Running Head: INFRARED INTERACTIVE FABRICS

The Future of Clothing: Infrared Interactive Clothing

Jacob Mukobi

Camas High School

Abstract

Until now, most clothing manufacturers rely on cotton or cotton/polyester blends to make their textiles. These materials however, are too warm to wear on a hot day or during exercise. Several companies have tried to combat this issue. One major contributor in this field is Nike with their “Dri-fit” sportswear variety. The goal of Dri-fit is to wick sweat faster so it can evaporate more efficiently cooling the user down. It does this very effectively, but this is not the most effective way to remove body heat. That is through infrared radiation. If a textile could be created which allows this radiation to pass through, it would be revolutionary in high-heat and sporting clothing. My team is testing how much heat a plethora of materials absorb. We are doing this by exposing a swatch of the desired material to the infrared radiation, then measuring its temperature. From this, we can find out how much infrared radiation is being absorbed by the different materials. My team has tested three different variations of cotton and polyethylene: 100% cotton, 100% polyethylene, and a composite material made of both cotton and polyethylene. The least absorbent of which being the last material named. The ability to create an operative textile from polyethylene or our own infrared permeable material is our ultimate goal. This is the main application of the research and its completion would mean success for the enterprise.

The Future of Clothing: Infrared Interactive Fabrics

Currently, most communities rely on cotton/polyester composite fabrics to create the “ideal” clothing. This may be fine in cooler weather, but this kind of material is opaque to electromagnetic waves of the infrared spectrum. This means that most of the heat produced by the wearer’s body will be reflected back at them or absorbed by the clothing which only makes them warmer. Even in widely used sporting clothing intended to help athletes stay cool, this occurs. In America alone, we spend over 22 billion dollars per year on air conditioning (Carlozo, 2014). This could be solved in part by using textiles which allow the wearer’s body heat to escape. Affordably solving this issue could mean the end of miserable summers for many. If we test fabrics which are infrared-permeable, these include bamboo textiles and polyethylene against currently used infrared-impermeable fabrics such as cotton, polyester, wool, etc. , the textile which allows infrared radiation to pass through most efficiently will keep its wearer the coolest. This is because unlike common textiles, when worn by a person, the infrared heat emitted from the person’s body will be able to radiate directly through their clothing.

Others have made attempts at creating a scientifically sound super-fabric such as Nanoporous Polyethylene or bamboo clothing. However, these have proven to be undesirable options due to their inconvenience of production and their ecological footprint, respectively. My team can test various materials by placing the certain fabric between an infrared wave emitter to simulate the human body’s heat and an infrared thermometer. With this setup, we will be able to measure the amount of infrared radiation passing through any given material. Using what we learn during the experiment, my team can attempt to design our own fabric specifically for the purpose of better thermal regulation which may execute the function better than any other previously created infrared-permeable fabric.

Historical Overview

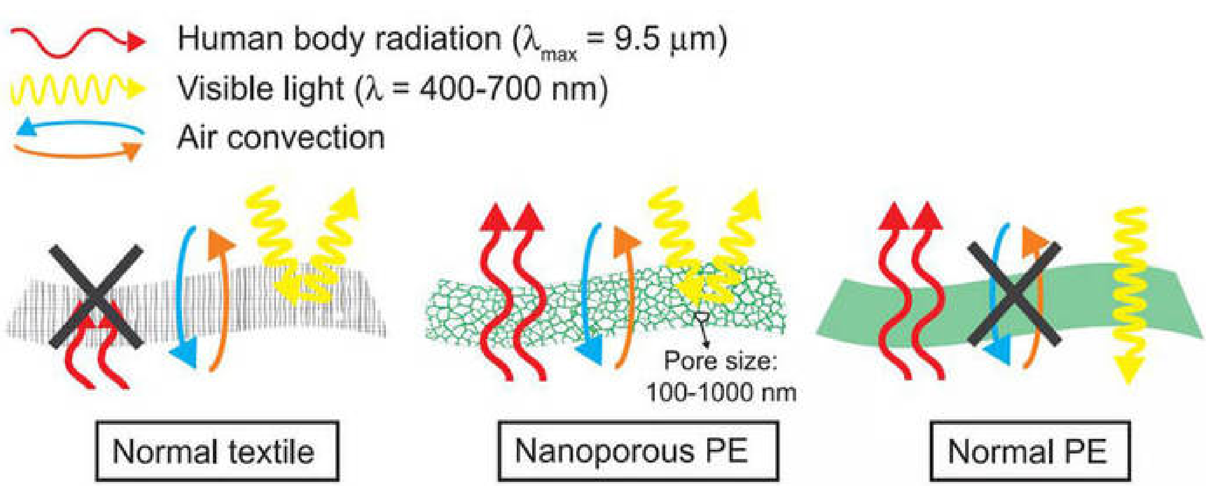
Clothing makes the human race unique. Originating as a tool, this technology has evolved into a massive and complex system of industry, trends, and science. From approximately 1000 BC to 1500 AD, the most common materials used in clothing included linen, wool, and fur. In the Renaissance Era from 1450 to 1600, new textiles appeared in apparel such as velvet, brocade, cloth, and silk. These were used in addition to previous types of fabric (Perkins, 2013). After this, the materials used to fabricate clothing did not vary much until the mid 19th century. At this point in time, the majority of civilization began to use cotton based cloth to make clothing. This evolved into cotton and polyester composite clothing we often wear today. Alongside this, denim jeans evolved as popular legwear options and still present but less common denim tops (Perkins, 2013).

