

Wave Characteristics and Availability on Far Infrared Ray of Kihouseki Stone Plate Sauna

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1. Introduction

It is said that a specific wavelength in the regime of far infrared ray plays a very important role for keeping our health due to the improvement of the blood circulation.¹ The characteristic of such wavelength is that its frequency is same as the resonance frequency of human body. Consequently, the stone plate sauna is effective only at the wavelengths near resonance frequency of human body.

The operation of far infrared ray to human body may be estimated as follows: when a specific wavelength in the regime of far infrared ray such as 1000 cm^{-1} wave number is discharged to the skin surface, the molecules such as H_2O which constitutes the skin surface violently vibrates accompanying with the resonance frequency and these vibration energies penetrates into the successive inner skin layers. This mechanism increases the internal energy of the blood and consequently, improves the blood circulation. These facts promote the perspiration from human body and also increase the sensory temperature. So, one can understand that such a radiant heat transfer mechanism is very different from that of thermal heat transfer based on temperature difference and temperature boundary layer.²

The present paper describes the characteristic wavelength and spectral emissivity of various kinds of stones employing typical stone plate sauna by Fourier Transform Infrared Ray Method. The paper also describes capabilities of stone plate sauna from the viewpoint of physical phenomena.

2. The effective wavelength on stone plate sauna

The effective wavelength of infrared ray from stone plate sauna ranges between $3\text{ }\mu\text{m}$ to $14\text{ }\mu\text{m}$ (evaluated based on strength of quantum energy). Table 1 shows the wave characteristics and effectiveness of far infrared ray ranged from $3\text{ }\mu\text{m}$ to $14\text{ }\mu\text{m}$.

In practical, the critical feature of wavelength emitted from stone plate sauna is that its frequency is identical with the resonance frequency of human body; such frequency may be estimated as approximately $10\mu\text{m}$ because of 36.5°C of body temperature. Also, the spectral emissivity of stone plate sauna needs to be more than 0.9 to maintain high-density energy. From Table 1, it can be seen that at the regime of far infrared ray of $3\mu\text{m}$ to $14\mu\text{m}$, the utilization of such wavelength is very significant and effective for our life living.³

Table 1. Wave characteristics of far infrared ray in the regime of $3\mu\text{m}$ to $14\mu\text{m}$

Wavelength (μm)	Characteristics	Effectiveness
8~10	Resonance frequency (human body)	Stone plate sauna
5~14	Promotion of plant growth	Agriculture
8	Absorption band of Methane	Combustion

3. Wave Characteristics of stone plate sauna

The main stones utilized in stone plate sauna are Black Silica, FU · Kihouseki, Germanium and Tensyouseki. Figures 1 and 2, respectively, depict the typical wave characteristics of Black Silika and FU Kihouseki as representative materials for stone plate sauna. The measurement of these wavelengths and spectral emissivities is carried out by method of Fourier Transform-Infrared Ray (FT-IR) and the measurement temperature of test material is 300°C so as to eliminate the spectral emissivity emitted from other materials. The calibration of spectral emissivity of stone plate material is conducted by using the standard test material of 0.94 spectral emissivity.

Fig 1 shows that the spectral emissivity of Black-Silica at $10\mu\text{m}$ is approximately 0.85. Fig 2 shows that the spectral emissivity of FU · Kihouseki at is approximately 0.9 for all wavelengths under consideration. If high performance of stone plate sauna is desired, its spectral emissivity needs

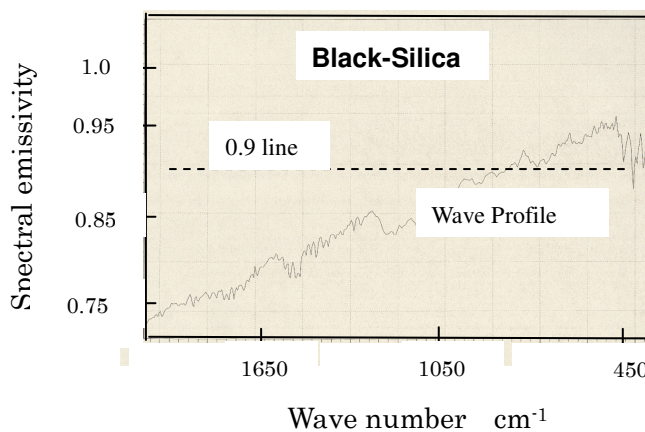


Fig.1. Spectral emissivity of Black-Silica

to be more than 0.9. Table 2 shows the spectral emissivities of Black Silica, Germanium, FU • Kihouseki and Tenshouseki at 600, 1050 and 1500 cm^{-1} wave numbers. From Table 2 it is concluded that FU • Kihouseki has a very high spectral emissivity. This means that FU • Kihouseki is very effective and very useful for stone plate sauna.

