ADVANCED TEXTILES MANUFACTURING INDUSTRY
Learning unit 2
Lesson 3

Raw materials for e-textiles

HACKTEX
Innovative smart textiles & entrepreneurship

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Content

Introduction

An e-textile is a textile with “smart” functions; in particular, conductive textile yarn or fibres interface with electronic devices and subsequently integrate into the textile materials. Many of the conductive yarns used are from metal yarns or fibres made from copper, stainless steel (SS), silver, brass nickel and their alloys (swicofil), other types of conductive materials are the conductive polymers, conductive coatings and inks. The e-textiles are apply, for medical and biophysical monitoring, in health, for industrial reasons, in industry; they used by consumers in fashion, fitness, gaming etc., by the government in military and for the public safety.

An active smart textile system is a textile system based in those materials and comprises components like sensors, actuators, data processing units, antennas, interconnections, GPS trackers, LEDs, microcontrollers, nanotechnology and energy supply. The sensors can measure the strain, the temperature, the pressure, the varius gas in the atmosfere, the humidity and the PH. The actuators can be mechanical, chemical, thermal, optical and/or electrical. That kind of systems can have specific properties, can measure specific parameters, initiate or take a preprogramed action under a specific situation, can collect and share, in wireless mode, various data and info, can connect different components to each other, and they have energy generation and storage capacity system to be able to function as a standalone suits. The microcontrollers and the nanotechnology are scientific disciplines on creating novel materials that have the advanced applications required in smart textiles systems. The microcontrollers are fabricated to control the functions of embedded systems; they consist memory, programmable input/ output units and a processor and are used in automatically controlled electronic devices occupied less space is possible. The nanotechnology is based in the fundamental physics, chemistry, and biology to develop materials in nanometre-scale. In the e-textiles, nanofibers find applications as filter medium, adsorption layers in protective clothing, etc. and they can be produced by techniques as the electrospinning process that create nanostructured fibrous materials. Of particular interest are electrospun membranes composed of elastomeric fibres, which are under development for several protective clothing applications.

At the end, as the e-textile contains a textile base and electronic parts is necessary to determinate a categorization to define the integration level between those two. The European Committee for Standardization (CEN) defined a classification from level 1 -where the electronic component can be removed without destroy the textile- to level 4 –where all components are of textile-type doing the textile the component. In this level, there is no border between electronics and textiles. So, in long term, might no longer need to define the electronics parts and the textiles separately, but as one, functional, textile.

1. Conducting fibers

1.1. Metal coated fibers

Coating is a process in which one or several layers of material are deposited on the surface of a substrate. Many different coating techniques have been developed to address the characteristics of a wide range of coating materials and substrates, to deliver the required performance in the final products while maintaining economically feasible productivity levels. Metal coatings and conductive coatings are an area of intense study for applying nonconventional coating materials to textile substrates. Screen-printing of conductive ink is one way to achieve it, but has its limitation. Several methods are being developed for conductive coating and other thin film coating applications. These include electro less plating, where surface layers of metals are formed on the substrate via chemical reactions in a coating bath- sputter coating, where a thin layer of metal is formed by incident particles or ions accelerated by an applied electrical potential colliding with the surface, PVD (physical vapor deposition), where vaporized material is transferred to the substrate surface and deposits a thin film on it, and CVD (chemical vapor deposition), in which the surface is modified by depositing layers through chemical reactions in a gaseous medium.

Metal coated fiber combines, at part, the flexibility of traditional fiber with the mechanical properties of the using metal, for example the steel has high temperatures resistance and thermal-electric conductivity. Metal fibers are obtained by successive wire bundle-drawings. The metals mostly used are the silver, copper, aluminum, nickel, tin, steel and gold. Metal-coated textiles can be applied for the antistatic properties, electromagnetic shielding and heating textiles (only for silver).