Scientifically speaking, apparel has been accelerating in its rate of innovation. One example of this comes from the Yu Cui group of Stanford University. They created their own super-cool textile which uses a fabric made specifically for this purpose: Nanoporous Polyethylene, usually referred to as Nano PE. It is transparent to infrared wavelengths because it has micro pores which are between 100 to 1000 nanometers in diameter that allow infrared but not visible light to pass through. This is used to so the clothing is not transparent and sunlight is unable to heat up the wearer. These pores are also used to wick sweat and allow for airflow through the material (Cui et al., 2016).

One of the major drawbacks of this material is the fact that the team has to create the pores in the material instead of using one with automatically occurring pores. This causes Nano PE to be quite impractical to make, much less sell, as a mainstream apparel option. My team's goal is to find or create our own fabric which includes the benefits of Nano PE and that of conventional clothing's availability.

Current Trends and Practices

Right now, the Yu Cui group is at the forefront of modern clothing technology. Their design, though somewhat impractical, is a major innovation. If advanced to the point of possible mass production, Nano PE could become the next super-fabric. Its properties are found scarcely anywhere else and have the potential to forever change the apparel industry. Shown here are the benefits of Nano PE compared with the benefits and drawbacks of other materials: Polyethylene and a normal textile (cotton/polyester).



This diagram shows the flow of air and electromagnetic waves through the different materials. It demonstrates that because of its nanoporous design, Nano PE allows air and infrared waves to pass through but not visible light. These are qualities which the other fabrics do not possess (Cui et al., 2016).

Though it may not seem at first, apparel is a major scientific and technological field. Everyday, new and exciting clothing technologies are born. However, most are unable to surface on the market for a plethora of reasons . Unfortunately, Nano PE falls into this category. This is because of its previously mentioned manufacturing difficulties. At the present, the clothing industry is dominated by cotton and polyester blends which work well for many situations and are relatively affordable to produce. The catch which comes with these is they aren't perfect for many situations. My team hopes to improve on the already great Nano PE to make it able to succeed in its inevitable journey to the shelves next to already used conventional clothes.

Controversies and Debates

Another possible avenue of pursuit for the perfect textile lies in bamboo. This resource might seem exotic to fabricate clothes from, though it definitely has noticeable positives. Wearers of bamboo textiles often compliment its soft, luxurious feel. Not to mention, it's easy to clean, temperature regulating, sweat wicking, hypoallergenic, and allows for sufficient airflow. "ultra softness of cashmere and the sheen (luster) of silk." It may seem that bamboo is the ideal textile for several reasons including its seemingly green nature. "Bamboos are no doubt a renewable and sustainable resource that requires very little to zero pesticide to grow. It does not also require too much water and sunlight to stand tall." (How Green Are Bamboo Textile Clothes, 2013) On the contrary, bamboo is actually one of the worst textiles from an environmental standpoint. In order to make this type of textile, bamboo is ground to a pulp which is then treated with carbon disulphide to create cellulose fibers known as viscose rayon. The carbon disulphide which the pulp is treated with is extremely harmful to the environment and makes bamboo textiles extremely unsuitable for mass production (Nayak, Mishra, 2014). The Federal Trade Commision intervened the bamboo clothing industry in 2009 for this assault on the environment. “Rayon is a man-made fiber created from the cellulose found in plants and trees and processed with a harsh chemical that releases hazardous air pollutants. Any plant or tree could be used as the cellulose source—including bamboo—but the fiber that is created is rayon.” (Alter, 2014) Essentially, the commission is criticizing the claim that bamboo textiles are eco-friendly on the basis of its renewability. In reality, the process used to create them is extremely eco-unfriendly. As we are now living at the feet of climate change, we cannot afford to continue or accelerate our current rate of environmental destruction. Also, they point out that the fabric doesn’t even need to be made from bamboo. It can be made from any other cellulose source. It is just another word designed to influence shoppers to buy it. Bamboo textiles is one of the negative stimuli which simply can’t exist if humanity is to prevail. This is why bamboo cannot be chosen as the perfect textile.

