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Research Article

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Reliability of Eco-friendly Nano-carbon Molding for Far-infrared Thermal Effects

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Abstract
In this study, charcoal is finely pulverized into a powder of about 300 mesh to cure a styrene monomer and a methylol acrylamide monomer as main components with a water-soluble acrylic emulsion adhesive, and a nanocarbon molded body is developed through redox agents and viscosity control. At this time, when the water-soluble acrylic emulsion adhesive (45%) and the 300 to 500 mesh coconut charcoal (55%) powder is mixed and stirred at a certain ratio for 25 to 30 minutes, a spherical body with a diameter of 1 to 3 mm is formed. When the molded composition is dried at room temperature after undergoing a firing process of 30 to 90 minutes at a firing temperature of 90 to 300°C, the charcoal molded product becomes a pure solid activated carbon of 95% or more. To prove the eco-friendly nanocarbon molded body, far-infrared ratio, energy analysis, gas concentration and antibacterial experiments are conducted to secure stability.

Keywords: Nano Carbon, Eco-Friendly Charcoal Molding, Far infrared, Gas Concentration, Antibacterial Test

1. Introduction

In the anti-aging era, various studies have been conducted on healthcare fusion that can promote digestive absorption, energy storage, waste, and toxins during 24-hour human activities [1]. Carbon materials using the strong adsorption power of traditional charcoal have been used for heat treatment, dehumidification, air purification, bioactivation, and detoxification using a large amount of far-infrared emission [2-3].Carbon materials using the strong adsorption power of traditional charcoal are used for thermal therapy, dehumidification, air purification, bioactivation, and toxic substances using large amounts of Far-infrared emissions [4]. Traditionally, there are many experiences with far-infrared thermal effects, but scientific data through clinical experiments are needed. When far-infrared rays having a wavelength of about 8 to 14μm are irradiated to the human body, they are easily absorbed (or resonated) and have a thermal effect [5]. Therefore, when the far-infrared thermal effect is absorbed into the human body, it is reported to be effective in treating chronic diseases such as fatigue recovery and stress by increasing the temperature of the deep part of the body, promoting blood circulation, and activating metabolism as a whole [6]. Figure 1 shows the process from charcoal to powder.

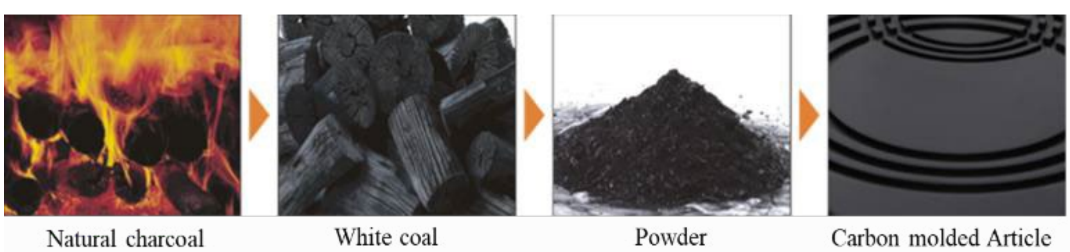


Figure 1: The Process from Charcoal to Powder.

Therefore, in order to find ways to utilize far-infrared therapy in the field of alternative medicine and to provide basic data for future research on its effectiveness, an object that can prove the effectiveness of far-infrared thermal therapy revealed in previous studies is needed. In addition, heat, moisture control, and wood and plastic products are prioritized for eco-friendly building products worldwide when considering eco-friendliness. As much as this, eco-friendliness is emphasized for doors, windows, and concrete [7]. This study develops nanocarbon chips for the far-infrared thermal effect and tests the eco-friendliness and stability that are harmless to the human body. At this time, a composition including an oxidation-reduction agent and a neutralizing agent viscosity control agent is mixed and prepared. When a water-soluble acrylic emulsion adhesive and a coconut charcoal are mixed and stirred at a certain ratio for 20 to 30 minutes, a spherical body with a diameter of 1 to 3 mm is formed, and aging is performed for about 50 to 60 minutes. After aging, it returns to its original properties and shows advantageous performance in securing fluidity.

