Change of Surface Temperature and Far-infrared Emissivity in Ceramics Manufactured from a Board Mixed with Sawdust and Mandarin Peel

Jung-Woo Hwang - Seung-Won Oh

ABSTRACT

The aim of the study is to use the by-products sawdust, formed during sawing and mandarin peel which are agricultural by-products. The boards were manufactured by mixing the sawdust and mandarin peel at different mixing ratio and density. In terms of changes in surface temperature of ceramics, we could found that the velocity was fast in the early time of heat transfer until 10 minutes and after that the velocity increased but not very fast. At the elapsed time of 30 minutes, the surface temperature of ceramics increased with the carbonization temperature and rate of mandarin peel addition did not influence the surface temperature. Far-infrared emissivity had no constant tendency in rate of mandarin peel addition, it decreased with increase of carbonization temperature.

Keywords: composite board, mandarin peel, surface temperature, far-infrared emissivity

1. INTRODUCTION

The policies for the protection of domestic wood industries in countries with wood resources have not been established because of which the lack of wood resources is likely to continue. Therefore, eco-friendly materials must be developed using the available wood resources such as waste wood resources, construction waste, and thinned logs as domestic wood prices are rising every year. To overcome this issue, a domestic timber supply and demand system must be developed that can substitute for wood fiber and other fiber resources. In addition, new material resources must be developed using other agricultural by-products. Annual production of domestic mandarins is ~640,000 tons as of 2016, and 90% of these mandarins are processed into juices and beverages. An enormous amount of peel is generated as a by-product during processing (KOSIS, 2016). Dried mandarin peel can be used as a medical herb. Pre-treated dried mandarin peel can be used as a feed (Jang et al., 2004). However, storage of this dried peel is a problem because mandarin is cultivated every two months in a year. Thus, a significant amount of mandarin peel is dumped into the ocean, thereby causing environmental pollution.

Sawdust, a by-product from wood processing, is used herein. Since sawdust has a high water uptake rate, it is mainly used for manure handling in livestock farms. Sawdust compost is used for producing by-products and for feed.
Although the quantity of sawdust generated depends on the log thickness and lumber dimension, sawdust with a volume ratio of ~10% can be generally obtained. According to the Statistical Yearbook of Forestry 2017, 979,527 m³ and 53.9 billion won worth of sawdust was produced in 2016 and consumer price was 55,000 won/m³, which is only 1/5 of the wholesale price for lumber. Therefore, if sawdust produced from thinning logs and forest wood waste is used effectively, it will significantly contribute to the activation of domestic forestry and wood processing industry.

In this study, woodceramics are manufactured using new porous carbon material developed by Okabe and Saito (1995), which was obtained by carbonizing in vacuum after impregnating with phenol formaldehyde resin. It is light and hard and has excellent corrosion resistance, durability, and thermal conductivity. It has several characteristics, including electromagnetic wave shielding effect and far-infrared radiation, and is cheaper than other C-C compounds. Thus, this new material will be used as raw materials for producing electromagnetic products, friction materials, and automobile accessories in the future (Okabe and Saito, 1995a, 1995b; Oh, 2001, 2002, 2003) measured the physical properties of woodceramics developed from sawdust board made of thinned logs, and Oh (2002) and Oh & Byeon (2002, 2003) fabricated woodceramics under various conditions using medium density fiberboard (MDF) and determined its properties. By re-carbonizing the woodceramics made from sawdust board, Oh & Hwang (2009) prepared high-density woodceramics and determined its basic properties. Byeon et al. (2010) investigated the effect of carbonization temperature and resin impregnation rate on the properties of the woodceramics made from Broussonetia kazinoki Sieb. Oh et al. (2014) measured the basic properties of the woodceramics made from miscanthus sinensis var. purpurascens particles, and Won et al. (2014) studied the development of new material using ligneous materials by evaluating the nondestructive bending strength of miscanthus sinensis var. purpurascens woodceramics at carbonization temperatures.

