Name:______________________________________**Teacher:**_________________

MOLECULAR STRUCTURE & FUNCTION | ASSESSMENT TASK HS-PS2-6

Scenario

It is common knowledge that when you are cold you can put on a jacket or a sweater. Material scientists are people who study the properties of matter and how they can be used. Recently a group of these scientists have been researching different materials and have developed a new reversible fabric that can both heat and cool the body depending on how it is worn. This fabric is described in the article excerpt below from *Chemistry World*, published by the Royal Society of Chemistry.

Reversible Textile Can Keep You Both Cool and Warm

BY **TIM WOGAN** 10 NOVEMBER 2017

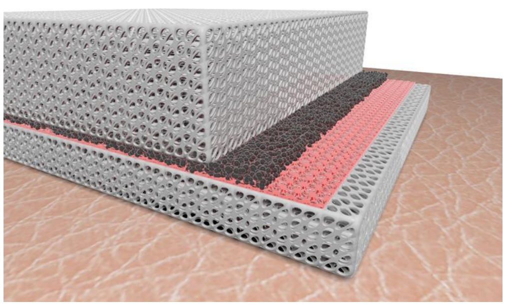


Figure 1.
The material features a thin copper and carbon layer sandwiched between a nanoporous polymer that can keep the wearer warm or cool, depending on which way it is worn.

A novel material (see Figure 1) could allow the creation of clothing that can keep you warm if worn one way, but cool you down if it's turned inside out. In the US, heating and air conditioning account for 12% of total energy consumption. In the developing world, extreme heat and cold often prove fatal. Clothing provides a simple solution for regulating body temperature, but traditional textiles' properties are constant, even though the weather can quickly change dramatically. A warm body always emits infrared radiation. Depending on conditions, this accounts for between 40% and 60% of human heat loss. A material designed to cool the body should enhance this emission, whereas one designed to keep it warm should suppress it.

Researchers at Stanford University have created a bilayer material comprising a micrometer-scale sheet of carbon, which emits radiation effectively, coupled with a copper layer, which is a very poor emitter. They covered each side of this bilayer with the breathable polymer nanoporous polyethylene, which is transparent to infrared radiation. The polymer above the copper is only half as thick as that covering the carbon.

When the metallic side faces a warm surface such as skin, the heat readily travels through the thin polymer to the bilayer by conduction. The heat then passes through the metal to the carbon and is emitted to the surroundings. If the material is turned around, the thicker polymer hinders conduction. The heat that <u>does</u> reach the bilayer is emitted much less readily by the metal surface.

The researchers studied the temperature of a synthetic skin sample when it was left bare, covered with a sweatshirt and covered with their material (see Figure 2). In the warm mode, their material kept the skin warmer than the sweatshirt; in the cool mode, it let the skin cool almost as well as bare skin. "The next step is for us to make this concept into a fiber structure so that these fibers can be woven together to make a textile that people will feel comfortable to wear," says principal investigator Yi Cui.

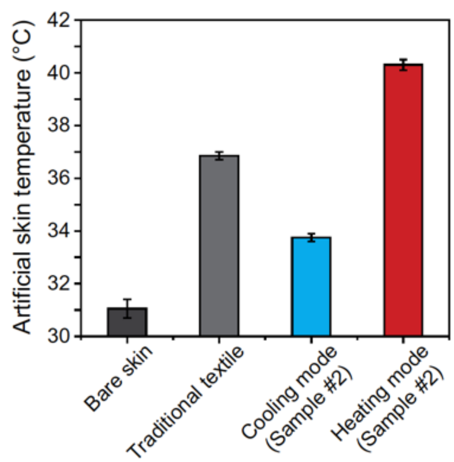
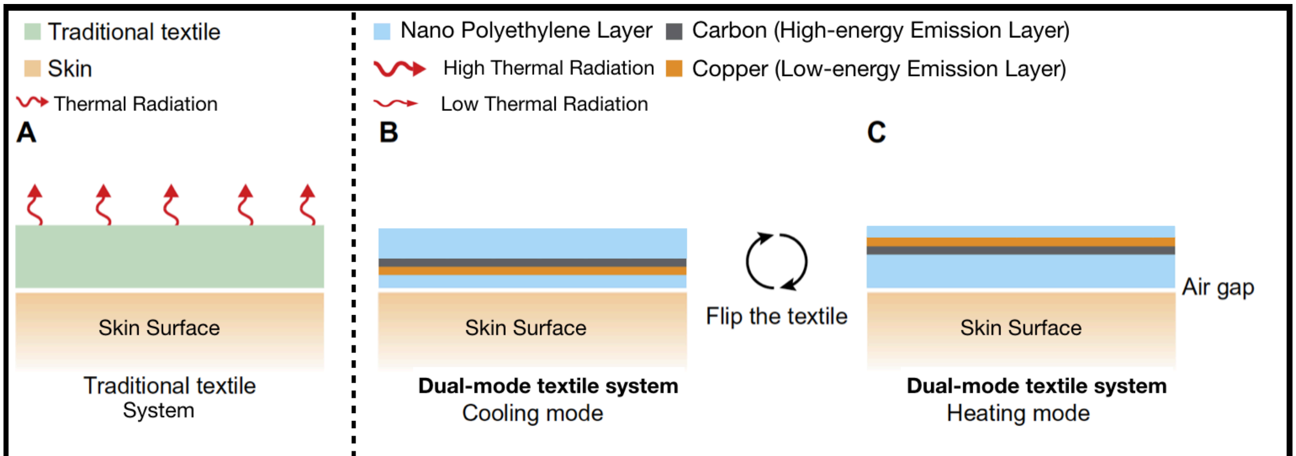