2. Implementation of Carbon Mold Chip

2.1 Carbon Molded Article

Around the world, heat, moisture control, wood and plastic products are prioritized when considering eco-friendliness for eco-friendly building products. As much as this, Eco friendliness is important for doors, windows, and concrete. Therefore, In the carbon molded body, a styrene monomer and a methylol acrylamide monomer are cured in acrylic acid as a main component with a water-soluble acrylic emulsion adhesive, and an oxidation-reduction agent, a neutralizing agent, and a viscosity modifier are mixed therewith. At this time, when the water-soluble acrylic emulsion adhesive and the 300 to 500 mesh coconut charcoal powder are mixed at a certain ratio for 25 to 30 minutes and stirred, a spherical body with a diameter of 1 to 3 mm is formed, which is aged for 50 to 60 minutes. The aged powder is passed through a roll mill and subjected to close mixing two to five times. Close mixing determines the fluidity of the powder, so technical treatment is important. Then, the volume of the close contact mixing treatment between the acrylic emulsion adhesive (45%) and the charcoal carbon (55%) is increased to about 120%. In this case, the completed charcoal powder may be used to prepare various eco-friendly charcoal molding compositions using a press [6]. The molded composition is dried at room temperature after a firing process of about 30 to 90 minutes at a firing temperature of 90 to 300°C. Finally, the acrylic emulsion adhesive component is vaporized during the firing process, and the charcoal molded product becomes pure solid activated carbon of 95% or more. The eco-friendly water-soluble adhesive bonding consists of charcoal (charcoal), which is light and floating in water, and the pores of the charcoal are alive, the charcoal powder is hard without getting on the hands [8]. Activated charcoal is a carbon body and is a porous structure with fine pores, so it can be widely used as a natural deodorant and a dehumidifying agent due to its excellent antibacterial and dehumidifying functions of various water resources. It can also be used as a material for health products such as electromagnetic absorption, far-infrared emission effects, air cleaning by anion emission, blocking of waves harmful to the human body from water veins, and electromagnetic interception of electronic products [9]. Figure 2 shows the pore and porous structure of charcoal.

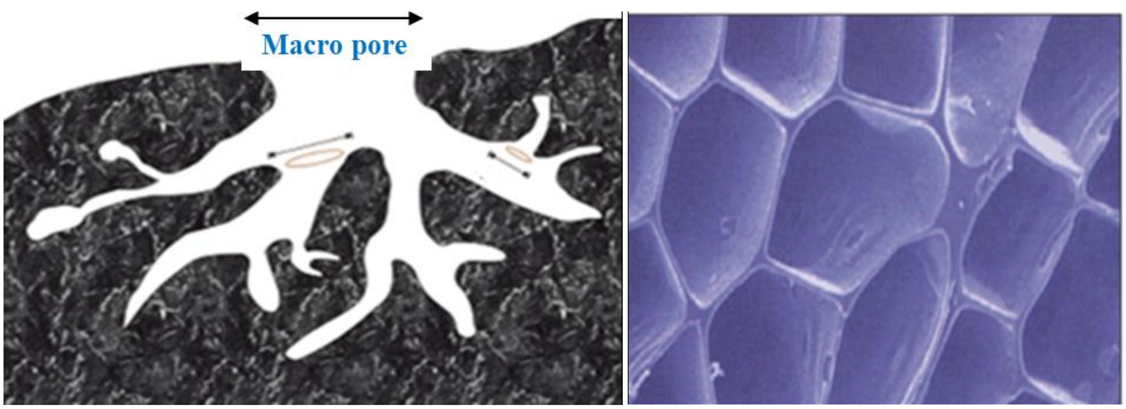


Figure 2: The Pore and Porous Structure of Charcoal.

