INCREDIWEAR

An Analysis of the Emissivity of Infrared Waves from Incrediwear Fabric

Background

The semiconductor elements embedded into Incrediwear products emit infrared waves and negative ions. Both infrared waves and negative ions are biologically active and have been shown to increase blood flow and velocity, mediate anti-inflammatory nitric oxide production, protect against or reduce muscle damage, scavenge reactive oxygen species, among other physiological benefits[1,2,3,4]. The purpose of this analysis is to report the infrared emissivity of Incrediwear and the effect of the emitted spectrum in mediating anti-inflammatory and pain pathways.

Incrediwear Fabric: Germanium and Carbonized Charcoal

The semi-conductor elements embedded into Incrediwear fabric are germanium and carbonized charcoal. Germanium, a pure element on the periodic table, is a semiconductor with 4 unpaired electrons in the outer-most orbital, or electron shell, moving around the atomic nucleus, or center of the atom. When germanium is exposed to temperatures above 32℃ (86.5°F), the outer most electrons absorb the energy and travel from the outer-most orbital to a higher energy orbital called the conduction orbital. As the electron falls back to the valence orbital, the energy that is emitted is in the form of infrared waves. Germanium has a small band gap of 0.66 eV at room temperature, making it particularly effective at emitting infrared waves[5]. In a similar fashion, Germanium facilitates the emission of negative ions, where one of the outer-most electrons from the atom becomes a free electron, combining with a molecule in the vicinity to produce negative ions. Since the human body temperature is >32℃ (86.5°F), the germanium present in Incrediwear fabric emits negative ions and infrared waves when it is worn.

Carbonized charcoal is created by heating bamboo to temperatures above 800°C. The resulting charcoal has a high porosity and large inter-particulate surface area, which can be ten times that of regular charcoal. The excellent adsorbent properties of bamboo charcoal have guided several studies to study the filtration and purification of air, wound healing capabilities, and anti-microbial uses[6]. Bamboo charcoal has also been shown to emit infrared waves and negative ions through the same process as germanium[7], which, in combination with the germanium in Incrediwear fabrics, provides the therapeutic benefit of the products.

Testing Methods and Design

The infrared emissivity of Incrediwear K100 and K300 fabric was tested at the Taiwan Textile Research Institute (TTRI) located in Taiwan. They utilized the FTTS-FA-010-2007 system which is an infrared spectrometer machine.

Molecular Vibrations and the Infrared Spectrometer Machine

An infrared spectrometer test machine analyzes a sample's emissivity by passing infrared radiation through the sample and measuring the energy absorption of the molecular bonds within the sample[8]. The absorption spectra from an atom or molecule gives information about which types of bonds are present[8]. Bond length and strength varies depending on the characteristics and composition of a molecule, meaning the frequency at which the bonds in the molecule absorb infrared energy varies for different molecules, which can help determine their identity. Germanium and carbonized charcoal have covalent bond between atoms. Figure 1 shows the different types of molecular vibrations present in covalent bonds[9]. The two broad types of molecular vibration are stretching and bending. The three-dimensional x,y, and z planes in which these vibrations occur give rise to the variability in vibration type.

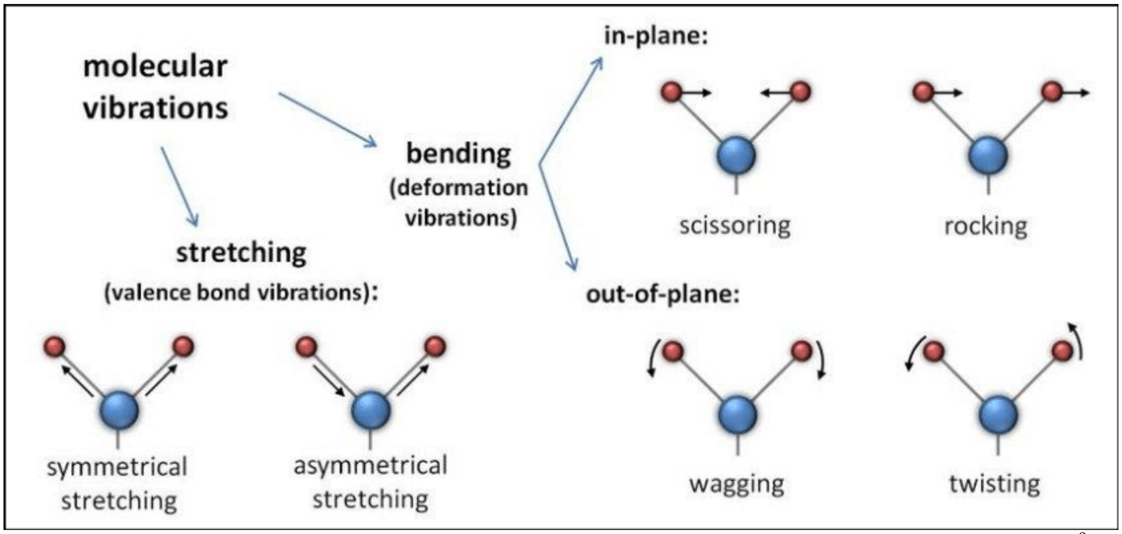

Figure 1. Visual of the different molecular vibrations with arrows indicating movements.[9]