Hwang & Oh (2017) determined the physical properties of woodceramics made from sawdust and mandarin peel. Oh et al., (2018) manufactured carbonized board at carbonization temperature using ash tree board, PB, MDF, and plywood and examined the possibility of using the carbonized board as a heating plate. Various manufacturing methods and applications have been studied (Hokkirigawa et al., 1996a, 1996b; Hirose et al., 2002; Iizuka et al., 1999; Xian et al., 2002; Zhao et al., 2002; Oh and Park, 2010; Oh and Piao, 2004; Hwang and Oh. 2017). This study examined the possibility of using carbonized board as a planar heating element by evaluating the changes in surface temperature of the composite woodceramics and the far-infrared radiation properties based on the manufacturing conditions. These parameters were evaluated for boards prepared using different density and mixing ratios of mandarin peel and sawdust. These boards were impregnated with resin and ceramicized via carbonization at ≥ 600°C.

2. MATERIALS and METHODS

2.1. Testing materials

2.1.1. Sawdust

Sawdust obtained from the thinning of Larix kaemferi C. was purchased from sawmill. For the uniformity of the samples during the manufacture of the board, the particle size of 18 mesh was selected and the water content was adjusted to ≤ 6%.

2.1.2. Mandarin peel

Mandarin peel was purchased from Jeju Island and dried under shade. To increase the bonding strength
during board manufacturing, a particle size of 18 mesh was obtained by crushing the peel using a pulverizer and water content was adjusted to ≤ 5%.

2.1.3. Resin
To prepare a board mixed with sawdust and mandarin peel, powder phenolic resin (KNB-100PL, manufactured by Kolon Chemical Industry Co., Ltd.) was used. The amount of resin added was 10% (weight ratio) of the mixed amount of sawdust and mandarin peel. A liquid phenolic resin (KPD-L777, KOLON CHEMICAL Co., Ltd.) was used for impregnation to produce woodceramics. Table 1 shows the properties of each resin.

Table 1. Characteristics of phenol-formaldehyde resin for the test

<table>
<thead>
<tr>
<th>Items</th>
<th>Powder resin (Novolak type)</th>
<th>Liquid resin (Resol type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid content (%)</td>
<td>99</td>
<td>51–53</td>
</tr>
<tr>
<td>Melting point (℃)</td>
<td>80–95</td>
<td>-</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>-</td>
<td>1.06</td>
</tr>
<tr>
<td>Gelation time (sec)</td>
<td>80–120</td>
<td>80–95</td>
</tr>
<tr>
<td>Plate flow (㎜)</td>
<td>30–35</td>
<td>-</td>
</tr>
<tr>
<td>Viscosity (cps)</td>
<td>-</td>
<td>45–65</td>
</tr>
</tbody>
</table>

2.2. Test method

2.2.1. Preparation of composite board
To manufacture the board, uniformly selected sawdust and mandarin peel and powdered phenolic resin were fully mixed and placed in a stainless square mold on a hot plate of a hot press. A board size of 26 cm in width × 26 cm in length – 1.4 cm in thickness was produced via hot press molding. To obtain a board of 0.6-g/cm³ density, mandarin peel was added in the ratios of 5%, 10%, 15%, 20%, and 25%.

When the mandarin peel addition ratio was 10%, a board with a density of 0.4, 0.5, 0.6, and 0.7 g/cm³ was manufactured. A total of 10 boards of each density was manufactured at a hot pressing temperature of 190°C, pressure of 40 kgf/cm² → 30 kgf/cm² → 20 kgf/cm² (three-stage pressurization), and pressing time was 6 min → 5 min → 4 min (three-step pressing time). To maintain a constant board thickness during hot pressing, a thickbar was used. A teflon plate was used to prevent the adhesion of the upper and lower surfaces of the board due to heat from the hot plate.

2.2.2. Impregnation of composite board
The size of the manufactured board was 1.4 × 12 × 12 cm³, and its density was calculated. In addition, a specimen with a target density of ± 0.03 g/cm³ was selected for each condition to keep the test conditions constant.