1.2. Intrinsically conductive polymeric yarns

Conductive fibers and yarns can be divided into mono and multifilament completely made of metal (alloys) such as copper, stainless steel, etc., into co-spun polymer-metal yarns and metal-coated polymeric filaments and yarns, into metal-filled polymeric filaments and carbon allotropes as the conductive agent such as for carbon fibers, or when in the synthetic polymeric filament production step conductive particles such as carbon black, graphite, graphene, or carbon nanotubes are used; into intrinsic conductive polymer such as polyaniline (PANI), polypyrrole (PPy), poly (3,4-ethylenedioxythiophene) (PEDOT) and a mechanically stable common fiber coated by a conductive polymeric.

Intrinsically conducting polymers (ICPs) such as polypyrrole (PPy), polyaniline, and polythiophene are conjugated polymers with alternating double and single bonds along their polymer chain that result in a wide range of electrical conductivity. Consequently, the ability of ICPs for electrical conduction originates from their electronic structure, as opposed to metal fiber or particle-filled conductive composites, which require significant concentrations of the filler to achieve a percolation threshold for conduction to happen; conductivity is not an intrinsic property of the polymer structure but the property of the material as a whole.

Commercial products are available as paste. They can be coated (on fibres, yarns or fabrics) or printed (screen or ink jet) on the textile. Conductive surfaces for anti-static or electromagnetic shielding applications are difficult to achieve with metals but can be realised by coating with conductive polymers. Conducting polymer-coated textiles, also, offer the possibility of heating without placing wiring across the fabric. The moderate to high resistance values of conductive fabrics are ideally suited for heating applications. Nevertheless, two major disadvantages of these materials are the cost ant that they become instable over time, due to their low resistance to humidity, oxygen and temperature.

1.3. Optical fibers

An optical fibre is a cylindrical light waveguide that exploits the property of light being refractive. It transmits light along its axis through total internal reflection. It is composed of a core surrounded with a cladding layer - both of which are made of a dielectric material - and possibly protected by a buffer coating. The refraction index, of the core material, is slightly higher than the refraction index of the cladding, which causes the light to be reflected back into the core of the fibre. When a light wave enters an optical fibre on one end, it undergoes multiple total internal reflections and propagates to the other end of the fibre with nearly no losses.

Optical fibres manufacturing consists of two major processes; by preform making influencing the attenuation and the dispersion characteristics of optical fibres and by drawing influencing glass geometry characteristics and strength. The materials used to produce an optical fiber can be glass, plastic and polymer clad silica. The differences between glass and plastic optical fiber, in advantage of glass optical fiber, is the high-temperature applications and the higher speed of data trasfering over long sensing distances, and in advantage of plastic one is the low-cost, the easy istallation and the flexibility of the fiber.

In the area of smart textiles, optical fibres can be applied for data transmission, sensors (strain, compression, temperature and chemical substances) and for illumination. Sensors can be created by adding a periodic variation in the refractive index of the fibre core. This causes some wavelengths to be transmitted, and others to be reflected, measuring the light allows determining properties like strain, bending, and temperature. Light and optical techniques have already been applied in clinical practice for disease treatment, and these methods have brought profound impacts on modern medicine. Light therapy, also, is used for pain relief, tendinopathy injuries, metabolic diseases, and tissue repair by adopting various wavelengths of light. Furthermore, optical fibres processed for wearable illuminating apparel have micro perforations on the lateral side passing through the cladding to the core. Light leakage then occurs because light scatters at the perforations, thereby enabling light emission on the fiber surface. The alternative is to achieve the light emission by macro-bending of the optical fibre where the light propagation angle is more than the critical angle C thus to emit part of the light out of the fibre. So they, usually, be used in vital signal monitoring, in medical treatments, in fashion and aesthetics.

Want to learn more about this topic?