2.2 Nanocarbon Coating Spray System

The carbon molded body is a product that finely pulverizes charcoal and processes it into a powder of about 300mesh, increases the fixed carbon content of charcoal through heating (2000~2400℃ using an electric furnace) and natural cooling processes (extraction pumps), has no harmful substances like conventional formaldehyde, and has a mass reduction rate of 10~18% even at a high temperature of 1700℃. However, when carbon molded bodies are preserved using existing carbon coating agents, they cannot adapt to heat resistance and there is a problem with the safety of the produc [6] t. When a molded body is manufactured using nanocarbon, it is vulnerable to cracking, damage, cracking, peeling, and fire over a certain period of time. Cracks and peeling of the coating liquid are the most fatal failures due to repeated wear due to external loads, heat, and complex causes by moisture penetration. Fluorine and Teflon systems, the most common coating methods, were used to solve this problem, but factors such as the water vapor of the parent agent are generated due to rapid temperature changes, and energy is used a lot. There is a method of using an aqueous acrylic system that requires temperature control under coating curing conditions of 100~200°C, but there is a possibility that Perfluorooctanoic Acid(PFOA) risk factors may occur during combustion and risks may occur under high-temperature environmental conditions. Finally, ceramic coating systems used without sudden temperature changes are the most efficient method to reduce energy use by 60-70% without risk factors.

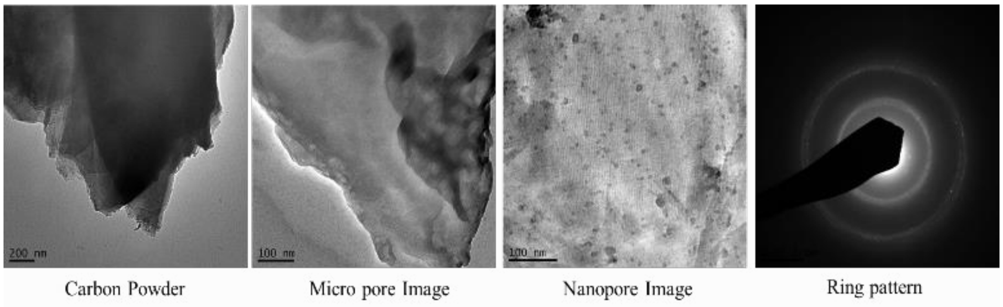


Figure 3: Types of Carbon Powder with a Transmission Electron Microscope.

The Nano carbon coating spray system in Figure 4 implements the optimal coating state by controlling the angle of the coating spray liquid, the optimal injection amount, and the temperature balance of the nozzle, and enables low temperature coating.

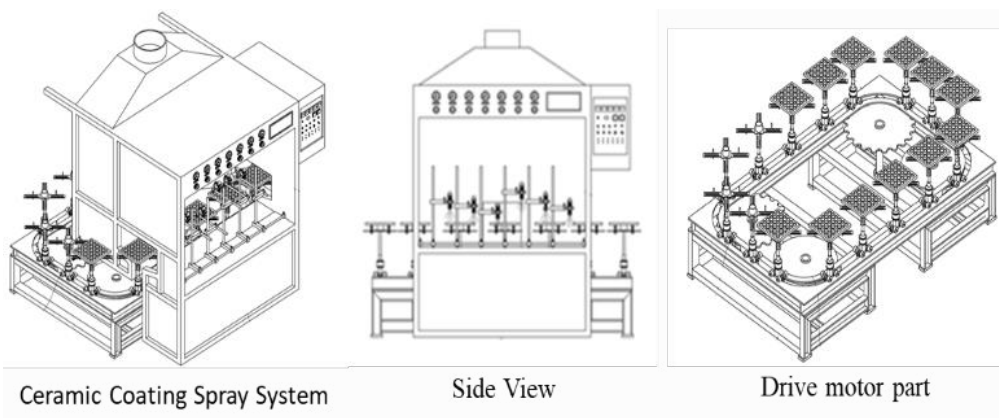


Figure 4: Nano Carbon Coating Spray System

Figure 5 secures the optimal control conditions for coating liquid injection through predicting the chemical phase change state and final change by controlling the driving speed of the injection system.