The prepared specimen was placed in an impregnation tank containing liquid phenolic resin. Then, decompression (1 atmosphere) and ultrasonic treatment (frequency: 28 kHz, output: 564 W) were performed for 20 min.

The specimen was subjected to these treatments at a normal pressure for 20 min. This process was repeated three times, and the impregnation rate was controlled by adjusting the repetition times. A decompression ultrasonic impregnation device used for impregnation comprises an impregnation tank, an ultrasonic vibration part, an ultrasonic oscillation part, and a vacuum pump. After the impregnated specimen was dried under shade for 8 h, it was placed in a drier and cured continuously at 60°C for 8 h and at 130°C for 8 h. Then, the physical properties of the board before and after impregnation were measured.

2.2.3. Manufacturing of woodceramics
Woodceramics were prepared by selecting boards with a resin impregnation rate of 60 ± 3% among boards with a mandarin peel addition ratio of 5%, 10%, 15%,
Change of Surface Temperature and Far-infrared Emissivity in Ceramics Manufactured from a Board Mixed with Sawdust and Mandarin Peel

20%, and 25% and board with a resin impregnation rate of 40 ± 3%, 50 ± 3%, 60 ± 3%, and 70 ± 3% among the impregnated boards with a mandarin peel addition ratio of 10% using a vacuum furnace. These boards were carbonized at 800°C. In addition, woodceramics were prepared by selecting specimens with resin impregnation rate of 50 ± 3% among the impregnated boards with density of 0.6g/cm³ and a mandarin peel addition ratio of 10% and carbonizing at 600°C, 800°C, 1000°C, and 1200°C, respectively. During this time, the temperature was raised from the room temperature to 4°C/min; after maintaining at the set temperature for 2 h, cold water was circulated around the carbonization furnace to cool it.

2.2.4. Measurement of properties

2.2.4.1. Calculation of impregnation rate

The resin impregnation rate of the impregnated material was calculated from Equation (1) as the percentage of resin injected for the oven-dry weight of the composite board.

\[
\text{Resin impregnation rate (\%)} = \frac{(W_1 - W_n)}{W_n} \times 100, \quad \text{········ (1)}
\]

where

- \(W_1\): the oven-dry weight of board after resin impregnation (g)
- \(W_n\): the oven-dry weight of board before resin impregnation (g)

2.2.4.2. Measurement of the surface temperature of woodceramics

To measure the surface temperature of the woodceramics, the surface temperature of the heater was increased. A temperature sensor was attached at the center of the heater after connecting the silicon rubber heater to the electric voltage regulator at the set temperature. The variation in temperature was measured by placing the woodceramics on the heated silicon rubber heater and attaching the temperature sensor to the four spots of the surface using a paper tape. The surface temperature of the silicon rubber heater was set as 60°C and the woodceramics was placed on it. The variation in the surface temperature of the ceramics was measured for 30 min at 3 min intervals. Then, the heater was turned off, after which the surface temperature of the ceramic surface and heater was measured for 30 min at 3 min intervals to determine the heat retention of woodceramics made from the manufactured board.

2.2.4.3. Far-infrared radiation

To investigate the far-infrared characteristics of woodceramics, a specimen of 30 × 30 × 2 mm³ was prepared and used as a test material. Far-infrared spectral emissivity was measured at 50°C using an FT-IR spectrometer (MIDAC, Corporation).

3. RESULTS and DISCUSSION

3.1. Surface temperature change of mixed woodceramics

To investigate the validity of the manufactured woodceramics as a planar heating element, the variations in surface temperature of the woodceramics were measured; the surface temperature of silicon rubber heater was maintained at 60°C. The results are shown in Figs. 1–6. Woodceramics’ surface temperature increases with time (Figs. 1–3). As shown in Fig. 1, surface temperature rapidly increases depending on the resin impregnation rate for 12 min and become gradual thereafter. Ceramic has a fast heat transfer rate in the beginning. After 30 min, the surface temperature was 40.5°C, 41.7°C, 40.6°C, and 41.3°C when the resin impregnation rate was 40%, 50%, 60%, and 70%, respectively, thereby showing similar values regardless
Fig. 1. Surface temperature for percentage of resin impregnation as a function of heating time.

