TEST REPORT

Applicant	: EMS Co., Ltd.
Address	: 50, LS-ro 115beon-gil, Gunpo-si, Gyeonggi-do, Republic of Korea
Sample Name	: Refer to Table 1
Sample Received	: June 3, 2019
Test Performing Date	: June 3, 2019 ~ June 12, 2019
Test Laboratory	: Korea Polymer Testing & Research Institute. LTD. (KOPTRI)
Test Item	: Thermal Conductivity
Test Method(s)	: Refer to Table 2
Test Result(s)	: Refer to Table 2
Analyzer	: Seolbin Kim / Assistant Researcher

Completed by,

Seolbin Kim / Assistant Manager

Approved by,

Kyoungho Min / Senior Manager

Issued Date: June 12, 2019

Tested by

Korea Polymer Testing & Research Institute (KOPTRI), Ltd.

(ISO 17025 Certified Laboratory)

Table 1. Sample Information

No.	Sample Name	Koptri ID	Picture of the Sample
1	Thermal Sheet	Koptri-19-06-07541-1	

Table 2. Test Result

Koptri ID	Test Item	Unit	Test Method	Test Result
Koptri-19-06-07541-1	Thermal Conductivity	W/(m·K)	ASTM E1461 (Laser flash: Thru-plane)	50.2
	Thermal Conductivity	W/(m·K)	ASTM E1461 (Laser flash: In-plane)	181

Note 1) Specific Heat : Differential Scanning Calorimetry Analysis

***Raw data**

1. Test Condition

1-1. Density

(1) Equipment : Electronic densimeter (Alfa Mirage Co. / MD-300S)

(2) Test Method : Density is calculated after measuring the specific gravity according to ASTM D792 (Standard test methods for density and specific gravity (relative density) of plastics by displacement)

(3) Test Temperature : (25±2) ℃

1-2. Specific Heat

(1) Test Method : KS M ISO 11357-4 (Plastics-Differential Scanning Calorimetry (DSC)-Part 4:Determiantion of specific heat capacity)

(2) Test Instrument : DSC (TA, DSC 25)

(3) Test condition: 0 °C (5 min Isothermal)
0 ~ 50 °C (1st Heating)
50 °C (5 min Isothermal)

(4) Heating rate: 5 ^{o}C/min

(5) Flow Gas : N_2

1-3. Thermal Diffusivity, Thermal Conductivity

(1) Test Instrument : Thermal Diffusivity Measurements (NETZSCH, LFA 447 NanoFlash)

(2) Test Method : ASTM E1461
(Standard Test Method for Thermal Diffusivity by the Flash Method)
$\lambda(T) = \alpha(T) \times Cp(T) \times \rho(T)$
Thermal Diffusivity (α), Specific Heat (Cp), Density (ρ)

(3) Sensor : InSb

(4) Test Temparature : 25 ℃

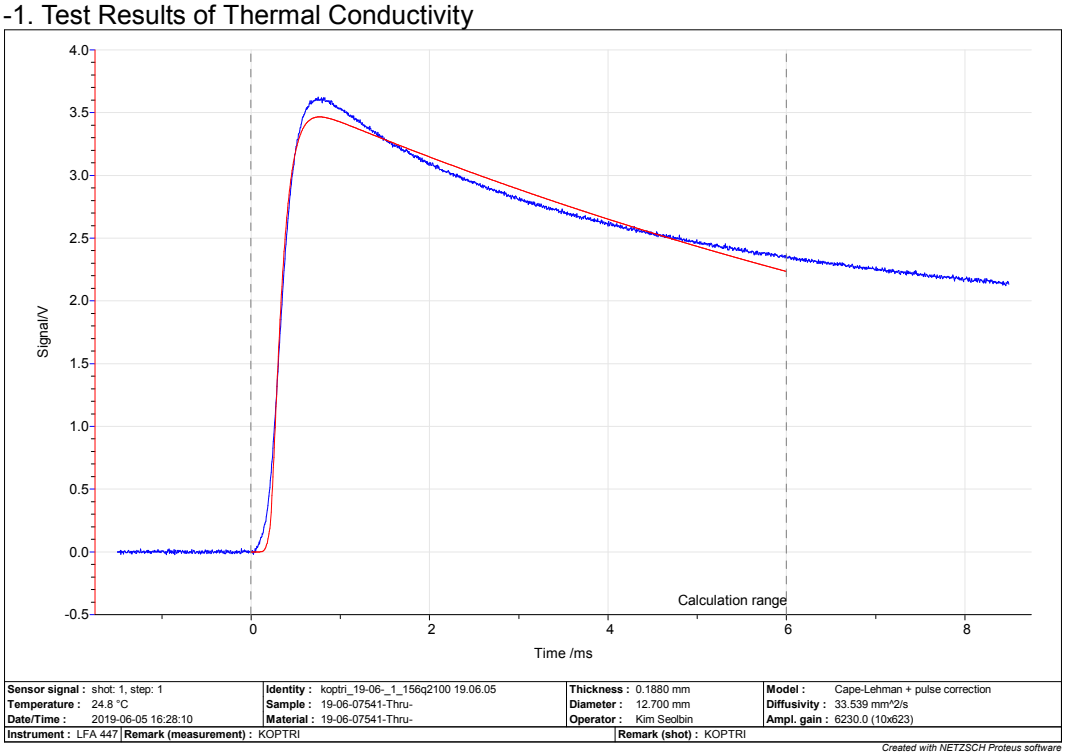
(5) Voltage / Pulse Width : Thru-Plane - 190 V / Medium
In-Plane - 270 V / Medium