The infrared spectrometer is an enclosed machine that has an ambient temperature of 20°C (68°F) and the sample surface temperature is 55 ± 2°C , which is optimized to provide a controlled environment and produce repeatable measurements. A schematic of the infrared spectrometer machine is shown in Figure 2.[10] A 5cm x 5cm piece of Incrediwear fabric is placed within the sample cell. The reference cell is a black body, which is an idealized physical mass that absorbs and re-emits the complete infrared spectrum, regardless of frequency of angle of incidence[11] and therefore a black body has an emissivity value of 1.0. The emissivity of Incrediwear fabric is compared to the black body, which serves as a reference point. The infrared energy source in the spectrometer emits infrared waves in the range of 2-22 µm. The waves are directed through several mirrors to focus the power and guide the beams to the sample cell[12]. These IR waves interact with the molecular bonds within the germanium and carbonized charcoal components, as well as the other thread types of the Incrediwear fabric. The absorbed and subsequently emitted IR waves are then passed through additional mirrors to re-focus the power and intensity. A diffraction element is used to determine the wavelength range, and a thermocouple measures the energy from the IR radiation. This energy is converted to a proportional electrical potential, which is then amplified and displayed on the recorder[13]. This test is repeated five times, and the average emissivity of the Incrediwear fabric is calculated through numerical analysis.

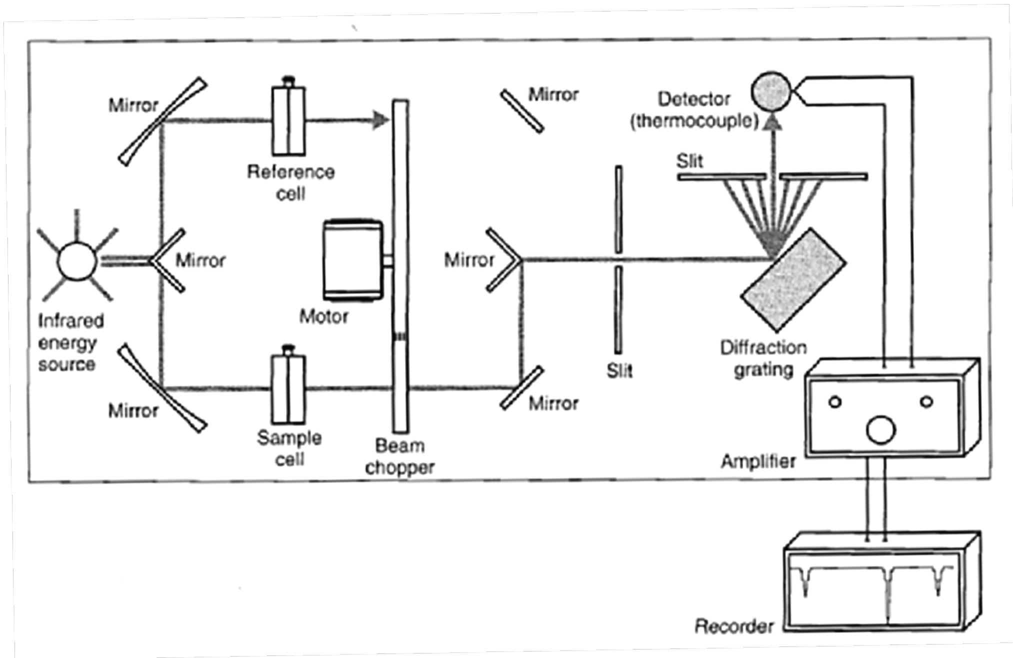

Figure 2. Diagram of an infrared spectrometer machine with a black body reference cell[10] used to conduct infrared emissivity measurement analysis on Incrediwear fabric. The fabric sample is placed within the sample cell and is compared to the emissivity from the reference cell.

Results

Emissivity is a measure of how efficiently a material emits infrared radiation compared to a perfect blackbody at a given wavelength. According to the IR measurement analysis report from the TTRI, the K100 fabric has an emissivity value of 0.83 and the K300 fabric has an emissivity value of 0.84. This means that the Incrediwear K100 fabric emits 83% of the IR radiation in the range of 2-22µm. The K300 fabric is 84% efficient in absorbing and re-emitting IR radiation within the 2-22 µm range.