Figure 5: Automated Coating Dispensing System

In order to make a nanocarbon molded body with optimal performance, an appropriate temperature maintenance device was placed on the six nozzles, and an optimized automatic coating angle and equal coating function were given. The cross-section of the carbon molded body has a shape as shown in Figure 6, and the thickness of the coating layer is about 47~48μm.

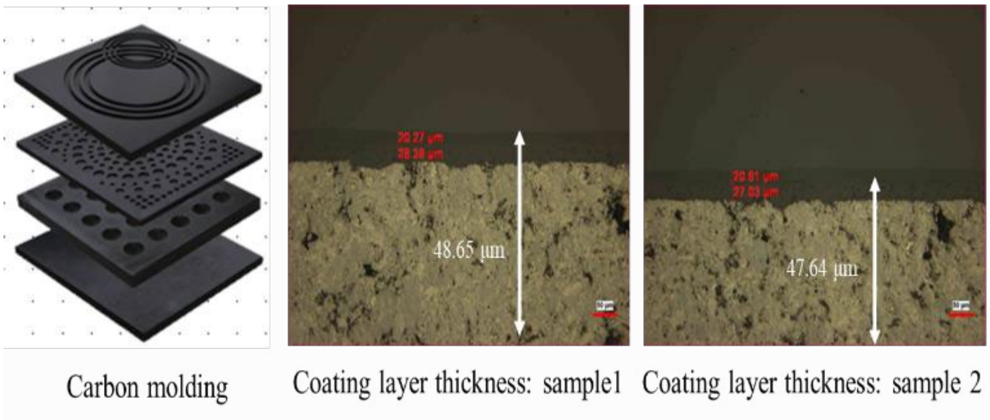


Figure 6: Carbon Molding and Coating Layer Sample

Four sample samples resistant to resistance, coating power, and abrasion were prepared through an automatic spray coating system. The product manufactured according to the coating method (Korea Ceramic Technology Institute) was measured through SEM photographs, and the coating state of the low-temperature coating solution could have an optimal state. Figure 7 shows examples of organic-inorganic composite coating, ceramic coating, and aqueous acrylic low temperature coating, respectively. Among them, the aqueous acrylic low-temperature coating is evaluated as the best coating case as the coating layer and the penetrating layer are properly represented. The presence of the penetrating layer indicates that the adhesion and function of the carbon molded body do not deteriorate easily over time.

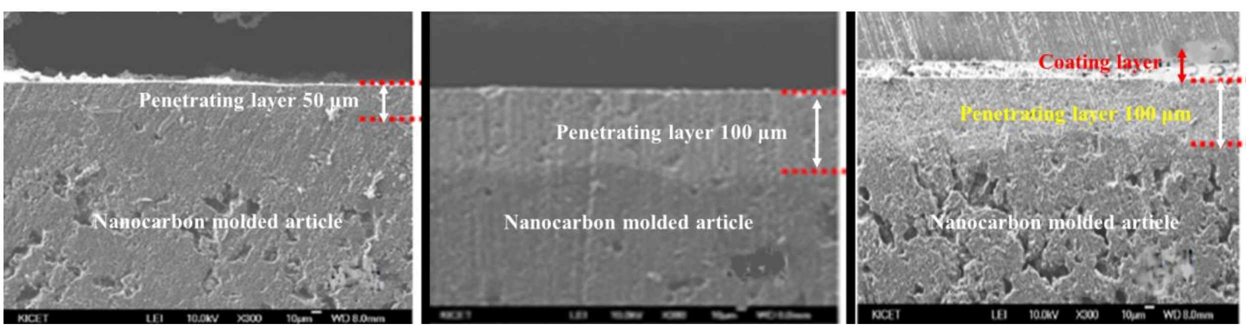


Figure 7: Organic-Inorganic Composite Coating, Ceramic Coating, and Aqueous Acrylic Low-Temperature Coating.