2. Test Result

Table 3-1. Test Results of Thermal Conductivity

Sample Name	Run	Density (g/cm^3)	Specific Heat (J/g·K)	Thermal Diffusivity (mm^2/s)	Thermal Conductivity (W/(m·K))
Koptri-19-06-07541-1 (Thru-plane) (Thickness : 0.188 mm)	1	1.218	1.265	33.539	51.664
	2	1.218	1.265	32.491	50.050
	3	1.218	1.265	31.811	49.003
	SD	-	-	0.87	1.34
	CV(%)	-	-	2.67	2.67
	Average	**1.218**	**1.265**	**32.614**	**50.239**

Picture 1-1. Test Results of Thermal Conductivity



SD : Standard Deviation

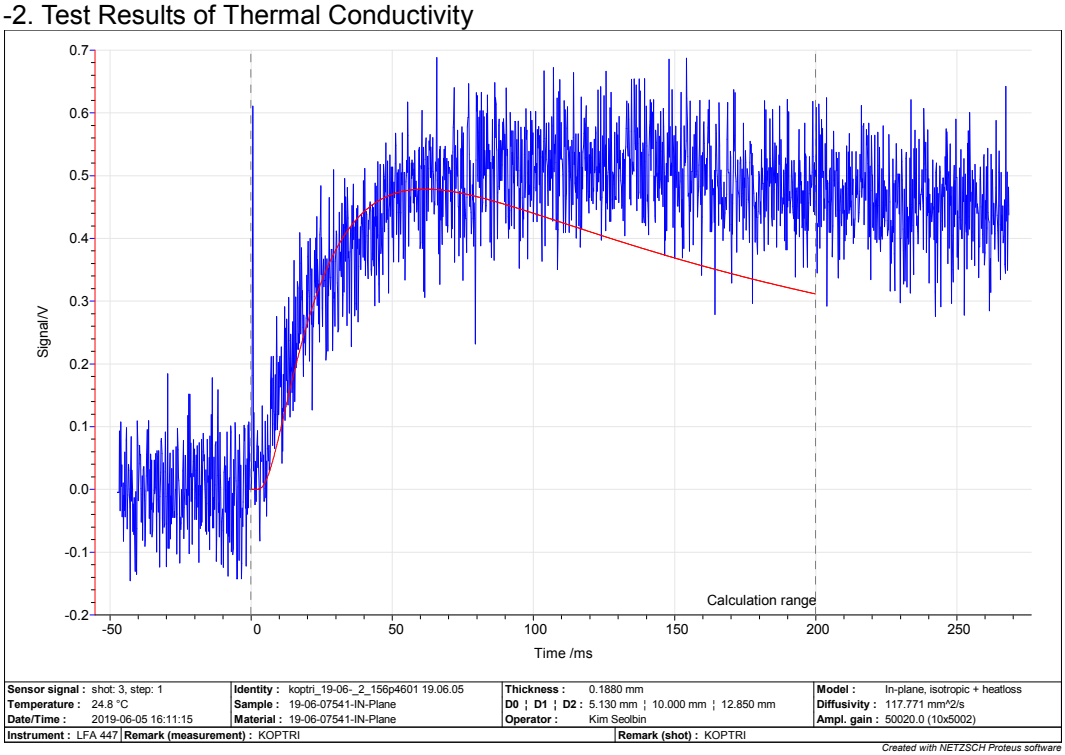
CV : Coefficient of Variation=(SD/average)x100

Note) Half Time $t_{1/2}$: 8.49 /ms

Table 3-2. Test Results of Thermal Conductivity

Sample Name	Run	Density (g/cm^3)	Specific Heat (J/g·K)	Thermal Diffusivity (mm^2/s)	Thermal Conductivity (W/(m·K))
Koptri-19-06-07541-1 (In-plane) (Thickness : 0.188 mm)	1	1.218	1.265	123.689	190.535
	2	1.218	1.265	117.771	181.418
	3	1.218	1.265	110.131	169.650
	SD	-	-	6.80	10.47
	CV(%)	-	-	5.80	5.80
	Average	**1.218**	**1.265**	**117.197**	**180.534**

Picture 1-2. Test Results of Thermal Conductivity



SD : Standard deviation

CV : Coefficient of variation=(SD/average)x100

Note) Half time t1/2 : 16.8 /ms

End of Test Report.