample cell	It's necessary to devise heat insulation methods as much as possible.
Therefore ◎ There is no restriction of sample shape ◎ Even a thin sample can be measured. ◎ Continuous measurement is performed in 3 axis XYZ directions for same work and same sample. ◎ Wide dynamic range ◎ Evaluation of distribution nonuniformity is possible.	Total	◎ Having a long history, it is most popular. ◎ Good at measurement of the homogeneous materials.

RANGE

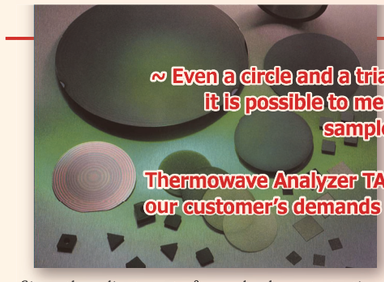
Wide measurement range
～Organic film to diamond～



The measurable range is different between in-plane and out-of-plane directions. Please contact us about the details.

FLEXIBLE SHAPES

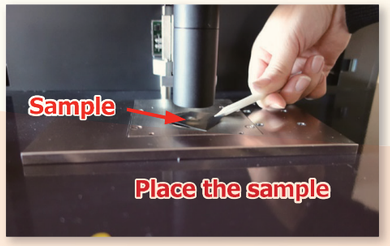
It's possible to measure regardless of sample shape.

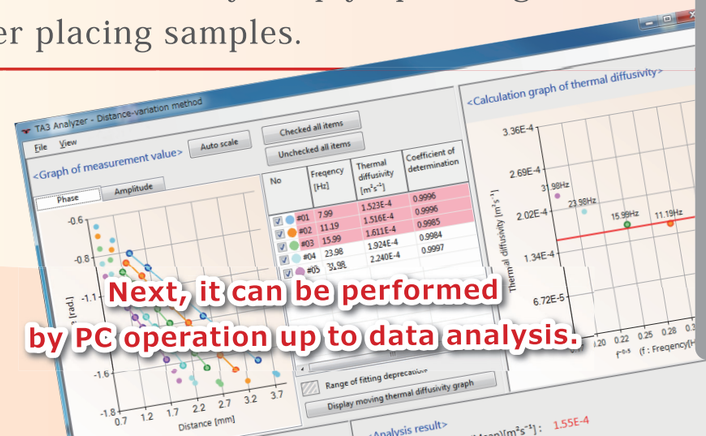


Since the adjustment of sample shape to testing device is not necessary, it is possible to attain significant reduction in a time-consuming job and cost.

SAFE & EASY OPERATION

Easy operation with only simply operating by PC after placing samples.



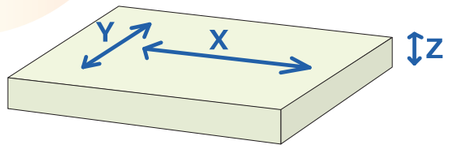


APPLICATION

In-plane　Out-of-plane

Anisotropy Evaluation

Continuous measurement for XYZ directions is possible
~ For evaluation of sample with anisotropy ~



＜ Application ＞
- To evaluate heat radiation material of electronic parts
- To evaluate semiconductor laser of electrode
- To evaluate thermoelectric power generation
- To evaluate coating of carbide tool　etc

Do you grasp the anisotropy of samples? For the composite materials of resin and various fillers (AlN, SiO_2, SiC, CNT), thermal diffusivity measurement is needed because the thermal conductivity changes significantly by the compounding ratio. Since this device can perform the continuous measurement for XYZ axis in the same work and same sample at a time, which is the best device to measure the sample required to grasp the anisotropy.
For example, the device is of great use to measure various samples such as heat dissipation sheet, carbon fiber reinforced resin, high thermal conductive resin and polyimide sheet used in electronics circuits, etc.

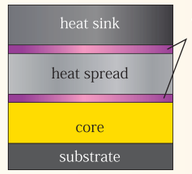
Mapping measurement

Visualizing of adhesion homogeneity of laminated lumber by the relative comparison of thermal conduction distribution.

In-plane

Defect inspection of parts
Check the homogeneity
Relative comparison of thermal conductivity

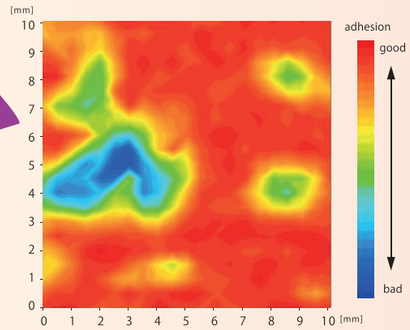
■ CPU section



Heat conduction changes drastically by the performance and adhesion of TIM

Visualizing the adhesion of TIM by distribution measurement

■ Evaluation example of the adhesion TIM



Because laminated materials are made by piling of materials with different thermal conduction, it is prefigured to change drastically heat transmission with homogeneity of adhesion. However, it was very difficult to perform the accurate measurement for thermal conductivity of laminated materials up to now and which has become one of pending issues in developing such materials. This device acquires continuously a phase delay of out-of-plane and further it is possible to evaluate relatively the thermal conduction of laminated materials by mapping data.
Not only performing the relative evaluation of thermal conductivity of materials, it is the most suitable for defect inspection or validation of homogeneity of parts.

