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The Bark Project – Materials Research across Design and Natural Sciences

Exploring and Harnessing the Potential of Natural Materials: Tree bark in Textile and Fashion Design.

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Short Bio of the author: Charlett Wenig is an interdisciplinary materials and industrial designer. She is interested in local biomaterials and their processing possibilities. She received her PhD from TU Berlin in Materials Engineering on the characterization and sustainable use of local tree bark species by combining science and design. In the MoA research group Adaptive Fibrous Materials at the MPI of Colloids and Interfaces, she investigates potential application fields and processing methods, designs different design scenarios for the high-value use of local plant species (e.g. paludiculture) considering her research results on structure, properties and functions.
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Johanna Hehemeyer-Cürten is a fashion- and material designer with a strong interest in biomaterials and material innovation. She studied at the Maastricht Institute of Arts and the Weissensee School of Art and Design Berlin. She graduated with a master in fashion design in 2021. Currently, as a PhD student at Max-Planck Institute of Colloids and Interfaces and the Cluster of Excellence »Matters of Activity« at HU Berlin she develops sustainable design strategies for pine bark. The research project fucuses on techniques and concepts of folding and weaving that are studied in a combination of basic research and design. This includes analysis of the chemical and structural composition of pine bark as well as investigations on material processing and form finding.
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Numerous current production methods contribute significantly to climate change, due to a high consumption of material and energy resources. The consequences for our environment and wellbeing are manifold and can be seen for example in biodiversity loss[01].

Hence a sustainable and responsible use of renewable bio-based materials for applications is becoming more and more important, but we also need to be aware that biogenic resources are at risk of becoming scarce[02]. Therefore, it is crucial to increase live cycles of products and promote cascade-use. Only at the very end of various life cycles of products, these materials should be used as a source for energy[03]. Additionally, factors such as sustainable growth and harvest, transportation and the use of locally sourced materials should be considered to build a future that is ecologically and socially fair.

This paper discusses tree bark, frequently seen as waste, as a raw material for future applications in textile and fashion design. We present results of current research on tree bark in design and natural sciences in four sections, starting with a chapter providing contemporary and historical examples of tree bark as a local raw material for products and artefacts. The next section, "The Bark Project – Connecting Experiments in Natural Sciences and Design for Research on Tree Bark", summarizes selected topics of Charlett Wenig's dissertation "Sustainable Tree Bark Objects by Combining Science and Design. "Slow Fashion, Fast Fashion and the Potentials for Tree Bark in Fashion" describes the importance of material choice for a future sustainable fashion industry based on Johanna Hehemeyer-Cürten's master thesis "Space In Between". The final section, "Workshop: Possible Applications for Tree Bark" describes results of a one-day workshop by students at the Department "Integrated Design" at the University of the Arts Bremen.

Tree bark as a local raw material

In 2020, approximately 80 million cubic meters of wood were harvested in Germany[04]. In general, wood is considered to be a renewable raw material, but climate change related effects such as dryness and heat weaken trees and facilitate insect infestations, also in Germany[05].

01 Walcher, Dominik and Michael Leube. 2017. Kreislaufwirtschaft in Design und Produktmanagement: Co-Creation im Zentrum der zirkulären Wertschöpfung: Springer.

02 Fehrenbach, Horst, Susanne Köppen, Benedikt Kauertz, Andreas Detzel, Frank Wellenreuther, Elke Breitmayer, Roland Essel, Michael Carus, Sonja Kay and Bernhard Wern. 2017. "Biomassekaskaden: mehr

03 Fehrenbach, Horst, Susanne Köppen, Benedikt Kauertz, Andreas Detzel, Frank Wellenreuther, Elke Breitmayer, Roland Essel, Michael Carus, Sonja Kay and Bernhard Wern. 2017. "Biomassekaskaden: mehr

04 Destatis. 2021. "Exporte von Rohholz im Jahr 2020 um 42,6 % gestiegen." accessed 2.5.2022. https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/05/PD21_N031_51.html.

05 Bocksch, R. 2021. "Holzeinschlag erreicht Rekordhoch." accessed 2.5.2022. https://de.statista.com/infografik/19446/entwicklung-des-holzeinschlags-in-deutschland/.

This raises more awareness that wood is not an unlimited resource. Nevertheless, about 44% of the harvested wood in German forests is being burned without any prior uses[06]. These 44% consist of wood cuttings, branches and bark with bark making up between 10 and 20 percent of a tree[07]. This means that ~ 4 million cubic meters of "waste bark" accumulate in German saw mills per year [08]. Despite bark being used for mulching and extraction of chemical components, almost all of this bark is being burned directly in the saw mills.