Data Analysis and Discussion

An emissivity value of 0.83 and 0.84 is highly efficient and suggests that Incrediwear fabric is within the moderate to high emissivity range. Table 1 compares other materials emissivity values to Incrediwear fabric[14].

Table 1. Common Materials and Their Emissivity

Material	**Emissivity Value**
Human Skin	0.98
Water	0.95-0.98
Wood	0.8 – 0.9
Incrediwear	0.83-0.84
Titanium	0.5-0.6
Aluminum	0.2-0.4
Stainless Steel	0.1

While emissivity affects the intensity of emission at each wavelength, it does not change the wavelengths themselves. The material will emit IR radiation at certain wavelengths regardless of its emissivity. This distinction is important because the Incrediwear fabric may have an IR emission spectrum that extend outside of the 2-22 μm range. To determine the complete spectrum of wavelengths emitted by Incrediwear, a Fourier Transform Infrared (FTIR) spectrometer would be used to provide an emission spectrum, displaying a graph of IR intensity versus wavelength[15].

In addition to further testing on the specific emission spectra of Incrediwear, the emission power of a material is also useful to determine the therapeutic effect and capabilities of Incrediwear. Emission power can be solved mathematically with the Stefan-Boltzmann Law. This law describes the total power emitted per unit area of a black body across all wavelengths as a function of temperature. For a real material, such as in the case of Incrediwear fabric, the total power emitted is the product of the black body radiation and the material's emissivity[16].

The formula is as follows:

$$P_{material} = \epsilon\sigma T^4$$

Where:

$P_{material}$ is the total power radiated per unit area from the material

ϵ is the material's emissivity

σ is the Stefan-Boltzmann constant ($5.67 \text{ X } 10^{-8}$ W m^{-2} K^{-4})

T is the absolute temperature in Kelvin

Given the data:

Temperature, T = 55°C (which is 55 + 273.15 = 328.15 K)

Emissivity, $\epsilon = 0.83$

The total emission power of Incrediwear fabric is:

$$P_{material} = (0.83)(5.67 \text{ X } 10^{-8} \text{ W m}^{-2} \text{ K}^{-4})(328.15 \text{ K})^4$$

$$\mathbf{P_{material} = 546.877 \text{ W/m}^2}$$

However, the temperature at which the testing was conducted (55°C) is not reflective of real-world applications. Incrediwear requires body heat from the person wearing the fabric to activate the semiconductors and the release of IR waves and negative ions.

Therefore, these calculations, as well as the the IR spectrometer analysis done at TTRI could be performed at temperatures between 32°C and 36.5°C (average skin temperature is 36.5°C).

With this new lower temperature, the total emission power of Incrediwear fabric can be calculated as:

$$P_{material} = (0.83)(5.67 \text{ X } 10^{-8} \text{ W m}^{-2} \text{ K}^{-4})(309.65 \text{ K})^4$$

$$\mathbf{P_{material} = 432.019 \text{ W/m}^2}$$

Despite the lower temperature within the IR spectrometer and lack of data on the entire emission spectra of Incrediwear fabric from a Fourier Transorm test, an emissivity value of 0.83-0.84 with an emission power of 432.019 W/m^2 is still within a therapeutic range. According to several clinical trials focusing on the physiological benefits of far IR emitting textiles, an emission power of over 340 W/m^2 is sufficient to produce statistically significant results. In a double-blind study, twenty-one elite soccer players wore FIR emitting clothing post exercise. The clothing had an emissivity value of 0.88 with power of 341W/m^2. There was significant delayed-onset muscle soreness and an increase in creatine kinase, suggesting that FIR emitting clothes has a therapeutic effect on physical performance recovery[17]. Interestingly, another study utilized Mid IR waves to irradiate mouse brain slices with Alzheimer's disease. They used Mid IR at wavelengths 5, 6.17, and 7.19µm with a power of 350 W/m^2. The amyloid plaque dissociated from the brain slices, suggesting that Mid IR waves with a power of 350 W/m^2 has the capabilities to mitigate the progression of Alzheimer's disease in this study[18]. This is a breakthrough finding that gives Incrediwear fabric the potential to provide therapeutic benefit for neurodegenerative diseases.

Conclusion

Incrediwear K100 and K300 fabric have high emissivity values of 0.83 and 0.84, respectively. Compared to clinical trials with statistically significant results, the emissivity power of Incrediwear fabrics tested suggests that these fabrics are well within the therapeutic range. However, if the fabric is tested with a Fourier Transform Infrared (FTIR) spectrometer, the exact emission spectra of Incrediwear fabric, along with the corresponding intensity at each wavelength will provide additional information. Further infrared emission data needs to be collected for the most detailed and accurate understanding of infrared emission by Incrediwear fabric.

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