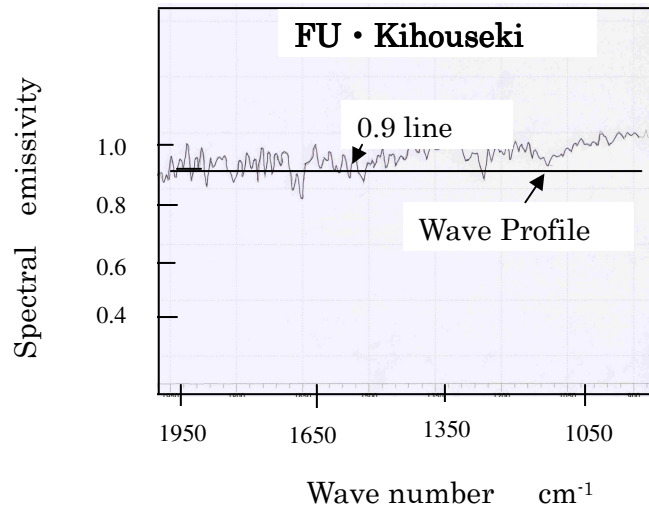


Fig.2. Spectral emissivity of FU • Kihouseki

Table 2. Spectral emissivity of several kinds of stone materials used for stone plate sauna.

	Wave number (cm^{-1})& spectral emissivity		
Wave number	600	1050	1500
Black Silica	0.92	0.86	0.80
Germanium	0.89	0.81	0.75
FU • Kihouseki	0.90	0.95	0.95
Tensyouseki	0.89	0.89	0.76

4. Physical property of far infrared ray emitted from stone plate sauna

The far infrared ray, which is a kind of electro-magnetic wave, may be 3 μm to 1000 μm in wavelength. The vibration frequency of electro-magnetic wave is expressed by equation (1),

$$\text{Vibration frequency} = (2.9979 \times 10^{14}) \div (\text{wavelength } \lambda \mu\text{m}) \quad (\text{Hz}) \quad (1)$$

and the energy of quantum from the electro-magnetic wave is also expressed by equation (2),

$$\text{Energy of quantum} = (1.2398) \div (\text{wavelength } \lambda \mu\text{m}) \quad (\text{eV}) \quad (2)$$

For example, in the case of 10 μm , the calculated values of vibration frequency and quantum energy are 2.9979×10^{13} Hz and 0.123 eV, respectively. The integral ratio of radiant energy between 3 μm to 20 μm is about 75% at 300K in ambient temperature.

Table 3 shows the values of quantum energy and vibration frequency at representative wavelength of far infrared ray, visible ray, ultraviolet ray and X-ray. From Table 3 one can understand that the wavelength in the regime of far infrared ray is very mild and safe for human body because it is 12 kJ/mol even at the quantum energy.

Table 3 Physical Properties of electro-magnetic wave

Electro-Magnetic Wave	Wavelength	Quantum Energy	Vibration Frequency
Far infrared ray	10 μ m	12kJ/mol	3×10^{13} Hz
Visible ray	0.5	239	6×10^{14}
Ultraviolet ray	0.1	1200	3×10^{15}
X-ray	10×10^{-5}	120000	3×10^{18}

5. Wave improvement of Stone plate sauna and FU • ERG

There are two desirable features for wavelength emitted from stone materials (stone plate sauna): one is the resonance frequency with human body and other is more than 0.9 in spectral emissivity. However, in natural world there are scarcely stone materials satisfying the above-mentioned two conditions. Fire-Up Ltd. has successfully developed the above-mentioned materials; see Fig.3 and Table 4.

Table 4. Physical contents of FU • ERG

Element	Character
Material Structure	multi-component of several kinds of electro-magnetic materials and metals
Wave • Spectral emissivity • radiant energy	①Spectral emissivity is more than 0.9 at 3 to 14 μ m in wavelength ②Integral ratio of radiant energy is about 75%.