Fig. 2. Surface temperature for carbonization temperature as a function of heating time.

Fig. 3. Surface temperature for mandarin peels addition as a function of heating time.

Fig. 4. Relationship between cooling and descent temperature of surface of ceramics with resin impregnation ratio.

As shown in Fig. 3, in case of mixed woodceramics for which specimen with a resin impregnation rate of 60% was carbonized at a carbonization temperature of 800°C, change in surface temperature of woodceramics according to the mixing ratio of mandarin peel showed a tendency to rise rapidly until the elapsed time of 9 min and gradually increased thereafter. When the addition ratio was 5%, 10%, 15%, 20%, 25%, the surface temperature of the woodceramics at the elapsed time of 30 min was 39.1°C, 40.6°C, 40.1°C, 40.4°C, and 40.8°C, respectively. All five specimens showed similar values, indicating that the mixing ratio of mandarin peel does not influence the thermal conductivity after carbonization. Conversely, after measuring the increase
In surface temperature, the power of the silicone rubber heater was turned off to lower the surface temperatures of the heater and the woodceramics. The decrease in surface temperature of the heater was measured for 30 min at 3 min intervals; results are shown in Figs. 4–6. As shown in Fig. 4, a decrease in surface temperature of the woodceramics according to the resin impregnation rate was observed as the surface temperature of the heater decreased from 60°C to 42°C for 30 min. The surface temperature decreased from 40.5°C to 33.8°C for specimen with a resin impregnation rate of 40% and from 40.6°C to 35.4°C for specimen with a resin impregnation rate of 60%. It decreased from 41.3°C to 35.7°C when with the resin impregnation rate was 70%. Accordingly, the surface temperature of woodceramics decreased gradually after a point of time. As shown in Fig. 5, the surface temperature of the woodceramics decreased as the surface temperature of the heater decreased from 60°C to 42.8°C for 30 min. The surface temperature decreased from 38.9°C to 34.5°C for specimen carbonized at 600°C and from 40.9°C to 35.0°C for the specimen carbonized at 1000°C. It decreased from 42.5°C to 36.0°C for the specimen carbonized at 1200°C, continuing to decrease gradually with time. The difference between the initial temperature of the specimen prepared at carbonization temperature of 1200°C and the temperature after 30 min was large (6.5°C), and the surface temperature of the specimen at 600°C was relatively low (4.4°C). Regarding the decrease of surface temperature of the woodceramics, a lower carbonization temperature was associated with higher degree of heat retention. As shown in Fig. 6, the surface temperature of the mixed woodceramics according to the mixing ratio of mandarin peel decreased as the surface temperature of the heater decreased from 60°C to 42.2°C. The surface temperature decreased from 39.1°C to 34.4°C for the specimen with mandarin peel addition ratio of 5% and from 40.1°C to 34.4°C for the specimen with mandarin peel addition ratio of 15%. It decreased from 40.8°C to 34.6°C for the specimen with mandarin peel addition ratio of 25%.

The higher the addition ratio, the rapidly the ceramic surface temperature decreases but the difference is insufficient. Thus, woodceramics manufactured with the resin impregnation ratio of ≥70% and mandarin peel addition ratio is 5% at 1200°C can be used as a raw material. Further, since the manufactured woodceramics retains heat for a long time, it can be used as a material for a planar heating element. However, as the change in surface temperature of woodceramics seems to be most closely related to the density of the specimen, parameters, such as resin impregnation rate, carbonization temperature,
temperature rise, material properties, and electrical properties, required for woodceramic manufacturing must be studied in the future.

