E-cellulose: symbiotic cultivation for the production of smart textiles in a framework of sustainable fashion and electronic art

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Abstract

Technology has become ubiquitous, it is all around us, being a permanent part of our day to day. Along with the emergence of the Internet of Things (IoT) and other innovative technologies such as Augmented Reality (AR), Artificial Intelligence (AI), Blockchain, IoT-based smart wearables and apparel harmonize functionality, with design, electronic art, and science. On the other hand, the textile industry is considered the second most polluting industry in the world, making it necessary to rethink and replace ordinary products in great global demand produced from unsustainable processes with ones that contribute to the reduction of the greatest number of environmental problems. For thus, the synthesis and structuring at nanoscale of an extracellular renewable biopolymer is proposed. This bacterial cellulose (BC), obtained from a fermentative process that requires low amounts of water for its production, it has been demonstrated having an excellent potential in the slow fashion movement due to low hydric and carbon footprint, and diminishing of tree falling or use of non-sustainable fibers; as well as, into the textile industry due to its low-cost raw materials, mechanical properties, and versatility.

Keywords

Emergent arts, e-wearables, slow fashion, electronic textiles, SCOBY, bacterial cellulose, nanostructuring, bio-based materials, sustainable products, low water and carbon footprint.

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Introduction

In a not-so-distant global IoT architecture, smart textiles are expected to be able to communicate massively with smart devices to process biometric information such as heart rate, temperature, breathing, movement, acceleration, or even mood, promising a new horizon for the intersection of electronic art and fashion in a sustainable way [1]. In this direction, electronic art understood as a fashion of making art through the use of technology including electronic devices came from conceptual art and systems art, and subsequently, it derived into the different information and media art branches; being precisely the International Symposium for Electronic Art—ISEA who has carried the banner of electronic art since 1988 at international level.

On the other hand, the textile industry is considered the second most polluting industry in the world, and it is estimated that around 120 m3 /Ton of effluents are discharged into water sources as a result of these activities,[2] which 2 to 50% are persistent pollutants that cannot be removed from wastewater by conventional methods,[3] mainly due to the presence of free chlorine and toxic heavy metals. which in addition to polluting reduces oxygen levels in the water and inhibits microbial activity that stabilizes the organic form.[4] In fact, the World Health Organization (WHO) affirmed that, in developed countries, this industry is responsible for the annual death of around 20,000 people involved in fumigation activities on crops for cotton production, mainly due to the amount of toxic pesticides that are required for this function.[5]

In this train of thought, a bacterial cellulose (BC) is proposed as an alternative textile material. BC is obtained from a fermentative process that requires low amounts of water for its production [6]. In contrast to vegetable cellulose, BC is highly pure, its structure is free of pectin, lignin and hemicellulose,[7] it has high porosity, excellent mechanical properties[8] and is also highly hydrophilic, with the ability to absorb 98% of its weight in water.[9] Based on its special structure and its unique properties, BC is postulated as a promising material that will revolutionize the industry in the coming years, due to its wide range of innovative applications, among which the textile industry stands out.

This is why bacterial polymer fibers are a potential substitute for cotton, a natural fiber considered unsustainable because its production requires high water consumption. It is estimated that around 2.6% of world water consumption is destined for the production of this fiber, during the bleaching, dyeing and printing processes, 150 m3 of water are required per ton of fabric[5] in which it is evaluated that for the production of a pair of cotton jeans weighing 1 kg, at least 1,100 liters are consumed between the wet treatment and the printing of the garment.[10]

Last but not least, nanotechnology has made it possible to introduce new properties to the materials we know today such as nanoparticles, nanofilms, nanowhiskers, nanoflowers, among others, stand out. Thus, the term "conductive textiles" refers to the transport of signals in the so-called smart textiles, which use a wide range of products with specific surface conductivities, for which the textiles can be modified with the incorporation of conductive particles in the spinning or electrospinning process, coatings of conductive metal, or the weaving or stitching of metal fibers [11].

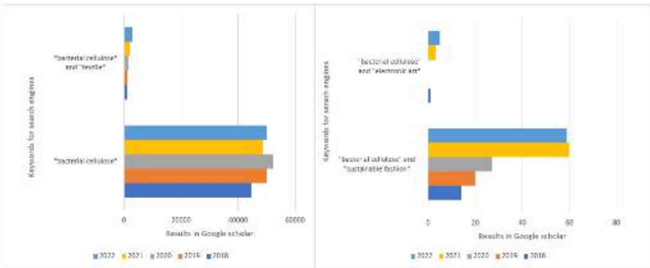

Figure 1. Number of scientific sources were found in Google Scholar after searching for different entries related to bacterial cellulose (or kombucha) and its application in the textile industry and electronic art. Source: The author.

