NAERO Light Your Energy

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Abstract
Naero is a practical wearable object that helps managing the physical exercise in a more efficient way. It is composed of two parts: a t-shirt made in a smart fabric that transforms the lactate present in sweat into energy and an electric circuit with an accelerometer and a Light Emitting Diode (LED) that works as interface. The purpose of Naero is to warn about the passage to the anaerobic respiration, and help the person who's doing the physical activity to prevent muscle pain and tiredness. When the LED is on it means that the fabric is starting to produce energy from the sweat, and the comparison with the data of the accelerometer gives important information about the performance of the user. This smart object can help a varied target, from professional athletes to aged persons or people doing physical rehabilitation. The presence of lactate in sweat is an important indicator and today athletes measure its value with an invasive medical test. With Naero this information can be checked by the user himself, in a pleasant and simple way.

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H.5, J.7

Introduction
This work started from the idea that the human body is a battery: it can give us more energy and information than those we use each day. We started our research from human waste and then we focussed our attention on sweat. Sweat is a rich source of information that we can analyze to understand our body. Particularly when people do physical activity the substances in the sweat are indicators of the physical well-being. So we tried to find a way to make understanding sweat's language easier.

Figure 1. Naero global appearance

Needs Nowadays we have a lot of tools to measure the level of physical performance. Such tools are often based on indicators like speed, distance, temperature, blood pressure, pulsation. We think that an useful indicator, not yet used, is the level of anaerobic threshold. Knowing the moment when the body switches from the aerobic respiration to the anaerobic one, means knowing that the exercise can't last much more time before getting tired and that the body starts producing lactic acid. This information can be useful for those who do not want to get strained. For example joggers wanting to improve their performance would know depending on their pace, the time needed to reach the anaerobic threshold.

Figure 2. If the body is a battery, can sweat produce energy?

Research

We researched into anaerobic respiration and how to use it for our goals.

Anaerobic Threshold

The anaerobic threshold is the exercise intensity at which lactic acid starts to accumulate in the body. Before this moment the body produces energy from the aerobic respiration, but when cells don't have sufficient

oxygen supply they have to switching to an anaerobic respiration. During this phase lactic acid, formed by lactate and hydrogen, is present in the blood and also in the sweat. The anaerobic respiration allows to do an high intensity activity for a short time before the lactic acid causes muscle fatigue and cramping. The anaerobic threshold is therefore used to calibrate training intensity in sport, but varies among individuals and can be raised with training.

Biofuel Tattoos

During our research we found a very interesting work describing the use of temporary tattoos to produce energy from sweat. This research is conducted by a team from the University of California of San Diego in the United States, called "Epidermal Biofuel Cells: Energy Harvesting from Human Perspiration"[1]. They created a biofuel cell composed of a cathode and an anode. The anode, made of a lactate-oxidase enzyme, oxidizes lactate to pyruvate while the cathode, based on platinum particles, reduces the oxygen present (Figure 3). During this transformation the cell produces energy. The cells were printed as temporary tattoos and then they were tested on humans subjects. The researchers found that the power produced while exercising ranged from 5 to 70μW/cm^2. Fitter individuals produce less lactate and so produce less power. However the team is considering the possibility of using a wearable storage device, and using the stored energy to power other devices.

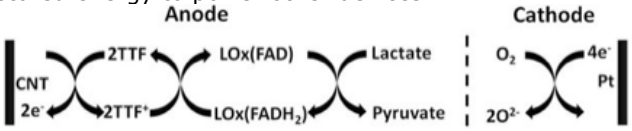

Figure 3. Scheme of the reaction inside anode and cathode of biofuel cell**.**

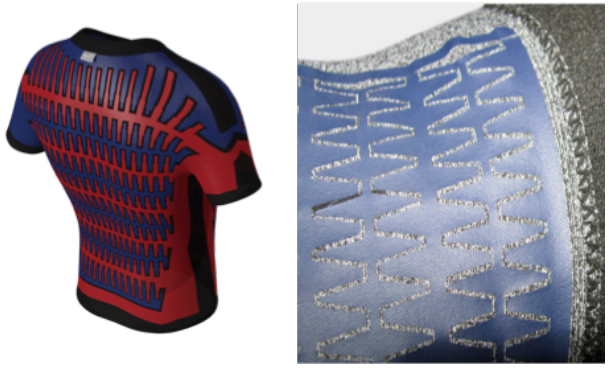

Figure 4. The circuit on the interior side of Naero. Colors mark the difference from the anode and the cathode

Project

Naero is a garment that uses biofuels tattoos technology applied to a polyester fabric. This way, one can realize a sport jersey that uses the lactate in the sweat to produce energy. The interior side of the fabric is printed to realize a circuit made of an anode and a cathode. The design of this part is thought to use as much sweat as possible and be close-fitting to the body (Figure 4). The circuit brings energy to four magnets placed on the sleeve. The magnets are used to hook up the electronic part, that is held in a 3D printed case. When the energy reaches the magnets and the case, it is stored in a energy harvester and used to turn on a LED, as well as to recharge a battery. When the anaerobic threshold is reached, the LED switches on thereby warning the user (Figure 5). The core of the system is: an electronic board that is connected to the LED; an accelerometer; a bluetooth module and a lithium ion battery. These elements allow Naero to transmit all the information to an external device for comparison. In this way the user can memorize his/her data and observe how he/she is improving his/her anaerobic threshold with training.