3. Experimental Results

Experiments is to analyze the carbon molding by selecting the standard test method (KSM ISO 11358:2006) from the Korea Institute for Construction Living Environment Test, a nationally recognized testing agency [10]. A steam composite wear tester was used for the fault reproduction test, and the test condition was to measure the thickness of the carbon molded body surface after repeated tests of 4,000 cycles under a load condition of 60°C and 30 kg. After the fault reproduction test, it can be seen that the coating surface is rapidly damaged, and if the coating surface is peeled off and its possession is revealed, the function of the product is lost due to surface contamination. Accordingly, the accelerated life test of the steam composite wear test is judged to be effective. Figure 8 indicates rapid damage to the coating surface after the fault reproduction test [11].

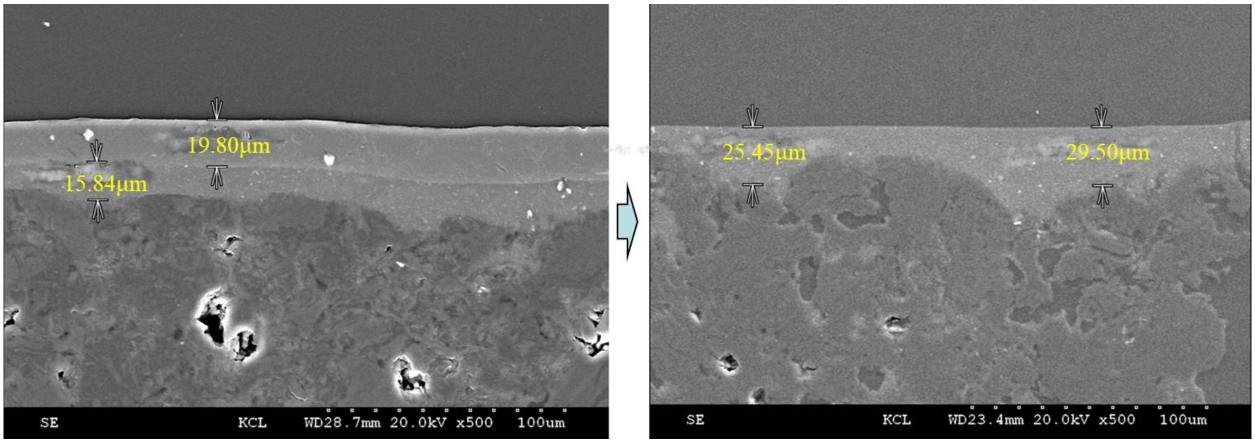


Figure 8: Coating Surface After the Fault Reproduction Rest.

The n sample tests follow a binomial distribution in which the failure number R for t hours is (n, F(t)) parameter.

$$R \doteq B(n, F(t)), \qquad F(t) = \int_0^t f(t)\,dt = 1 - e^{-\alpha t} \tag{1}$$

If the value of F(t) is sufficiently small, the failure number R approximately follows a Poisson distribution with parameter n F(t).

The fixed carbon content test is in accordance with ASTM D 5142, and is evaluated as shown in Table 1

Sample	Carbon rate(%)	Moisture(%)	Ash(%)	Volatile matter(%)
1	97.3	0.17	0.95	1.80
2	97.7	0.90	0.01	2.05
3	95.8	0.11	1.97	1.55

Table 1: Fixed Carbon Content.

The deodorization rate test follows KFIA-F1-1004. The deodorization rate test showed a deodorization rate of 85.4 to 89.6% in the initial sample test piece, but after improvement, the deodorization performance of the sample was enhanced to 93.8 to 100%. The initial concentration of the test gas is injected at 50 μmol/mol and measured at intervals of 30, 60, 90 and 120 minutes. During the test, the temperature is maintained at 23 ℃ ± 5 ℃ and the humidity is maintained at 50% ± 10%. Figure 9 shows the gas concentration curve (mol) over time.