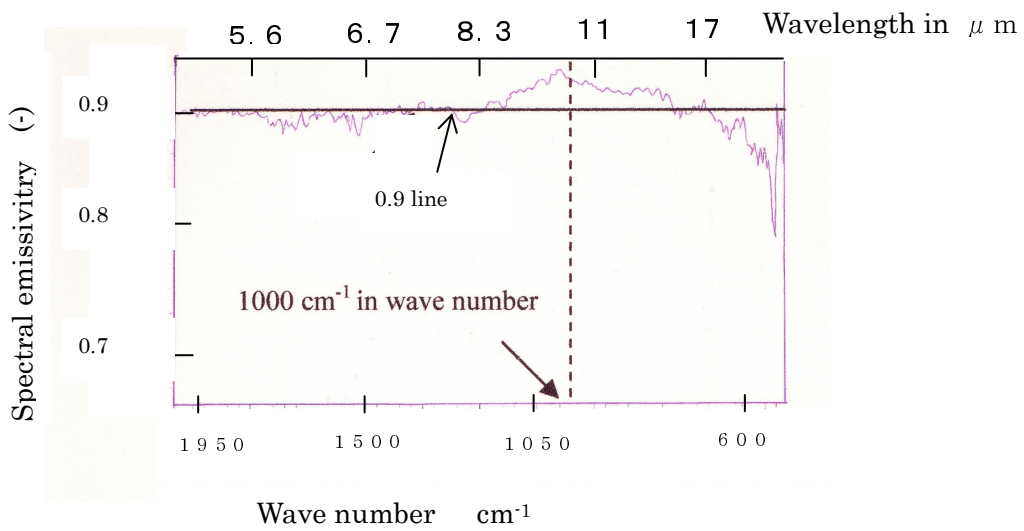


Fig.3. Spectral emissivity of FU · ERG developed by Fire-Up Ltd.

6. Safety of stone materials for stone plate sauna

The wavelength in the region of far infrared ray, that is, the wavelength used for stone plate sauna, is quite safe for human body. Fig.4 shows the safety standard on radioactivity. The strength of radioactivity of both FU · Kihoseki and FU · ERG is about 0.04 μ Sv. This value is considerably lower than that of national safety standard.

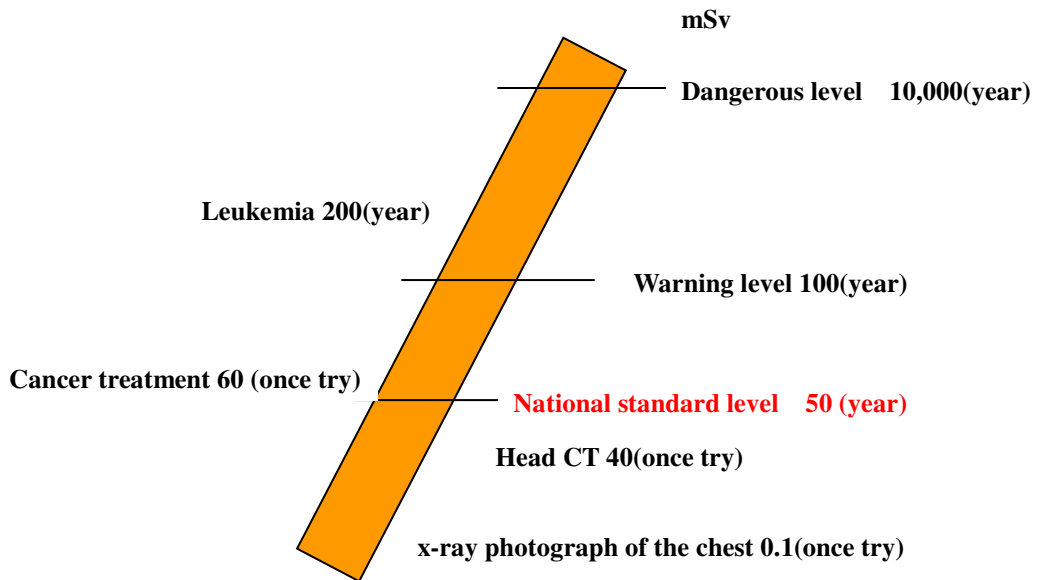


Fig.4. Safety criterion of radioactivity.

7. Conclusion

- ① The wavelength emitted from stone material of stone plate sauna has to include the resonance

frequency with high density energy.

- ② For FU • Kihousei and FU • ERG, the radiant energy and radioactivity are very small so that they are considerably safety for human body.

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