Figure 2.
Skin Temperature Under Various Conditions.

Funded by a USDE Math Science Partnership (MSP) grant through the Oklahoma State Department of Education.

Task 1

1. Using information from the article above **complete the model below by using wavy arrows to indicate how thermal energy (heat) is transferred in both (B) cooling and (C) heating mode** in the new dual mode textile (fabric). The traditional textile has been completed for you.



TRADITIONAL TEXTILE:
A) Traditional textile (fabric) have a fixed amount of heat transfer based on the material from which they are made.

DUAL MODE TEXTILE:
B) In cooling mode the high energy emission layer is on the outside reflecting heat away from the body while the low energy emission layer is absorbing energy from the body and transferring it to the high energy emission layer causing the body to cool.

C) In heating mode the low energy emission layer is on the inside reflecting heat toward the body while the low energy emission layer is absorbing energy from the outside and transferring it to the high energy emission layer causing the body to heat.

2. Explain how you completed the model to show transfer of heat in each system and how that heat transfer might help cool or heat the skin surface.

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Task 2

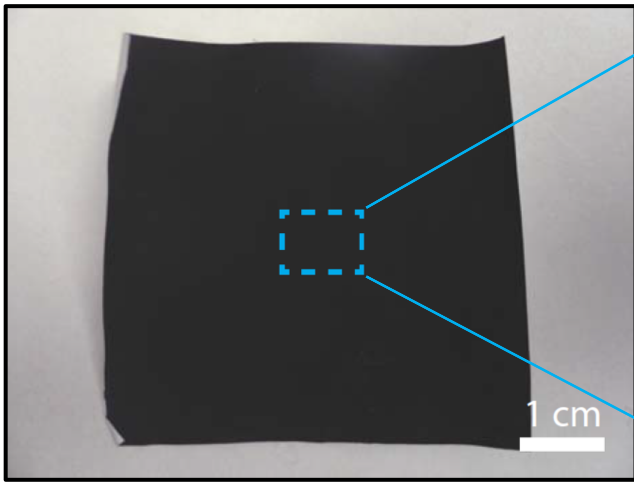

Figure 3.
Carbon (High-Energy Emission) Layer

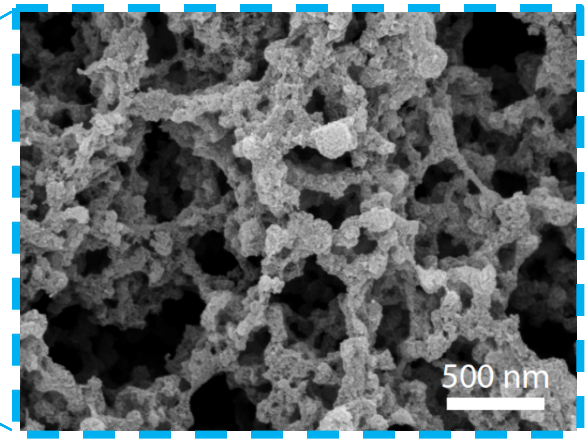

Figure 4.
Scanning electron microscope image of the molecular structure of a section of the carbon layer. Carbon atoms form covalent bonds with one another in a crystalline pattern.

3. Using figures 3 & 4, record observations of the molecular structure of the carbon in the carbon layer of the new fabric.

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4. How might the molecular structure of the carbon layer ***(Figure 4)*** affect the layer's appearance (***Figure 3***) at the scale that we can see with the naked eye?

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5. How might the molecular structure and the appearance of the carbon layer help it to absorb low amounts of heat (thermal radiation) and emit higher amounts of heat?