Historically, many cultures used bark for various purposes,[09] e.g. for everyday products such as containers but also for textiles. The sheer length of bark strips (theoretically as long as a tree is high) makes it also suitable for large objects. Indigenous peoples in North America turned birch bark into canoes[10] and Austrian lumberjacks used to roof their shelters in the woods with barks of different tree species[11].
One of the most widely used barks was harvested from birches, occurring in various geographic regions. The ease of peeling the outer layer of birch bark from living trees without the need of felling has given rise to numerous different applications of the material worldwide. Birch bark is still being used today for making objects such as boxes and containers[12], furniture[13], flooring[14] and facades of houses[15]. Despite the use of birch bark, the use of other barks as a material for applications is very limited yet highly desirable considering the large amount of bark waste.

06 Mantau, Udo. 2012. "Holzrohstoffbilanz Deutschland: Entwicklungen und Szenarien des Holzaufkommens und der Holzverwendung von 1987 bis 2015."

07 Harkin, John M. 1971. Bark and its possible uses. Vol. 91: Forest Products Laboratory, US Forest Service.

08 Wollenberg, Ing Ralf, and Dipl-Ing Christian Warnecke. 2005. "Neue Einsatzgebiete für Rinden durch Produktentwicklung."

09 In Southern China a pounder used to soften bark has been found that is some 8000 years old, providing one of the earliest pieces of evidence for the manufacture of textiles from bark (Li et al. 2014). By pounding bark, the inner fibres were prepared for further processing.

10 Adney, Edwin Tappan, and Howard I Chapelle. 1964. "The Bark Canoes and Skin Boats of North America" (Washington: Smithsonian Institute, 1964):67.

11 Ast, Hiltraud, Georg, Winner. 2011. "Historische Holzverwendung und Waldnutzung in der Schneebergregion: Rindennutzung." Institut für Holztechnologie und Nachwachsende Rohstoffe.

12 Mergelsberg, Tim. 2019. accessed 8.3.2022. https://sagaan.de.

13 Koshcheeva-Rasehorn, Anastasiya 2021. Last Modified 8.32022. https://moya-birchbark.com/de.

14 Mergelsberg, Tim. 2021. "nevio." accessed 8.3.2022. https://www.nevi.io/.

15 Blocksdorf, Helga. 2021. "Weissensee." accessed 8.3.2022. https://www.helgablocksdorf.de/.

The Bark Project – Connecting Experiments in Natural Sciences and Design for Research on Tree Bark

The "Bark Project" aims to combine methods of basic research and design to gain in-depth knowledge of different bark species and tailored material-based processing techniques and application scenarios.

To make use of the structure and the overall length of bark for research and design, we needed large bark pieces. We manually peeled bark of local (Brandenburg) pine trees (*Pinus sylvestris*, L.), common oak (*Quercus Robur*, L.), European larch (*Larix decidua*, Mill.) and European white birch (*Betula pendula*, Roth) ❑ ILL-01.

To get a better idea about the harvested raw materials, we examined density and internal structure of the bark by using various techniques such as microscopy and computed tomography ❑ ILL-02. Birch bark turned out to be comparably dense, cause by "islands" consisting of thick-walled cells. Larch bark is composed of individual scales with sizes depending on the age of a tree. While the bark of some trees (e.g. larch or birch) appear similar along the whole length of the trunk, pines differ in that respect. The bark of young pines and bark of older trees further up the stem is thin and commonly known as "mirror bark". The bark of older pines on the lower trunk is thick, consisting mostly of large scales.

The first experiments on structure and mechanical behavior served as a starting point for a number of experiments related to bark processing and design applications. In one experiment, pine bark was infiltrated with a glycerol water solution. As a result, the mirror bark kept some of its flexibility, even after drying and was haptically comparable to leather. Pieces of this flexible bark were cut and sewed or riveted together in additional experiments. The usage of flexible bark was tested in different design prototypes. A jacket ❑ ILL-03 was created to examine comfort in wearing bark. In other experiments bark was processed into shoes or a skirt ❑ ILL-04. Aesthetics and smell, additional factors for applications in design, turned out to be pleasing. Disadvantage of using glycerin treated bark for the above-mentioned prototypes was a limited degree of flexibility which was also confirmed by tensile tests, demonstrating a much higher stiffness than leather. However, the qualities of bark can be optimised by using weaving techniques. Flexible bark was cut into thin strips and then woven into fabrics. The applied twill weave added flexibility and stronger resistance to tearing to the bark. The woven fabric was used to create another jacket with a better wearing comfort ❑ ILL-05.