HYPERLINK "https://doi.org/10.3390/fib7060051" Electrically Conductive Coatings for Fiber-Based E-Textiles,

by Kony Chatterjee, Jordan Tabor and Tushar K. Ghosh,

Department of Textile Engineering, Chemistry and Science, Wilson College of Textiles, North Carolina State University, Raleigh, NC 27606, USA

2. Sensors, actuators and energy supply

2.1. Definition of sensors, types and applications

With the word sensor is defined the device that has the function to receive a specific parameter from the environment, to create a signal, to transform that signal into another analogue or digital signal and then to transmit it, with the purpose to be recognized, redden and understood from another device or person. When a device, called "sensor", must transform and transmit the signal or signals to another device, then the ultimate conversion of the signals is in electrical ones. In the sector of the textiles, the components that, usually, been used to accomplish this conversion are the thermocouples, quantum tunnelling composites and the fibres brag grating sensors (optical fibres). Furthermore, to integrated sensors, that can monitor continuously a human and/or his nearby environment, in an textile system and be wearable, they must have specific proprieties, as to follow an unobtrusive method during the process, to be as little and lighter is possible or even better been the textile itself.

The classification of the sensors is basing on the parameters that they measure or on the characteristics that they have. Therefore, doing a classification based on the parameters that every sensor can measure, we are having nominally the followings:

- The ECG electrode or the electrocardiogram can conduct electric current. So, if we apply a surface ECG electrodes on the human body the electrical potential (millivolts) of heart activity will give signals at the sensor, which will transmit them into an cardiogram or on a diagram of heart beats per unit of time. They are three type of ECG electrodes: wet, dry and the insulating ones· in the textiles, we exclude the wet because they need an electrolytic gel to create a conductive layer between the electrode and the skin. The dry electrodes consist a metal, usually from stainless steel. The insulating electrodes consist a metal or a semiconductor with a thin dielectric surface, which creates a capacitor by the skin contact and they are functional under the presence of moist. To improve the contact and avoid the movement between the electrode and the skin the fitting of the garment must be tight and/or the electrodes thicker. The principal challenge with that kind of sensors in the clothes is to remain the same properties to the yarns after the multi washing cycles. Because of that, they must easily removable before washing or they must be water resistant in long terms.

- The EMG electrode or electromyogram can measures the electrical activity of skeletal muscles. Neurons transmit electrical signals that cause a muscle to contract and an EMG records this electrical activity.

- The strain sensor is a device to measure the strain of an object. Stretching the sensor within the limits of its elasticity causes a measurable change of electrical resistance. Measurements with a strain sensor should be repeatable over a large number of cycles. Therefore, dimensional stability of the structure is of crucial importance.

- The temperature sensor is a sensor that measures the temperature of the environment and/or the body temperature. In the textiles application a temperature sensor can content a material which resistance changes accordingly the temperature changes, either with two conductors (thermocouples) of different material that produce a voltage with the heating. The results of the measurements could be through others electronic micro-devices or the used materials can be thermochromics to indicate the temperature by the changes of their colour.

- The pressure sensor is a device that senses pressure and converts it into an electric signal where the amount depends upon the pressure applied. Its' working principals are basing at reactions that the change of pressure provoke in resistance of a material or in the capacitance. A pressure sensor in a textile can be used as a keyboard or controller where with different types of pressure can communicate with a device to type a message or to order an action.

- The gas sensor measures the presence and/or the concentration of combustible or toxic gases in the atmosphere. At the electrical gas sensors the gas when contacts the surface of the sensor causes change in the electrical properties of a gas sensitive material. A gas sensor could be electrochemical -where the gas molecules react electrochemically with the electro catalytic sensing electrode, catalytic –where the surface of the sensor oxidises in contact with a combustible gas, or metal oxide semiconductor –where volatile compounds are absorbed by the surface of the semiconductor and cause a change in electrical resistance. That kind of sensors in clothing are mainly aimed to protect the user from dangerous gas.

-The humidity sensor is the sensor that can measure the humidity, the moisture and the solvent based on the principles of the resistive resistance and the capacitance.