Conclusion

Clothing, like any other significant aspect of our humanity has evolved over time in part due to science. Trail blazers in the field have helped accelerate this process. Bamboo and Nano Porous polyethylene are two fabrics which have potential for excellence but were unable to meet all of the requirements to reach the shelves. These are because bamboo clothing’s impact on the environment would be detrimental in the case of mass production, and Nano PE’s fabrication process is currently too difficult to be widely used similar to cotton and polyester. My team plans to contribute to the field by finding or designing and testing our own fabric in order to discover the most worthwhile textile. We will test currently popular “Dri-fit” and cotton/polyester composite against, materials which are permeable to infrared radiation (polyethylene, bamboo fabric, and others) to see which is most effective at keeping its wearer the coolest. During the experiment, it should be noted that the perfect textile is not only one which is permeated by infrared radiation the best but also which is ideal to fabricate clothing from. In example, paper is extremely functional as being transparent to infrared radiation. However, its extremely low tensile strength and water soluble nature makes it quite undesirable as a clothing option. As shown by prior creators, finding this perfect textile will be extremely difficile. However, when we consider the prospect of helping scientifically evolve the apparel industry, it is almost too tempting to turn down.

Materials and Methods

As of now, most clothing retailers sell mainly cotton and cotton/polyester composite textiles. These materials are also commonly used in high heat and exercise clothing. They can be great because they are easy and cheap to manufacture and generally satisfy consumers. The only problem with these is their heat absorption capabilities. In high heat and exercise conditions, these textiles display these capabilities quite well. When a user’s clothes absorb the majority of infrared radiation from the body and transform it into heat energy stored in the the clothes, instead of releasing that excess heat, the clothing acts as a heat magnifier. Several clothing companies have attempted to combat this issue by creating their own activewear clothing lines. One example of this is Nike’s “Dri-fit” which is designed to wick sweat more effectively than conventional clothes and remove heat from the body. However, when designing “Dri-fit” textiles, apparel designers did not focus on the most effective way to eliminate excess body heat. The main way the body does this is through infrared radiation. The goal of Dri-fit is to help sweat evaporate quicker which is also a large contributor to heat removal but not the largest.

In the experiment, we sought to detect the amount of infrared radiation that is absorbed by each material. To do this we suspended a swatch of the desired material in front of an infrared radiation emitter, the Presto 120v, 60hz, 1000w heat dish. The swatch was suspended in between the thermometer and heater at 58 centimeters from the heat dish. From this point, our team proceeded to turn on the heat dish to its maximum setting (“high”) to best highlight differences in heat absorption rates. We periodically measured and recorded the temperature reading on the thermometer of the swatch when it was first exposed to the infrared radiation, then again every two minutes until eight minutes had passed. We repeated this for each material being tested. In our experiment, my team used swatches of 100% cotton, a composite material of cotton and polyethylene, and 100% polyethylene.

Results

After measuring how much infrared radiation was absorbed through each variation of cotton and polyethylene fabrics, our team found that the composite fabric made of polyethylene and cotton was the least absorbent of infrared radiation from the Heat Dish. Shown in Table 1, it had an average starting temperature of 26.78 ºC and an average ending temperature after 8 minutes of exposure to the infrared radiation of 36.2 ºC. This is significantly less absorption than the other fabrics with the highest starting and ending temperatures being 28.26ºC and 40.6 of polyethylene and cotton, respectively. Also, clearly shown in Graph 1, the composite material maintained a cooler or equal temperature relative to the others throughout the entire experiment.