3.2. Far-infrared radiation characteristics of mixed woodceramics

Far-infrared emissivity and infrared-radiation emission power were measured for mixed woodceramics with a resin impregnation rate of 60% carbonated at 800°C. Results are shown in Figs. 7 and 8. Total emissivity compared to ideal blackbody in the 5-20-µm wavelength region of the woodceramics was 0.929, 0.927, 0.929, and 0.930 when the mandarin peel addition ratio was 5%, 10%, 15%, and 20%, respectively. The far-infrared emissivity by mandarin peel addition ratio increased slightly with increasing mandarin peel addition ratio. IR emission power was 375, 373, 374, and 375 W/m² when the mandarin peel addition ratio was 5%, 10%, 15%, and 20%, respectively. Thus, the IR emission power was the highest when the mandarin peel addition ratio was 5% but there was no significant difference when compared to other specimens.

Moreover, far-infrared emissivity and IR emission in accordance with the carbonization temperature of the mixed woodceramics were measured after carbonizing

![Fig. 7. Relationship between percentage of mandarin peels addition and IR emissivity.](image)

![Fig. 8. Relationship between percentage of mandarin peels addition and IR emission power.](image)

![Fig. 9. Relationship between carbonization temperature and IR emissivity.](image)

![Fig. 10. Relationship between carbonization temperature and IR emission power.](image)
the board with a resin impregnation rate of 60% and a mandarin peel addition ratio of 10%. Results are shown in Figs. 9 and 10. The far-infrared emissivity was 0.930 and 0.927 when the carbonization temperature was 600°C and 800°C, respectively. The far-infrared emissivity was 0.927 and 0.922 when the carbonization temperature was 1000°C and 1200°C, respectively. This indicates that the far-infrared emissivity decreased as the carbonization temperature increased. IR emission power was 374 and 373 W/m² when the carbonization temperature was 600°C and 800°C. IR emission power was 374 and 371 W/m² when the carbonization temperature was 1000°C and 1200°C, respectively. IR emission power tended to decrease as the carbonization temperature increased. Oh (2016) reported that higher carbonization temperature is associated with decreasing emissivity in far-infrared emissivity measurement of woodceramics made with sawdust and rice husk. This far-infrared emissivity was higher than silica sand (0.60 ~ 0.80), elvan (0.90), and SiO₂ (0.83) and similar to charcoal (0.93), graphite (0.93), and ceramic-coated board (0.924). In particular, woodceramics made with sawdust and rice husk showed higher value than the measured far-infrared emissivity of woodceramics made from thinned logs (Oh and Byeon,2006).

4. CONCLUSION

Using sawdust and mandarin peel, a mixed woodceramics was prepared using various resin impregnation rates, carbonization temperatures, and mandarin peel addition ratios. The surface temperature and far-infrared radiation characteristics of the mixed woodceramics were determined and the following conclusions were deduced:

1. As the surface temperature of the mixed woodceramics rapidly increased until the elapsed time of 10 min, the rate of temperature rapidly increased at the initial time of heat transfer. At the elapsed time of 30 min, the surface temperature increased as the carbonization temperature increased and the mandarin peel addition ratio had no significant effect on the surface temperature variations.

2. The far-infrared emissivity did not have a certain trend depending on mandarin peel addition ratio and decreased as carbonization temperature increased. IR emission power also showed a similar tendency as the far-infrared emissivity.

REFERENCES

Hwang, J.W., Oh, S.W. 2017. Physical and Mechanical Properties of Board Made from Carbonized Rice
Jung-Woo Hwang · Seung-Won Oh


Korean statistical information service. 2016. Agriculture, forestry and fishery.


주목: 본 연구는 톱밥과 농업부산물인 귤박을 이용하여 보드를 제조하고 세라믹화 하여 표면온도 및 원적외선 방사특성을 조사하였다. 세라믹의 표면온도는 경과시간 10분까지는 급속히 상승하였고, 30분 후에는 탄화온도가 높을수록 높았고, 귤박 혼합율별로는 별 영향이 없었다. 원적외선 방사율은 귤박 혼합율에 따라 일정한 경향이 없었고, 탄화온도가 증가할수록 낮은 값을 보였다.