-The pH sensor is a sensor that uses halo chromic materials, which are changing colors respect the varying pH environment. The read-out could be by comparing the color respect the available color scale or with a colorimetric measurement device. Those sensors are used to clothing to measure the pH of the human body, which during the exercise changes respect the acid in muscle cells.

- The optical textile sensors work with the variation of the light intensity or the amplitude that can be sensed by a fiber Bragg grating (FBG) sensor. The small glass optical fibers diameters make these materials suitable for seamless textile integration with industrial processes. The optical fiber light source can be a small light emission diode (LED), and the light amplitude at the end of the optical fiber can be sensed with a small photodetector. The optical textile sensors can be used to sense textile displacements and pressures in applications where the electrical currents cannot cross textile substrates. (Article Wearable E-Textile Technologies: A Review on Sensors, Actuators and Control Elements Carlos Gonçalves 1,2,* ID , Alexandre Ferreira da Silva 3 ID , João Gomes 2 and Ricardo Simoes 1)

2.2. Definition of actuators, types and applications (motors, switches, other electronics)

With the word actuator is defined the device that has the function to react under a specific parameter, which works like a trigger. This reaction can be an alarm (visual or audible), a vibration, or a temperature change and the categories of the actuators are according by the type of the reaction, namely the outcome signal. On the other hand, the trigger who provokes the outcome signal can be chemical -like a pH, oxidation, solvents, reduction or gasses change, or physical -as a light, deformation, temperature or electric change. Additionally, the way that works an actuator to have the reaction, determines the type of the actuator, who can be mechanical, chemical, thermal, optical or electrical.

In particular, in a mechanical actuator, a trigger causes a deformation on a shape memory material. For example, in the smart textiles industry, the Defence Clothing & Textiles Agency (DCTA) in Colchester UK developed shape memory alloy (NiTi) conic springs to create adaptable thermal insulation for heat-protecting clothing. Those conic springs have 25mm diameter and are sewing between two textile layers in order to change the insulation properties of the cloth. In normal conditions, they are flat, but when the temperature increases they open up creating a bigger air gap between the inner and the outer layer of the garment and because the air is a good insulator, the thermal insulation properties of the vest increase. In opposition, the Italian company “Corpo Nove”, in cooperation with “d’Appolonia”, developed a textile, weaving shape memory alloy (SMA) with traditional fibers. The long sleeves of this cloth, at higher temperatures, transform into short due to the zigzag shaped SMA’s that contains in the sleeves, and when temperature drops the sleeves can manually pulled down, and the threads take their, trained memory, straight shape. Therefore, mechanical actuators are mainly base on materials that have shape memory, react in temperature changes and they can form as alloys to integrate, easily, in a textile structure.

Similar to a mechanical actuator, a thermal one, also, is relate to thermal comfort, but while a mechanical acts in a passive way, a thermal actuator has active heating elements to regulate the temperature. The manufacturing of heating textiles is basing on phase change materials or an electrical heating. The phase change materials have high heat capacity to absorb or release, but they are changing temperature difficulty. Those materials, first, must be encapsulate into microcapsules to apply and incorporate them to the textiles, so when the body temperature, of a user who wears a cloth from this textile, increases, the phase change materials will store energy to release it, when the body temperature decreases, in order to improve the thermal comfort of the user. On the other hand, the resistive or Joule heating happens when the electric current through a conductor generates heat. Therefore, to succeed heating, an electro conductive yarn should integrated into the textile structure to turn it in a heating one. The arrangements, used to integrate those yarns into the textile, are different and they depend on the yarn resistance. So, the low resistive (thus highly conductive) yarn, such as silver-based, must arranges in a series circuit because the overall resistance will increase linearly with the length of the yarn. In contrast, the less conductive yarn (with higher resistance), such as stainless, steel based yarns or intrinsically conductive polymers, must preferably be arranged in a parallel way because this will lower the overall resistance. The garments with electrical heating actuators have rechargeable batteries mounted in a battery pack with power control. Metal snap fasteners connect the heating textile and the battery pack to be able to remove the device before washing. In general, heating textiles are commercially available, ranging from undershirts, gloves and socks to tights.