Graph 1: Average Heat Absorption of Different Materials Over Time

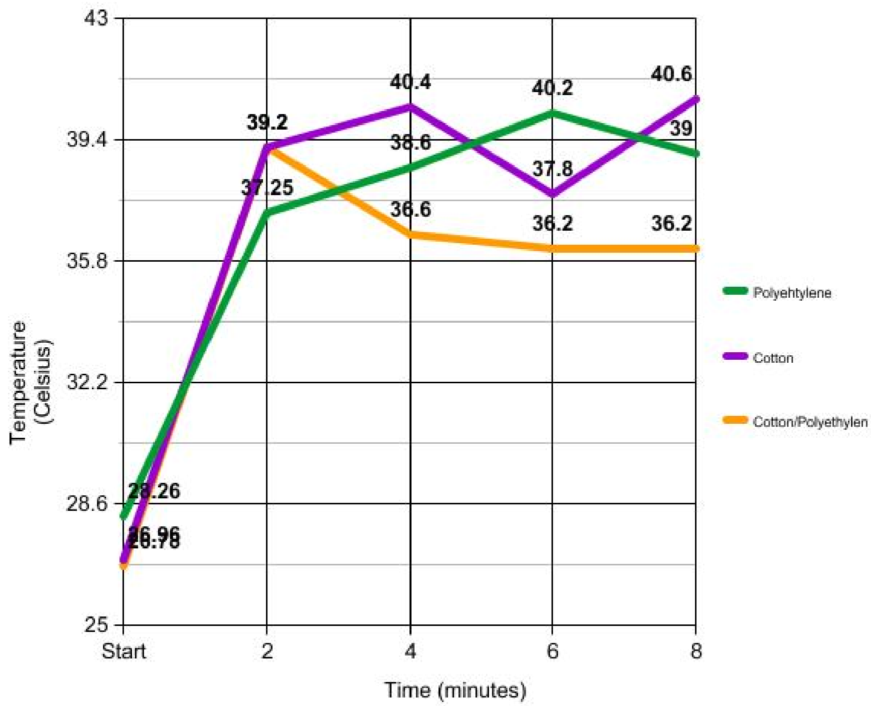


Table 1: Average Heat Absorption After Exposure to Infrared Radiation

Material	Start temp.	2 min	4 min	6 min	8 min
Cotton	26.96°C	39.2°C	40.4°C	37.8°C	40.6°C
Polyethylene	28.26°C	37.25°C	38.6°C	40.2°C	39°C
Cotton/Polyethylene Composite	26.78°C	39.2°C	36.6°C	36.2°C	36.2°C

Discussion

After analyzing our data, my hypothesis was not supported. I expected the pure polyethylene to absorb the least heat as our sample did in an earlier stage of the experiment and as it has been stated prior to our experiment in the Yi Cui group of Stanford University's paper on the topic: "Polyethylene is transparent to mid-infrared human body radiation but opaque to visible light." (Cui et al., 2016). Contrarily, our composite swatch with polyethylene and cotton absorbed significantly less heat than the other fabrics. This is likely due to the fact that we used high-density polyethylene in this stage because it has a marginally higher tensile strength than low-density polyethylene, making it more analogous to what would be used in a textile. As the name suggests, high-density polyethylene is more dense than low-density, thus making it more absorbent of infrared heat than its previously tested counterpart. However, the pure polyethylene was still less absorbent of infrared radiation than the swatch of cotton overall. This is due to its property of infrared transparency while less significant, it is still present in the high density variation.

Our research should be repeated and would be ideal if this could occur in more formal lab conditions. However, similar to any experiment, my team's could not be perfectly controlled making unintentional manipulations noteworthy. Especially with our budget and time limitations, we introduced several minor uncontrolled variables to the environment in which we were testing the materials. While it is unlikely they had any effects significant enough to deem data points erroneous, it would be worthwhile to control them to improve the accuracy of future results. In the weaving process, the cotton and polyethylene twine we used were of slightly different sizes and densities. This was because polyethylene is an uncommon material for weaving and is typically used in plastic bags, thus it is not commonly found in a twine/yarn form, so my team had few options to work with. Also, because the fabrics needed to be woven by hand, there were inevitable discrepancies in the form of the swatches. We also encountered several possible testing inconsistencies. One is temperature fluctuations and air currents. As in any environment, it is virtually impossible to perfectly stabilize the temperature and position of all particles. Though these changes are relatively insignificant, they can slightly alter measurements taken on the thermometer, performance of the infrared emitter, and properties of the air and subject materials, thus it was likely that the ambient air temperature fluctuated slightly during testing which could have unintentionally altered background rates of the fabrics' heat absorption and dissipation. Another problem with the method is inadvertent infrared emitter malfunctions. Without my team knowing, the heat dish could possibly vary its energy output due to faulty manufacturing, usage, unstable power source, and more. These problems, may not all have occurred or changed the outcome of the experiment but they should be noted in the context of a description of the experiment.