1. 서론
Content in this document is a natural representation of a page with the text:

Change of Surface Temperature and Far-infrared Emissivity in Ceramics Manufactured from a Board Mixed with Sawdust and Mandarin Peel

를 제조하고 수지를 함침한 후 600℃이상의 고온으로 탄화하여 세라믹화한 후 제조조건에 따른 혼합세라믹의 표면온도변화 및 원적외선 방사특성을 조사함으로써 혼합세라믹을 면상발열체 소재로 이용가능성을 검토하였다.

2. 재료 및 방법

2.1. 공시재료

2.1.1. 톱밥

톱밥은 낙엽송(Larix kaemferi C.) 간벌재 제재 시 발생된 것을 시중 제재소에서 구입하여 사용하였으며, 보드 제조시 시료의 균일함을 위하여 입자의 크기를 18 mesh로 선별하고 함수율은 6%이하로 조절하였다.

2.1.2. 귤박

귤박은 제주도에서 구입하여 음건한 후 보드 제조 시 결합력을 높이기 위하여 분쇄기로 분쇄하여 입자크기를 18mesh로 선별하고 함수율은 5%이하로 조절하여 사용하였다.

2.1.3. 수지

톱밥․귤박 혼합보드 제조를 위하여 분말상 페놀수지(KOB-100PL)를 사용하였으며, 수지첨가량은 톱밥․귤박 혼합량의 10%(중량비)로 하였다. 세라믹 제조를 위한 함침에는 액상 페놀수지(KPD-L777)를 사용하였으며 각 수지의 특성의 Table 1과 같다.

2.2. 시험방법

2.2.1. 혼합보드 제조

보드를 제조하기 위하여 균일하게 선별된 톱밥과 귤박 및 분말상 페놀수지를 충분히 혼합하여 열압기의 열판위에 있는 스테인레스 정방형 몰드 속에 넣고 시료상부의 높이를 일정하게 조절한 후 열압 성형하여 가로 26㎝×세로 26㎝×두께 1.4㎝의 보드를 제조하였다. 보드의 제조 조건은 밀도 0.6g/㎤일 때 귤박 혼합율 5%, 10%, 15%, 20%, 25%인 보드, 그리고 귤박혼합율 10%일 때 밀도 0.4g/㎤, 0.5g/㎤, 0.6g/㎤, 0.7g/㎤인 보드를 각각 10장씩 제조하였다. 이때 열압온도는 190℃, 가압압력은 40 kgf/㎠ → 30 kgf/㎠ → 20 kgf/㎠(3단 가압), 가압시간 6분→5분→4분(3단 가압시간)으로 하였다. 열압과정에서 보드의 두께를 일정하게 하기 위하여 thickness bar를 사용하였으며, 열에 의한 보드의 상하면과 열판의 부착을 방지하기 위하여 테프론 판을 사용하였다.

2.2.2. 혼합보드의 함침처리

제조한 보드를 두께 1.4㎝ 그리고 단면의 크기를 가로 12㎝×세로 12㎝의 크기로 재단한 다음 밀도를 계산하였다. 또한 시험조건을 일정하게 하기 위하여 조건별로 목표밀도 ± 0.03 g/㎤인 시편을 선정하였다. 준비된 시편을 액상 페놀수지가 들어있는 함침탱크에 넣은 후 감압(1기압)과 초음파처리(주파수: 28kHz, 출력: 564 W)를 20분 동안 병행한 후 다시 상압에서 20분 동안 방치하는 방법으로 3반복하였고 반복시간을 조절하여 함침율을 조절하였다. 함침에 사용한 감압 초음파 함침장치는 함침탱크, 초음파진동부, 초음파 발진부, 진공펌프 등으로 구성되어 있다. 함침 후의 시편을 8시간 음건한 후, 다시 건조기에 넣고 60℃에서 8시간, 130℃에서 8시간 연속 건조 및 경화시킨 다음 함침 전후의 물리적 특성을 측정하였다.