Continuing, in a chemical actuator, triggers -as temperature, pH, humidity or other chemical changes- cause the release of a specific substance –as fragrance, skin care or antimicrobial products- that can chemically bonded to a fibre, with the help of cyclodextrins, or stored in microcapsules, a technique called microencapsulation. In smart textiles systems, this type of actuator gives the opportunity to numberless applications in the beauty, as well as in the medical sector.

Conversely, an optical or visual actuator is connected to a battery and its' reaction is to illuminate when it is triggering by electricity. In the smart textiles, the visual actuators can be optical fibres, LEDs, electroluminescent wires and textiles or flexible electrochemical displays integrated into common textiles or mixed with common fibres.

Ending, the electrical actuators use electrostimulation electrical impulses to stimulate the muscles. This procedure is considared as therapy because provokes local warming and activation of the muscles without physical movements and is frequently used in sports and in rehabilitation. In the textiles, we use electrodes who are flexible –so can follow various shapes- and can be fully integrated into the garment structure to make possible to position them wherever we desire the electrostimulation.

Figure 1. Textile image from pexels.com

2.3. Energy harvesting and storage (batteries, capacitors, kinetic, triboelectric)

One of the most important challenges of the e-textiles production progress is the energy harvesting and the storage. The sensors and the actuators, that do not use passive smart materials, need energy to work. This energy should be able at any moment that the user needs the properties of the garment, so storage systems are necessary in the development of an e-textile.

In nowadays, energy harvesting devices that generate electricity from human motions, body heat and sunlight can fully integrated in smart textiles systems. The human body is a storehouse of energy with around 4 × 108 Joules stored in the average person (Starner, 1996). The body also consumes energy at a surprising rate to produce heat (thermal energy) and motion (mechanical energy). The mechanical energy converting, into an electrical power, could happen via piezoelectric devices; instead, semiconductor devices, called thermoelectric generators, convert heat into electricity based on the Seebeck effect (Nolas, 2001). The thermoelectric power generation has the advantage to be continuous by nature, but the problems with the use of body heat are the difficulty to take that energy from all the surface of the body, so the realistic taken power is sufficient for low-power applications. In addition, the thermoelectric generators are bulky and rigid, which is a disadvantage in the textiles sector. By contrast, piezoelectric devices have simpler structure and the generated electrical energy is easily produced by compression, bending or slapping them. Even if only a very small fraction of the mechanical or heating energy is converting into electricity, in both cases, the possibility of harnessing human body energy provides an attractive solution to the power problems of smart textiles.

Although, an alternative way harvesting energy is the harness of the daylight. The electromagnetic radiation, called also solar energy, is another source of energy around the human body, which the photovoltaic cells can capture and convert it into an electrical. A photovoltaic or solar cell is a semiconductor device in which solar energy of certain wavelengths can be absorbed to generate free electrons (negative charges) on one side and holes (positive charges) on another. However, the most efficiency solar panels are made from silicon or other inflexible materials, so they cannot be used in clothing. The plastic films have the required flexibility and function as solar panels, but convert 8% of the solar captured energy. The advantage of the plastic solar films is that their technology can be apply on fibres; an important step that gives the opportunity to weaving solar fibres into textiles and to create wearable and washable solar cells, therefore, to make a wearable and washable energy harvest device.

Nonetheless, piezoelectric and photovoltaic devices cannot offering power continuously, for that, except from harvest systems, we need, also, storage energy systems to incorporate in the smart textiles. Those storage energy systems are the capacitor and the batteries. The capacitors store electrical energy producing a potential difference across its plates, as a small rechargeable battery. They consist of two parallel conductive plates of different polarities separated by a dielectric material or by an electrolyte. They are fully charge when the voltage across both plates is equal to the applied voltage and the flow of electrons onto the plates stops. Capacitors are high-energy storage capacity systems, but for short time. On the other hand, the batteries work in electrochemical way storing chemical energy in them electrolytes and convert it into electric energy through an electrochemical reaction, when this reaction is reversible then the battery is rechargeable. In general, the batteries have a high-energy storage capacity over a long time; provide direct current, but they have low efficiency and limited lifetime.