Figure 1 shows the results obtained from the Google scholar search from January 2018 to December 2022. Although bacterial cellulose has been widely studied from biology, biotechnology and bioprocess engineering; it is important to highlight that BC has not been explored in the sustainable textile industry or in electronic art, as is the focus of this research.

Methodology

Culture medium preparation

The preparation of the medium was carried out by adding a mixture of sugar as a carbon source and tea as a nitrogen source, which were put in potable water, heated to boiling and cooled afterwards. However, a starter of SCOBY (Symbiotic Colony Of Bacteria and Yeast) or as well called Kombucha is needed to produce a membrane using the above medium.

Bacterial culture variables

Bacterial culture at temperatures below 20°C will take more time to produce a new biomaterial, thus, 1 month to produce a 1 mm thickness dried membrane; however, at higher temperatures it will take a week having the same results. Finally, different mechanical properties will depend mainly on the culture time, and other factors such as carbon and nitrogen content and origin.[12, 13]

BC membrane obtaining

After the culture time for the membranes to have the desired properties or thickness, the membrane was removed from the culture medium, washed with tap water, and dried at room temperature (approximately 14 °C) for 1 week. This process can be speeded up by using a blow dryer; however, the objective of this study was to find the most environmentally friendly conditions to achieve the same results using a lower water and carbon footprint.

E-cellulose production

A graphene spray coating was selected to deliver electrically conductive properties to BC. This process was carried out by preparing a 5 mg/L graphene solution pulverized and diluted in, which was used to charge an airbrush. The process coating was carried out at 20 psi, 50 repetition cycles and a time between each 10 s cycle. Subsequently, the BC sample was located with a total area of 1 cm^2 at 15 cm distance from the sprinkler.[14] Finally, a sputtering DC magnetron process allowed adhesion of films metallic on the surface of a substrate. For this purpose, a camera of high vacuum with a pressure of 1x10-3 mbar and O2 as electric potential gas high was employed to obtain 50 nm gold films.[14]

Results and discussion Bacterial (SCOBY) culture

The culture medium was dark yellow due to the sugar and tea presence (Figure 2). The initial smell was sweet and it turned to vinegar-like one from the fermentation process carried out by the bacterial culture.

Figure 3 shows membranes with different thickness and culturing times. However, in any case, BC membrane is a useful material as textile and applied in garments or leather goods, due to easy biofabrication, as well as low cost and feasible scale-up. In order to obtain similar mechanical properties from nature, cows and sheep (for example) must be raised for months and years, in addition to food, antibiotics, water, maintenance, among other variables of cattle care.

Cellulose, in addition to being a material of renewable, biological, and biodegradable origin, among other characteristics, is a potential textile material with relevant versatility. Figure 4 shows the different opportunities to freely use it as a textile. The leather-like color is obtained from the culture media; however, it can be coloured with natural pigments from seeds, vegetables, roots, etc. (Data not shown).

Functional application of BC membranes

SCOBY is a symbiosis approach to natural collaboration to benefit the environment. Similarly, transdisciplinary work is needed among microbiologists, materials engineers, biotechnology engineers, fashion designers, and so on, in order to obtain sustainable textiles. This synergistic collaboration allowed the material design, bio-based material, and garment design. Figure 5 shows several examples of design from accessories to shoes, taking advantage of the mechanical properties of the material in different stages of its cultivation. In fact, some E-cellulose samples (Figure 6) are presented using different coating thicknesses, patterns that can be included in the design of their visual appearance.

Figure 2. Bacterial culture produces a cellulose (BC) membrane, which is observed as white material above the whole culture. Photo taken by the author in real cultivation conditions.

Figure 3. Dried BC membranes of different culturing times had both different mechanical properties and potential applications in the textile industry. Photo taken by the author.