2.2.3. 세라믹 제조

귤박혼합율이 5%, 10%, 15%, 20%, 25%인 보드 중 수지함침율 60±3%인 보드와 글박혼합율이 10%인 함침보드 중 수지함침율 40±3%, 50±3%, 60±3%, 70±3%인 보드는 실험에 사용하였다. 또한 밀도가 0.6g/㎤이고, 글박혼합율이 10%인 함침보드 중 수지함침율이 50±3% 시편을 선정하여 600℃, 800℃, 1000℃, 1200℃로 각각 탄화하여 세라믹을 제조하였다. 이 때 실험에서 설정온도까지 4℃/min으로 승온 하였으며, 설정온도에서 2시간 유지한 후 탄화로 주위에 납각수를 순환시켜 납각시켰다.

- 77 -
2.2.4. 물성 측정

2.2.4.1. 함침율 계산

함침재의 수지함침율은 혼합보드의 전건중량에 대하여 주입된 수지량을 백분율로 표시한 것으로 식 (1)로부터 구하였다.

\[ \text{수지함침율(\%)} = \frac{(W_1-W_n)}{W_n} \times 100. \]

여기서, \( W_1 \); 수지함침 후의 보드 전건중량 (g)  
\( W_n \); 수지함침 전의 보드 전건중량 (g)

2.2.4.2. 세라믹의 표면온도 측정

혼합보드로 제조된 세라믹의 표면온도 변화를 측정하기 위하여 전기전압 조절장치에 실리콘러버 히터(Silicon rubber heater)를 연결하고 목표온도를 설정한 후 온도센서를 히터의 중앙에 부착하여 히터의 표면온도를 고정하였다. 시간의 경과에 따른 세라믹의 표면온도 상승 및 하강변화는 실리콘러버 히터위에 세라믹을 올려놓고 그 표면 4곳에 온도센서를 종이테이프로 부착하여 온도상승 및 하강시간을 측정하였다. 가열된 실리콘러버히터위에 세라믹을 올려놓고, 그 표면 4곳에 온도센서를 종이테이프로 부착하여 온도상승 및 하강시간을 측정하였다. 시간의 경과에 따른 세라믹의 표면온도 상승 및 하강변화는 실리콘러버 히터의 표면온도를 60℃로 설정하고 그 위에 세라믹을 올려놓은 다음 3분 간격으로 30분 동안 세라믹의 표면온도 상승을 측정한 후 히터의 전원을 고고 세라믹 표면 및 히터의 표면온도를 3분 간격으로 30분 동안 온도상승 및 하강변화를 측정하여 세라믹의 열유지 정도를 조사하였다.

2.2.4.3. 원적외선 방사

세라믹의 원적외선 특성을 조사하기 위하여 가로 30mm×세로 30mm×두께 2mm의 시편을 제작하여 공시재료로 사용하였다. 원적외선 분광 방사율은 FT-IR Spectrometer(MIDAC, Corporation)를 이용하여 50℃에서 측정하였다.

3. 결과 및 고찰

3.1. 혼합세라믹의 표면온도 변화

톱밥과 귤박의 혼합보드로 제조된 세라믹을 면상발열체로 사용하기 위한 기초자료를 조사하기 위하여 실리콘러버 히터의 표면온도 60℃위에서 세라믹의 표면온도 상승과 하강을 측정한 결과를 Figs. 1~6에 나타내었다. 시간의 경과에 따른 세라믹의 표면온도 상승은 Figs. 1~3에 나타내었다. 수지함침율별 표면온도 상승은 Fig. 1과 같이 시간이 경과함에 따라 경과시간 12분까지 빠르게 상승하다가 이후에는 완만히 상승하는 경향을 나타내어 세라믹은 초기에 열전달속도가 빠름을 알수 있다. 30분 후의 표면온도는 수지함침율 40%, 50%, 60%, 70%일 때 각각 40.5℃, 41.7℃, 40.6℃, 41.3℃로 함침율에 관계없이 유사한 값을 나타내었다. 이는 시편들이 탄화 후 수지함침율에 따른 열전도도가 큰차이가 없는 것을 알 수 있다. 탄화온도별 세라믹의 표면온도 상승은 Fig. 2와 같이 경과시간 9분까지 빠르게 상승하다가 이후에는 완만히 지속하는 경향을 나타내어 세라믹은 초기에 열전달속도가 빠름을 알수 있다. 30분 후의 표면온도는 수지함침율 40%, 50%, 60%, 70%일 때 각각 40.5℃, 41.7℃, 40.6℃, 41.3℃로 함침율에 관계없이 유사한 값을 나타내었다. 이는 탄화온도 600℃시편은 38.9℃에서 41.7℃로, 1200℃시편은 42.5℃에서 42.8℃로 시간이 경과함에 따라 우드세라믹의 열 유지 정도를 조사한 결과를 Figs. 4~6에 나타내었다.