Concisely, no single energy harvesting method is able to satisfy the power needs of the wearable computing. Therefore, the success will depend upon the efficiency and compatibility of energy converters with storage energy technologies.

2.4. Output devices (LED's, passive displays)

The output devices, used in the textiles sector, are Light Emission Diode (LED) arrays, thermo-chromic ink, vibration, and shape memory alloys.

The Light Emission Diodes or LEDs are used on the electro-luminescent based displays. Moreover, in that type of displays, the textile is used as base for the LEDs and as cover for protection or aesthetical reasons. Another optical output device is the OLED (Organic Light-Emitting Diode) wearable display, which it is made by ultrathin fibers of organic molecules that generate light. The OLED fibres are working with electricity, as LED does, but the application via thermal vapor deposition, instead of the printing or annealing, gives them better performance and compatibility with the textiles.

Conversely, the electrochromic displays or passive displays, in textiles structure, are emitting multicolor lights, not by photons, but by using chromic or luminescent materials, as electroluminescent diodes, that reflect light in different ways. Electrochromic is defined a material that has the ability to change its color when electrical power across it. This color change is caused of the oxidation and reduction of chemical processes of the material during the application of the electricity; when the electricity stops, the material can retain or return to its initial state. The stimulus used can be optical, thermal, electrical, chemical or mechanical and it used to light the display. The more light falls on, the more visible the display is. The variation of their optical proprieties is caused by insertion or extraction of cations in the electrochromic films. At the start, the films are transparent or have a stablish initial colour and when an electrical voltage, of a fraction of a volt to a few volts, across them, provoke optical and colour changes.

2.5. Nano and micro electronics

Nanoelectronics are electronic devices with extremely reduced size based to nanotechnology. They have the mechanical properties of the hybrid material; have semiconductors, single dimensional nanotubes, nanowires, memory chips and displays, but the challenge is to have the same capabilities of the normal-size electronic devices, while their dimensions, weight and power consumption are extremely reduce. At the nanoscale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter, with the reduction in size, the surface area of materials and surface energy increase. There is four dimensions of nanostructures the clusters (0D), the nano tubes, fibers and rods (1D), the films and coats (2D) and the polycrystals (3D). To create nanomaterials or existing materials should crumbled and modify to obtain required size and shape or molecules of materials should be put in structural units to become nanomaterials. The nanomaterials, in turn, can be used for the creation of nano or microelectronics devices to be able their optimal integration into the fibres or the structure of the textiles.

Want to learn more about this topic?

Sensors and Actuators Engineering System Instrumentation Second Edition, by Clarence W. de Silva

3. Microcontrollers

3.1. Definition of microcontrollers

Microcontrollers is an embedded controller used in automatically controlled electronic devices. Any device that stores, measures, displays or calculates in electronic way, comprises a microcontroller. Practically, a microcontroller (μC or uC) is a chip that works as a microcomputer and gives order to the other parts of the device controlling the functions of its system. The more requirements the device has, the more the microcontroller is potential. A microcontroller comprises components like memory, peripherals, and a processor. The processor, called Central Processing Unit (CPU), is connecting all the components of the microcontroller fetching data, decoding them and completing the various assigned tasks successfully makes it work as a single system. The CPU decodes instruction fetched by the programmable memory. The memory chip works as a microprocessor, storing all programs and data. The types of memory are the ROM, RAM (EPROM, EEPROM, etc.), or the flash memory. Other components of the microcontrollers are:

- the input and output ports that are employed to interface or drive different appliances such as printers,

-the serial ports that give serial interfaces amid microcontrollers and various other peripherals such as parallel ports,

-the timers that control all counting operations within a microcontroller and count external pulses,

-the analog to digital converter (ADC) that is used to convert analog signals to digital signals.