Figure 5. The case that holds the electronic part, in the two versions: with the LED off and on.

Technical Elements

A lot of elements make Naero an easy object to use. The technology of the tattoo is the main feature of the project, but it is not the only one. The material of the jersey is polyester which is often used for sport clothes and has the advantage not to absorb sweat and not to conduce energy. The internal side of the fabric is composed by the print of the cathode and the anode, designed like a circuit to bring energy to the magnets. Each magnet is a pole and is connected with the external case (Figure 6). The case is made with 3D printing technology to hold each electronic component and follow the shape of the arm. Six different elements are present in the case:

1. Blend Micro: development board composed of an Arduino (a single-board micro-controller) and a Bluetooth shield. Arduino can read and memorize the inputs and sends them to an external device for comparison, through the Bluetooth Shield.
2. A button Switch: it is the element synchronizing the external device whit Naero.
3. Three Axis Digital Accelerometer: this element allows for calculating the speed of the user at fixed intervals.
4. The Energy Harvester : a breakout board used to harvesting energy. It collects the energy from the magnets and use it to recharge the battery.
5. The battery: the battery is recharged both by the energy harvester and through the USB port present in the Blend Micro.
6. The LED: connected with the development board, that controls its lighting when the energy arrives to the Energy Harvester. The LED lights up the logo's that is printed under the surface of the case.

All these elements work together and power Naero thanks to the body's energy: the user just has to do physical activity and let Naero checking his/her anaerobic threshold.

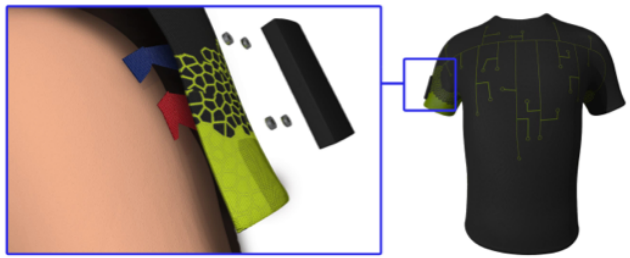

Figure 6. A focus on the elements of Naero.

Illustration of a possible scenario

Energy Possibilities
Nearo uses the energy produced by the lactate in its battery. We estimated the produced energy as follows:
We take as an example a medium size jersey: Waistline: 90 cm Lenght: 60 cm

Jersey Surface: 90 cm x 60 cm = 5400 cm^2

Minimum power produced by lactate: 5μW/cm^2
Maximum power produced by lactate: 70μW/cm^2

Naero minimum power: 5μW x 5400cm^2 = 0,027W
Naero maximum power: 5μW x 5400 cm^2 = 0,378W

Energy Harvester Features:
Input Quiescent Current: 950nA Input Operating Range: 2.7V to 20V

Naero minimum Input Current:
0,027W : 2,7V = 10 mA
Naero maximum Input Current:
0,378W: 2,7V = 140 mA

Considering that a white LED needs a max current of 20mA, Naero will be able to start warning the user when he/she is producing 10μW/cm^2. Instead, at the maximum production of lactate the Energy Harvester can use the remaining 120mA produced to recharge the battery.

Ecodesign Strategy
In designing Naero, we tried to create an object that not only is useful for the user but also environment friendly. The possibility of pulling out the electronic platform from the jersey makes this objects smart. Users can buy more jerseys but just one electronic element. For example, if the fabric is damaged the user can buy a new jersey and keep using the old case. As the production of electronic components is very energy demanding, an important feature is the possibility to replace single components in case of failure instead of having to replace the whole device. Finally, Naero never stops working because is powered by a human battery.

Scenario:
Even if every human sweats, not everyone cross the anaerobic threshold. Naero is a product addressed to active persons. To understand how such kind of target could use Naero we imagined a series of scenarios. Hereby one of the possible scenarios: Louise likes sport, since three months she's part of a running relay team. In a week the team will be taking part to its first competition. During the training Louise and her team mates wear Naero. After the exercise data recorded by Naero are sent to the coach's tablet. In this way the coach can evaluate each result and personalize the training! By analyzing the data the coach can also decide how to organize the relay to increase the chances of the team. Louise enjoys this method and she is motivated to improve her anaerobic threshold. In addition, she knows the exact time to stop running and save her muscles from lactic acid. At home she washes the jersey and, after a shower, she loves checking her results and sharing them online.

CONCLUSION

Naero introduces a new and important variable to physical activity monitoring: the anaerobic threshold! This sport jersey uses a smart fabric to transform the lactate produced during the anaerobic respiration into energy. Naero, thanks to some electronic elements, helps users to monitor their body and to know their anaerobic threshold. The main feature of this process is that the user himself/herself powers the electronic system, just producing lactate. We think that this product can be very useful because nowadays people give more importance to the health and the body. Data analysis has become of common use, and everybody can benefit from that. Benefits aren't ordinary: the users can do their exercise in safety and auto-monitor their physical state. It doesn't request specific competences and the interface is simple and clear. In addition, the lighting interface is useful also for trainers and doctors that can easily take care of weak persons..

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