수지함침율에 따른 우드세라믹의 표면온도 하강은 Fig. 4에 나타낸 바와 같이 히터의 표면온도가 30분 동안 60℃에서 42℃로 감소함에 따라 수지함침율 40% 시편의 경우 40.5℃에서 33.8℃로, 60% 시편은 40.6℃에서 35.4℃로, 70%일 때 41.3℃에서 35.7℃로 시간이 경과함에 따라 우드세라믹의 표면온도가 완만히 하강하였다. 탄화온도별 우드세라믹의 표면온도의 하강은 Fig. 5와 같이 히터의 표면온도가 30분 동안 60℃에서 42.8℃로 감소함에 따라 탄화온도 600℃ 시편은 38.9℃에서 34.5℃로, 1000℃ 시편은 40.9℃에서 35.0℃로, 1200℃에서 42.5℃에서 36.0℃로 시간이 경과함에 따라 완만하게 하강하였다. 한편 탄화온도 1200℃로 제조된 시편의 처음온도와 30분 후의 온도차이가 6.5℃로 온도 변화가 컸으며, 600℃ 시편은 4.4℃로 상대적으로 작아 우드세라믹 표면온도의 하강은 탄화온도가 낮을수록 열 유지 정도가 높은 것으로 생각된다.
Change of Surface Temperature and Far-infrared Emissivity in Ceramics Manufactured from a Board Mixed with Sawdust and Mandarin Peel

The surface temperature change and far-infrared emissivity in ceramics manufactured from a board mixed with sawdust and mandarin peel is shown in Fig. 6. The surface temperature of the ceramic decreased from 60°C to 42.2°C as the surface temperature of the heater decreased. The ceramic with 5% mandarin peel had a surface temperature of 39.1°C, which decreased to 34.4°C when the surface temperature of the heater was 40.1°C. A 25% ceramic had a surface temperature of 40.8°C, which decreased to 34.6°C when the surface temperature of the heater was 40.1°C. The decrease in surface temperature was more significant as the mandarin peel content increased, but the difference was not significant.

The result shows that the mandarin peel⋅topsoil mixed board used to manufacture the ceramic has thermal properties and is a good material to use as a ceramic material. It is especially important to examine the effects of the mixing ratio, the peeling temperature, and the surface temperature on the ceramic surface temperature and far-infrared emissivity.

3.2. Emissivity of the Ceramic
The mixing ratio of 60%, the peeling temperature of 800°C, and the peeling temperature of 800°C resulted in a constant emissivity of 0.929, 0.927, 0.929, and 0.930, respectively. The emissivity increased slightly as the mandarin peel content increased, but the differences were not significant.

The emissivity of the ceramic increased slightly as the peeling temperature increased, and the emissivity was similar to that of wood⋅graphite (0.93), wood⋅coating plate (0.924), and other materials. The emissivity was higher than that of Oh and Byeon (2006) for the wood⋅graphite coating plate.

4. Conclusion
The results of this study show that the peeling temperature and far-infrared emissivity of the ceramic are affected by the mixing ratio, peeling temperature, and surface temperature. The ceramic with a lower mixing ratio and peeling temperature has a lower far-infrared emissivity. The ceramic with a lower surface temperature also has a lower far-infrared emissivity.