-the digital to analog converter (DAC) that is used to convert digital to analog signals.

-the internal or external interpret control that is employed for transmitting delayed control for a working program.

-and, the special functioning block that has additional ports which functions to carry out some special operations.

3.2. Types of Microcontrollers

Microcontrollers are broadly classified into various categories based on bit configuration, memory, instruction set and architecture memory. The bit configuration is its potential of the its accuracy and performance and is measure in 4bit, 8bit, 64bit and 128bit, the more bits, the more potential the microcontroller is. A further division is the two categories based on its Memory configuration: the external memory and the embedded memory. The External Memory Microcontroller has not a program memory on the chip; conversely, of the Embedded Memory Microcontroller that has all programs, data memory, counters, timers, interrupts, in and output ports on the chip. In addition, the instruction set is dividing the microcontrollers, in two types the CISC- CISC -a Complex Instruction Set Computer that allows the user to apply one instruction as an alternative to many simple instructions- and the RISC- RISC -a Reduced Instruction Set Computers that reduces the operation time by shortening the clock cycle per instruction. At the end, another characteristic is the Architecture Memory of a microcontroller that could be respect the Princeton Architecture that utilizes the same memory and data paths for both program and data storage or respect the Harvard Architecture that utilizes a physically separate memory and data paths for program and memory.

3.3. Wearable Microcontrollers

Adafruit Industries designed two types of wearable microcontrollers the GEMMA and the FLORA. The platform board, named GEMMA, has 2,54cm diameter, a processor “Attiny85” powers it, and an “Arduino IDE” programs it over an USB port. The Attiny85 is a unique processor, because despite being so small, it has 8K of flash, and 5 I/O pins, including analog inputs and PWM analog outputs. This wearable microcontroller is capable of objectifying any wearable project as desired connecting a computer with the USB bootloader. Although GEMMA does not have a serial port connection for debugging, so the serial port monitor will not be able to send or receive data, and some computers' USB v3 ports do not recognize the bootloader, so the users must put an USB v2 port or an USB hub in between.

On the other hand, FLORA, is more powerful than Adafruit's GEMMA, but has 4,445cm size so is bigger; has a relatively small but efficient onboard reset button for rebooting the system and the power supply is also designed to be considerably users friendly. FLORA, also, contains a built-in USB support, which means that the program shows up once plugged and it works perfectly fine with Mac, Windows, Linux, and any USB cable; this sewing microcontroller is built around the Atmega32u4 chip, which has USB support. It is almost impossible to damage - even by connecting a battery backwards - due to polarized connector and protection diodes. The built-in regulator means that even connecting a 9V battery will not result in damage or tearing. Therefore, Adafruit designed low-cost microcontroller boards that are small enough to fit into any textile project and be wearable. Other wearable microcontrollers are, also, the LilyPad Arduino, TinyLily Mini and the StitchKit.

Want to learn more about this topic?

Make: Wearable Electronics: Design, prototype, and wear your own interactive garments, by Kate Hartman

4. Wirelless communication devices

4.1. Textile antennas

Antennas are metallic structures that transmit or capture information and data by radio electromagnetic waves. To succeed the transition are able two antennas, so when the one transmit the other can receive the signal and opposite. The frequency of the electromagnetic waves used for this radio transmission ranges from 300 Hz to 300 GHz, which corresponds with waves of an ever shorter wavelength; different frequencies require different antennas formats and their transmitted data can travel at the speed of light (3,108 m/s). In the textiles' world, are necessary because they are offering a wireless way of communication.