ACCURACY

High precision measurement

The error between reference※ and measurement values is less than 2%　(In the case of substance)

■ Measurment accuracy of the major metals

Sample	Thickness [μm]	Orientation	Thermal diffusivity α [×10⁻⁶m² s⁻¹] TA measured	Thermal diffusivity α [×10⁻⁶m² s⁻¹] Reference value※	Difference to reference value※
SUS304	100	In-plane	3.91	4.05	3.58 %
		Out-of-plane	3.92		3.32 %
Ni	300	In-plane	23.1	22.9	-0.87 %
		Out-of-plane	22.5		1.78 %
Mo	300	In-plane	54.1	54.3	0.37 %
		Out-of-plane	54.3		0.00 %
Cu	500	In-plane	120	117	-2.50 %
		Out-of-plane	117		0.00 %
Ag	500	In-plane	180	174	-3.33 %
		Out-of-plane	177		-1.69 %

※ Reference values show literature and catalog values, or values measured with other methods.

■ The defference between measurment accuracy and reference value※ when same point was repeatedly measured ten times.

Time	Thermal diffusivity α [×10⁻⁶m² s⁻¹] Cu	Thermal diffusivity α [×10⁻⁶m² s⁻¹] Ta
1	115	25.2
2	118	24.9
3	114	25.1
4	115	24.9
5	116	25.0
6	115	24.9
7	115	25.1
8	117	24.9
9	116	25.1
10	114	25.2
Average value	115.5	25.0
Standard deviation	1.27	0.13
Repeatability	1.1%	0.5%

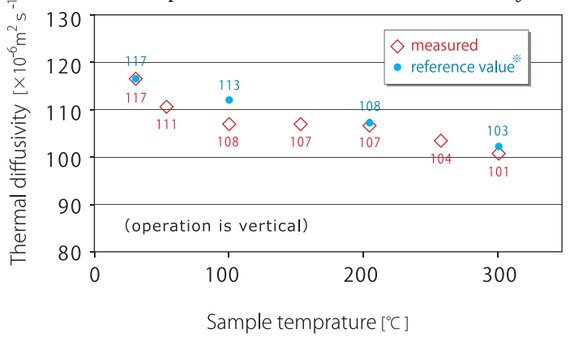
	Thermal diffusivity α [×10⁻⁶m² s⁻¹] Cu	Thermal diffusivity α [×10⁻⁶m² s⁻¹] Ta
Measured	115.5	25.0
Reference value	117	25.0
Difference to reference value※	-1.3 %	0.1 %

◇ Orientation is vertical.
◇ Continuous measurement performed ten times under the same condition.

By a built-in heater, it's able to evaluate the change of thermophysical property by temperature.　(option : heater)

Evaluation of Temperature Modulation

■ For copper with temperature change,
Comparison of the measured value by TA versus the reference value※



Temperature	Thermal diffusivity [×10⁻⁶m² s⁻¹] TA measured	Thermal diffusivity [×10⁻⁶m² s⁻¹] Reference value※	Difference to reference value※
27℃ (room)	117	117	0.0 %
100℃	108	113	-4.4 %
200℃	107	108	-0.9 %
300℃	101	103	-1.9 %

Since a pyrometry (RT–300℃) can be made, it is possible to evaluate thermal property at the same temperature as the actual usages. The measurement accuracy is not degraded even if changing temperature.

Wide variety of Measurement track record

◇ CNF
◇ Sillicon heat dissipation sheet
◇ CNT
◇ Graphite sheet
◇ High thermal conductive resin
◇ Multicrystal diamond
◇ Resin
◇ Ceramics
◇ Glass
◇ Metals
◇ Semiconductor materials
◇ Carbon materials
◇ etc...

It's possible to measure regardless of sample shape.

■Wire-shaped／Fibrous materials

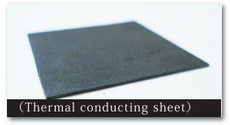

(Aluminum wire)

For the thermal property to be evaluated, the shapes of materials are various, and particularly, there are many needs to evaluate industrial material like wire, fibrous with shape as it is. For this device, we made it measurable for thermal conductivity by adjusting precisely positions of the laser beam radiation and detection optical system observation to measuring samples.

Sample	Diameter [mm]	Thermal diffusivity [×10⁻⁶m² s⁻¹] Measured	Thermal diffusivity [×10⁻⁶m² s⁻¹] Reference value	Difference to reference value※
Aluminum wire	0.5	94.9	96.8	-1.9 %
Titanium wire	0.1	9.7	9.25	4.8 %

We use 99.999% purity Aluminum and Titanium wire, productd by The Nilaco Corporation.

■Thin sheet materials


(Thermal conducting sheet)

Measured by this device after preparing 2 samples with same materials and different thickness. The thermal conductivity was converted from thermal diffusivity by applying specific heat and density.

For the thermal conducting sheet, while keeping the high conductivity, flexibility and adhesion being able to adhere along the shape of heating element, which has an effect on reducing of the interfacial thermal contact resistance. Thermal property measurement is naturally necessary, but it was difficult to evaluate the anisotropy of thin sample up to now. In the case of this device, it is able to save time for sample preparation, and enables users to perform the continuous measurement for XYZ 3 directions with the thickness as it is. And it is able to evaluate not only the anisotropy but also the difference of thermal property value with the thickness. In the above table, it is shown that a thinner material has higher thermal conductivity (diffusion) than thicker ones even the same material.

Sample	Thickness [mm]	Specific heat [Jg⁻¹K⁻¹]	Density [gcm⁻³]	Orientation	Thermal diffusivity [×10⁻⁶m² s⁻¹]	Thermal conductivity [Wm⁻¹K⁻¹]
Thermal conducting sheet	0.426	0.83	2.5	In-plane	0.71	1.4
				Out-of -plane	4.50	9.2
	0.213			In-plane	1.21	2.5
				Out-of-plane	5.22	10.6

■Other special shapes

After CVD diamond and other materials created on a substrate, it's standing state. Even flaky material is measurable.
Because "TA has a function to measure the temperature change at high speed", it is able to accommodate to such special measurement.