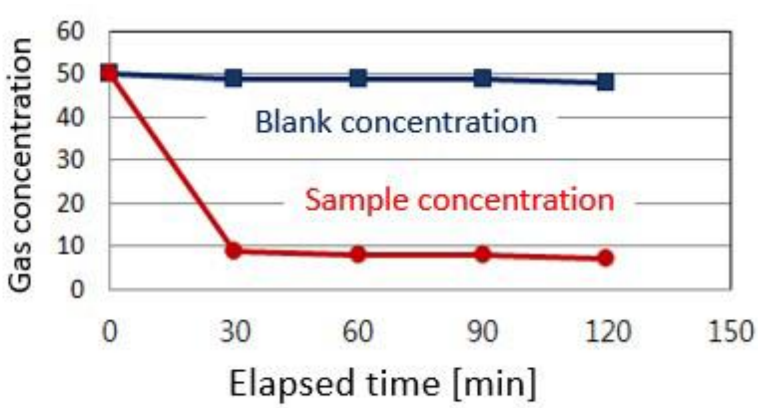
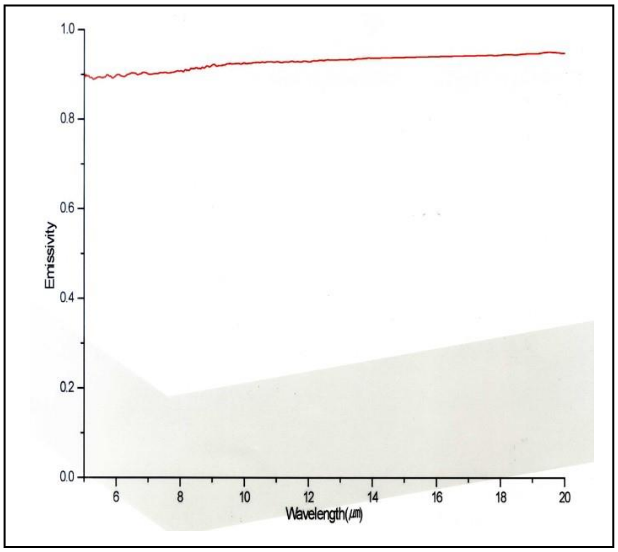


Figure 9: Gas Concentration Curve (mol) Over Time.

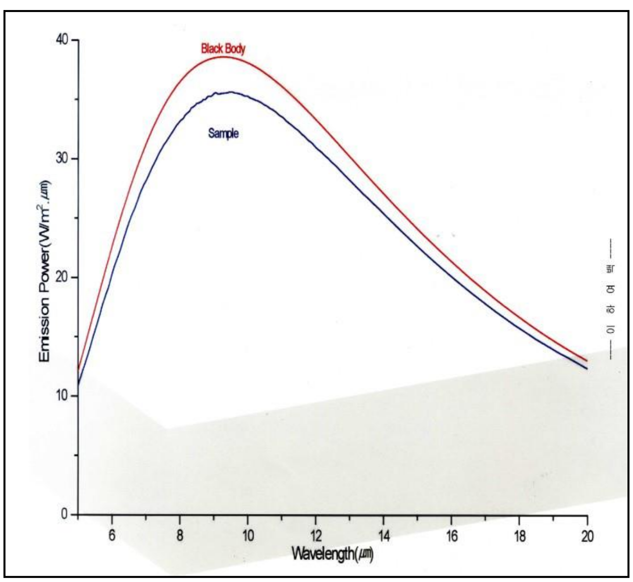
Elapsed time(Min)	Blank concentration	Sample concentration	deodorization rate (%)
0	50	50	0.00
30	49	12	75.5
60	49	6	87.8
90	49	4	91.8
120	48	3	93.8

Table 2: shows the Gas Concentration and Deodorization rate Over Time.

Figure 10 shows (a) far-infrared emissivity and (b) radiation energy measured using a spectrometer (FT-IR) at a temperature of 40°C and a wavelength range of 5 to 20µm. At this time, the average emissivity is 0.927, and the radiation energy is 374 W/m2.