After flushing out our research, my team can expand the project to a wider area of application. The main use for such a material as we are searching for is in apparel technology, sportswear specifically. This is because of the unique property of textiles which are transparent to infrared radiation. The main heat dissipation technique the human body uses is emitting infrared radiation. The majority of commonly used clothes today absorb this radiation or reflect it back toward the wearer. Since infrared radiation is the main heat removal technique of the human body, this only further heats up the user. If the radiation is allowed to pass through the clothing, the user will be able to relieve themselves of their excess thermal energy much quicker than while wearing conventional clothing. Current sportswear attempts to remove heat by wicking sweat so it evaporates quicker than usual. It is effective at this, however, said technique is not the most effective form of heat dissipation.

In a later stage of our project, my team can use what we learn now to create a more advanced fabric which is transparent to infrared radiation and is more suited for use as a textile. Our design would be centered around this goal instead of accidentally acquiring the property. This would make it even more efficient at allowing infrared radiation to pass through than others and may have a greener production process than polyethylene. When designing the new fabric, it should be kept in mind that it must be durable, stretch-capable, non-irritating (tactile), and opaque to visible light. These positive qualities are all those which conventional clothing possesses and need to be included to have a functional textile.

Conclusion

Overall, our data displayed the least infrared absorption in the composite swatch, not my hypothesized front runner: Polyethylene. This means that when a user wears it, the infrared radiation emitted from their body will be able to pass through their clothing more efficiently than currently used textile varieties rather than being absorbed by the clothing.

This information adds a great deal of contributions to the specific area of research it occupies. Other than by the Yi Cui group of Stanford University who created Nano PE, a microporous infrared penetrable fabric, this is a previously unexplored field. Our findings also unlock paths for future research. For example, it's evident my team should attempt to not just find a material which is permeable to infrared radiation, but make a functional clothing article from it. This would be a proof of concept to show that it's possible to use the technology in sportswear and high heat clothing just like conventional versions of these clothes.

In a real-world situation, the application of our research is quite considerable. Improvement and eventual use of this technology will lead to an extensive improvement to athletics and warm-environment clothing. Once we learn how to create a fabric which is not only permeable to infrared radiation, but also sweat wicking, comfortable, and breathable, the product will be different than any other previously made clothing. On a hot day in direct sunlight, if a user is wearing a shirt made of this material, said user would feel like they are shirtless in the shade. This is because the visible light cannot pass through the membrane, yet air currents, sweat, and heat can pass through. The making of a textile permeable to infrared radiation is quite difficult but will be an important step in the evolution of apparel and is a path well worth following.

References

Alter, L. (2014, July 27). Whatever happened to: Bamboo clothing? Retrieved October 18, 2016, From http://www.treehugger.com/sustainable-fashion/whatever-happened-bamboo-clothing.html Carlozo, L. (2014, June 12). Americans spend billions for air conditioning. How to spend less while keeping cool. Retrieved October 18, 2016, from http://www.csmonitor.com/

Business/Saving-Money(2014, June 12). Americans-spend-billions-for-air-conditioning. -How-to-spend-less-while-keeping-cool

Healy, M. J. (2016, September 1). Hot? You Can Cool Down by Suiting Up in this High Tech Fabric. Retrieved October 06, 2016, from http://www.latimes.com/ science/sciencenow/la-sci-sn-cool-shirt-20160901-snap-story.html

Manthiram, K. (Ed.). (2015). Yi Cui Group - Stanford University. Retrieved October 18, 2016, from https://web.stanford.edu/group/cui_group/index.htm

Mass, E. (2009, Mar). Bamboo textiles. *Natural Life,* , 36-39. Retrieved from http://search.proquest.com/docview/213061034?accountid=40453

Nayak, L., & Mishra, S.P. (2016, January 26). Prospect of bamboo as a renewable textile fiber, historical overview, labeling, controversies and regulation. Retrieved October 15, 2016, from http://link.springer.com/article/10.1186/ s40691-015-0054-5

Perkins, S. (2013, April 19). Apparel History Timeline – The Evolution of Clothing Over Time. Retrieved October 18, 2016, from http://www.blankstyle.com/articles/apparel-history-timeline-evolution-clothing-over-time

Po-Chun Hsu, Song, A. Y., Catrysse, P. B., Liu, C., Peng, Y., Xie, J., . . . Cui, Y. (2016). Radiative human body cooling by nanoporous polyethylene textile.*Science, 353*(6303), 1019-1023. doi:http://dx.doi.org/10.1126/science.aaf5471

Rob, B. (2013, July 29). How Green Are Bamboo Textile Clothes. Retrieved October 12, 2016, from http://www.thegreenguide.com/how-green-are-bamboo-textile-clothes