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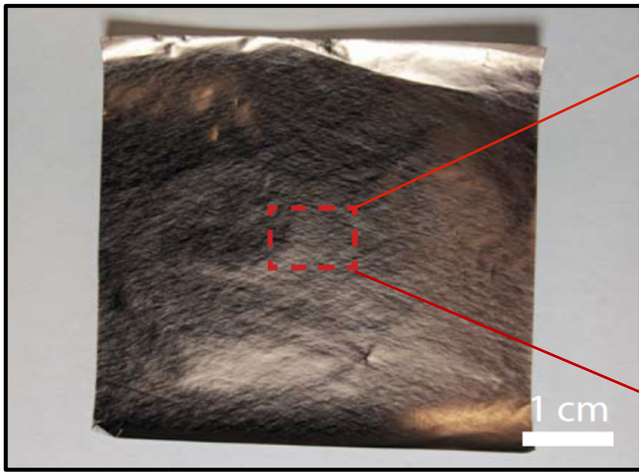

Figure 5.
Copper (Low-Energy Emission) Layer

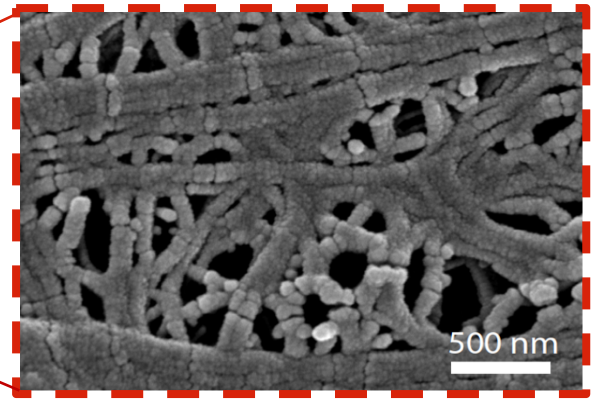

Figure 6*.*
Scanning electron microscope image of the molecular structure of a section of the copper layer. Copper atoms form ionic bonds with one another in flat bands through which electrons freely flow.

6. Using figures 5 & 6, record observations of the molecular structure of the copper in the copper layer of the new fabric.

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7. How might the molecular structure of the copper layer **(Figure 6)** affect the layer's appearance **(Figure 5)** at the scale that we can see with the naked eye?

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8. How might the molecular structure and the appearance of the copper layer help it to absorb high amounts of heat (thermal radiation) and emit lower amounts of heat?

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Task 3

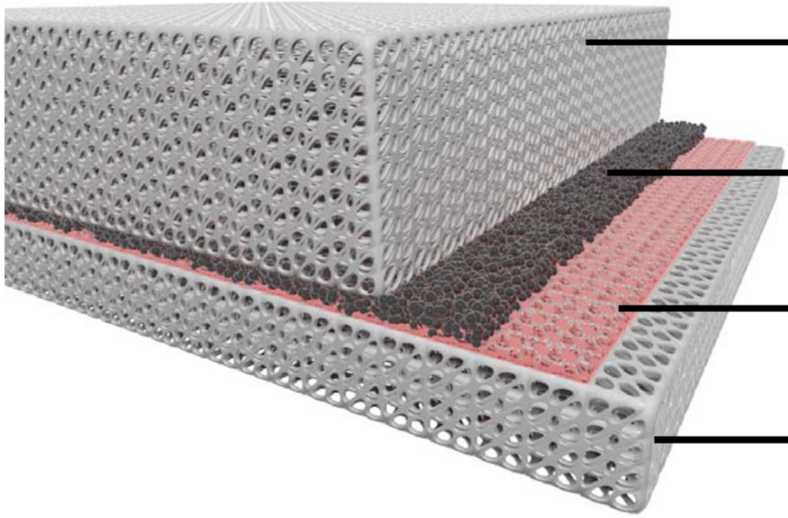

Figure 7.
Completely assembled fabric featuring a thin copper and carbon layer sandwiched between a nanoporous polymer that can keep the wearer warm or cool, depending on which way it is worn.

9. Explain how the newly engineered fabric can both heat and cool the body's skin surface using information from the article, Figures 1-7, and what you know about the structure and function of molecular bonds. Be sure to relate the molecular structure to the function of the fabric.

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References:

Hsu, P.-C., Liu, C., Song, A. Y., Zhang, Z., Peng, Y., Xie, J., . . . Cai, L. (2017). A dual-mode textile for human body radiative heating and cooling. *Science Advances, 3*(11), e1700895.

Wogan, T. (2017). Reversible textile can keep you both cool and warm. *Chemistry World*. Retrieved from https://www.chemistryworld.com/news/reversible-textile-can-keep-you-both-cool-and-warm/3008268.article

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