In general, everything that has to do with the communications centered on the human body is divide in off-body, on-body and in-body. In off-body communication, the antenna radiates away from the body, in In-body communication the antenna is in the body and in off-body communication, a system provides a communication link between a wearable system and an external base station. For off-body communications, the easier way to integrate an antenna in the wearable system is to use planar antennas (patch antennas) made of textile materials, that operate in the license free 2.45 GHz ISM band. Those types of antenna comprise three layers: a nonconductive antenna substrate, a conductive antenna patch, a conductive ground plane, which shields the human body from the EM waves transmitted by the patch, and connector who connects the antenna to the rest of the system. The conductive elements can be made out of electro conductive textiles or can be screen-printed onto the substrate material. The frequency that is used for the data transmission determinates the shape and dimensions of the antenna, so the smaller the operating frequency, the larger the antenna patch will be. Furthermore, when integrating the antenna into a garment, the antenna patch must be oriented away from the body and its ground plane should be oriented towards the body.

Another way of wireless communication is the Radio Frequency Identification tags (RFID). A RFID tag is a microchip combined with an antenna in a very small package. The purpose of such a tag is to track the object, which is attached. There are two groups of RFID tags: Passive RFID tags that do not contain a battery and the power is supplied by the reader -the reading can only be done at very short distances and they are typically small and inexpensive devices- and the active RFID tags that required a battery and they can be read from great distances, but they are physically larger and more expensive.

The integration of RFID tags into textiles gives interesting perspectives for the clothing industry; a garment could be traced from production stage to recycling, simplicity the logistics and selection in transport and warehouses.

However, talking for textile means that embedded tags should be washable and there are, but they are rigid, so the researchers study the possibility to manufacture the tags out of textile material, since the dimensions of the microchip are very small the antenna can be embroidered, stitched or printed on the textile substrate.

4.2. Bluetooth and zigbee transmitter and receiver modules

The most commonly used technology in e-textile is “Bluetooth”. The last version of Bluetooth is 5.0, gives the max transmission speed at 48Mbit/s and a communication distance about 300 meters. Bluetooth can be considered as the PAN level of communication. The Bluetooth devices are divided into two categories: Basic Rate/Enhanced Data Rate and Bluetooth Low Energy (BLE). In e-textile applications can provide considerably reduced power consumption and cost while maintaining a similar communication range.

Zigbee is another low power, low data rate and close proximity, wireless communication technology. Like BLE, ZigBee is classified into PAN level; supports both star and tree networks, and generic mesh networking. In a ZigBee network, there are three kinds of Zigbee devices: Zigbee Coordinator, ZigBee Router and Zigbee end Device.

Zigbee End devices do not route traffic. They may also sleep, which makes end devices a suitable choice for battery-operated devices. All traffic to an end device is first routed to its parent. The end device is responsible for requesting any pending messages from its parent.

Zigbee Routers are responsible for routing traffic between different nodes. Routers are also responsible for receiving and storing messages intended for their children. In addition to this, routers are the gatekeepers of the network and they are responsible for allowing new nodes to join the network.

At the end, a Zigbee coordinator is a special router. In addition to all of the router capabilities, the coordinator is responsible for forming the network. To do that, it must select the appropriate channel, PAN ID, and extended network address. It is also responsible for selecting the security mode of the network.

Want to learn more about this topic?

Fundamentals of Wireless Communication, by David Tse and Pramod Viswanath

Summary

Write a short summary (200-300 words) with the main highlights of the lecture.

Word word.

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Further resources

- List of resources for further reading/learning
- APA style
- Include them in the recap after each topic

Partnership

Project coordinator
TUIASI - Universitatea Tehnica Gheorghe Asachi din Iasi
www.tuiasi.ro

AEI Tèxtils - Agrupació d'Empreses Innovadores Tèxtils
www.textils.cat

CIAPE – Centro pre l'Apprendimento Permanente
www.ciape.it

CRE.THI.DEV - Creative Thinking Development
www.crethidev.gr

TITERA - Technically Innovative Technologies
www.titera.tech

UB – Högskolan i Boras
www.hb.se

UNIWA - Panepistimio Dytikis Attikis
www.uniwa.gr

UPC - Universitat Politècnica de Catalunya
www.upc.edu

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