E-cellulose and electronic art

It should not be neglected that the materials, in addition to being clothing items, can be considered electronic devices for a wide range of applications that would include from biomedicine to art. Therefore, the bio-based textile model presented here would allow not only a sustainable garment design—from its production to its use, since by its nature it should not be washed as frequently as a regular garment-but also, with its electrically properties would allow the development of new forms of artistic expressions, emerging from the sensing of emotions, for example, captured directly by the wearables and then submitted to different displays, from large-format screens, to building facades, and data visualization systems, allowing to share your moment-to-moment feeling. Human sensations can be detected by e-wearables (e.g., E-cellulose), and then transmitted to a canvas, where each person will be represented by a group of pixels allowing each emotion appears with features such as a color tone, a certain sound, different shapes, and movements. The union of all pixels would reveal an artwork based on emotions in situ, thus being a piece flowing between feelings, wearables, and multiple possible visualization/sonification display outcomes. In this train of ideas, it is possible to foresee that with the appearance of these technologies certain social, economic, and cultural behaviors could be shared (and eventually modulated).

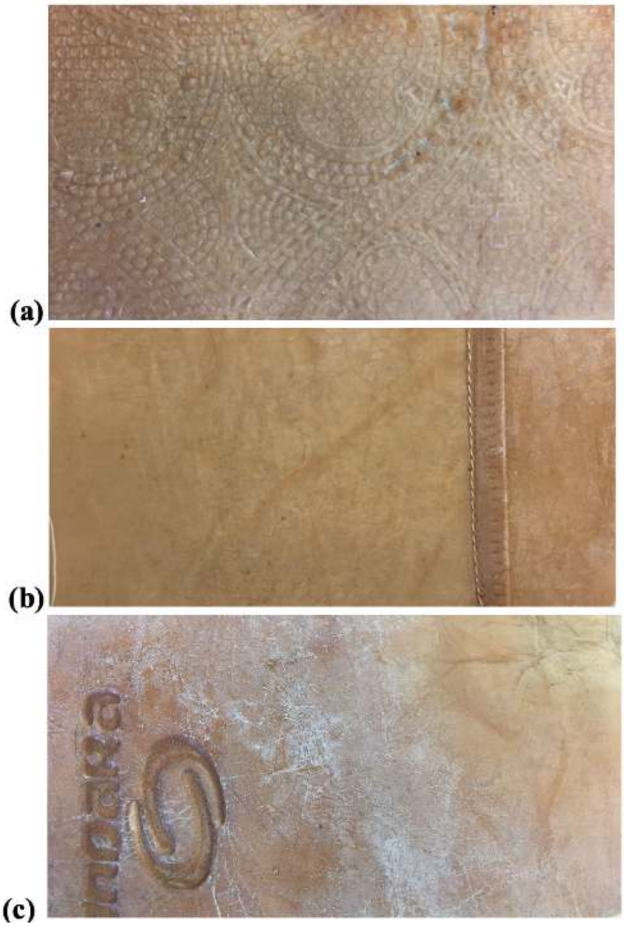

Figure 4. Dried BC membranes showing different material properties: embossed (a), lined and sewn (b), and stamped dry (c). Photos taken by the author.

Figure 5. All above are original design earrings and shoes for women based on BC membranes of different culturing time Photos taken by the fashion designer.

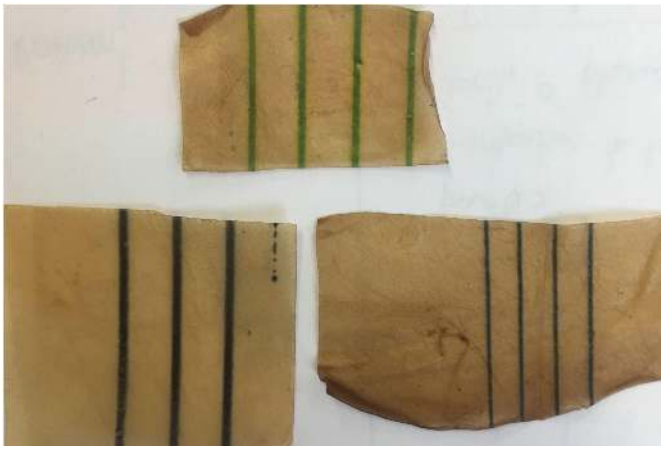

Figure 6. Examples of nanostructured BC membrane with electrically conductive properties. Photos taken by the author

Conclusions

E-cellulose is presented here as a primer bio-based and sustainable material intended to sense and transmit human emotions to multiple electronic formats, including large screens, and data visualization systems. Emotions captured as a group of pixels, sounds, etc. can produce a collective (when sensing multiple individuals simultaneously), on-the-move, and in situ e-art expression. This technologically mediated artistic manifestation may later involve other perceptions (e.g., odors, movements), extracted from joint participation in such a way that the experience can be expanded.

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