(a) Far-infrared emissivity



(b) Energy distribution

Figure 10: Far-infrared Emissivity and Radiation Energy Measured

The antimicrobial test strains were selected by reviewing the strains that have a high frequency of occurrence in real life and can cause pathogenicity among the strains stipulated in various domestic and international test standards, and four bacteria (Escherichia coli ATCC 8739, Pseudomonas aeruginosa ATCC 15442, Staphylococcus aureus ATCC 6538P and Salmonella) were finally selected. In the test method, the inorganic foam board specimen (5 cm × 5 cm) was wiped with 70% alcohol to purify it, and then allowed to stand on an empty Petridish. The fungus cultured with the test strain on the stationary specimen is inoculated at a concentration of 1 to 4 × 105 CFU/mL. Then, after inoculation of the fungus, a film (4 cm × 4 cm) is covered. Thereafter, the specimen inoculated with the fungus was allowed to stand in a 37°C ± 1°C incubator for 24 hours, and the fungus on the specimen inoculated with the fungus was washed with buffer and smeared on the medium, and the fungus was measured by incubating it at 37°C ± 1°C for 24 hours. Table 3 shows the antimicrobial at 36-38 °C and he bacterial reduction rate is 99.9%.

Test issue		**1h density *(CFU/mL)***	**24 h *(CFU/mL)***	**Reduction rate (%)**
Colon bacterium	Blank	1.6×10^2	5.5×10^2	-
	Nano carbon	1.6×10^2	<10	99.9
Pseudomon-as aeruginosa	Blank	2.1×10^2	6.3×10^2	-
	Nano carbon	2.1×10^2	<10	99.9

Table 3: Anti-disease Germs Test.

In Figure 11, the thermal conductivity test was conducted according to ASTM E 1461, and this method measured the heat transfer time by projecting a laser onto one side of a small disk-shaped material with an infrared sensor.

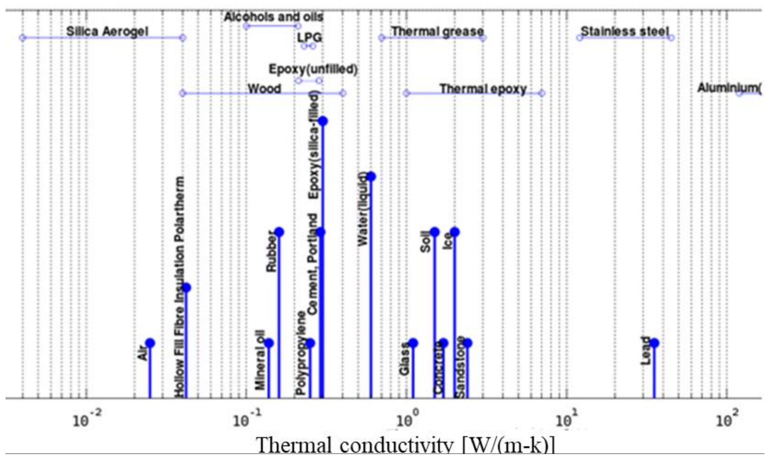


Figure 11: The Thermal Conductivity Test.

4. Conclusion

A nanocarbon molded body was realized by curing a styrene monomer and a methylol acrylamide monomer as main components of an acrylic emulsion adhesive, which is a water-soluble redox agent, and a reliability test was conducted. At this time, when the mixing ratio is composed of an acrylic emulsion adhesive (45%) and a 300 to 500 mesh coconut charcoal (55%) powder and mixed and stirred for 25 to 30 minutes, a spherical body with a diameter of 1 to 3 mm is formed. The molded composition undergoes a firing process at a firing temperature of 90 to 300°C for about 30 to 90 minutes and then dried at room temperature, the charcoal molded product becomes a pure solid activated carbon of 95% or more. Although there are many pores in the fired charcoal, it has a small surface area, so compared to the quick effect and the continuous effect, the surface area is widened and the pores are maximized when the charcoal is pulverized and activated. Therefore, it can be applied through various firing as well as building materials by conducting far-infrared ratio, energy analysis, gas concentration, and antibacterial experiments to prove eco-friendly charcoal molding.

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