Practical experiments demonstrated that mechanical properties of bark can be changed and optimised for specific uses by applying techniques such as weaving, knitting, crocheting or sewing.

Slow Fashion, Fast Fashion and the Potentials for Tree Bark in Fashion

Locally sourced bio-materials are crucial for a more sustainable garment industry. To put this into practice, a holistic approach ranging from harvest to processing, manufacturing and final applications is necessary. This is evident, for example, in the impacts of producing leather, one of the oldest biogenic materials in human history[16].
Leather is known to create prosperity and culture, but at the same time, its production is associated with environmental issues. Its main applications are in the lifestyle industry, interior design and automotive upholstery. According to current projections, leather consumption is expected to continue to rise in the coming years[17].
High-quality leather products can last for more than 100 years even with constant use. In this regard, leather can be considered a highly sustainable material. However, considering the rapid social change and the associated desire for suitable consumer goods - both in terms of technology and functionality, as well as aesthetics and trends - most leather goods are unlikely to be used for long times.

Besides the short lifespan of products, the production of leather is also critical. Animal hides are typically made durable by tanning them with chromium salts. Several reports indicate that conventional tanning with highly toxic chemicals is one of the most environmentally damaging industries[18]. In addition to the environmental impact, leather production poses a health risk to people working in tanneries and ultimately to end consumers[19].
Furthermore, the ongoing, ethical discussion surrounding the use of fur and leather in the fashion and lifestyle industry is creating an increasing demand for vegan alternatives[20].

Tree bark has been used as a material for textiles in the past. Stone tools for processing bark into textiles have been found in China, dating back to around 8000 BCE [21]. Bark cloths are considered one of the oldest anthropogenic textiles and are still produced and used for clothing on islands in Oceania, as well as in Central America and Uganda[22].

16 Kite, Marion, and Roy Thomson. 2006. Conservation of leather and related materials: Routledge.

17 UNIDO, United Nations Industrial Development Organization Vienna. 2010. "Future trends in the world leather and leather products industry and trade."

18 Muthu, Subramanian Senthilkannan, and Miguel Angel Gardetti. 2016. Green fashion. Vol. 2: Springer.

19 Muthu, Subramanian Senthilkannan. 2020. Leather and Footwear Sustainability: Manufacturing, Supply Chain, and Product Level Issues: Springer Nature.

20 Muthu, Subramanian Senthilkannan, and Miguel Angel Gardetti. 2016. Green fashion. Vol. 2: Springer.

21 Rwawiire, Samson, George William Luggya, and Blanka Tomkova. 2013. "Morphology, Thermal, and Mechanical Characterization of Bark Cloth from *Ficus natalensis*." ISRN Textiles 2013:925198. doi: 10.1155/2013/925198.

22 Rwawiire, Samson, George William Luggya, and Blanka Tomkova. 2013. "Morphology, Thermal, and Mechanical Characterization of Bark Cloth from *Ficus natalensis*." ISRN Textiles 2013:925198. doi: 10.1155/2013/925198.

In Europe, the barks of trees such as birch, lime, and cork oak were traditionally used for making clothing, shoes, bags, and other fashion items. Bark vessels and strings were already among the belongings found with the Neolithic iceman 'Ötzi'[23]. Hats made from birch bark have been discovered in Celtic graves, likely serving as status symbols, similar to crowns[24].

Today, cork is used to make shoes[25], bags or wallets[26]. Other types of bark barely play a role in the Western fashion market. Cork oak (Quercus suber) is native to the Mediterranean climate, particularly the west coast of North Africa and the south coast of Portugal and Spain. It is not a waste material, as cork is harvested from living trees. The material's compressive strength relative to its weight, along with its high elasticity[27], makes it particularly suitable for sustainable products that are used extensively for a long period of time. In response to increasing resource scarcity and anthropogenic climate change, a growing desire for such durable products in the fashion industry (slow fashion) is emerging in parts of society.

However, the demand for fast fashion products remains. Companies like H&M or Zara are even being overtaken by so-called ultra-fast fashion corporations like Boohoo and ASOS[28]. ASOS, for example, launches up to 4500 news items per week[29].
Such a large industry cannot be transformed overnight. Therefore, in addition to fundamental changes in consumer behavior and the lifespan of fashion products, medium-term solutions are needed that take into account the fast pace of fashion and align the lifespan of products and materials accordingly.
Many fashion products are only worn seven to ten times before being discarded[30].

23 Oeggl, K. (2009). The significance of the Tyrolean Iceman for the archaeobotany of Central Europe. Vegetation History and Archaeobotany, 18(1), 1-11. doi:10.1007/s00334-008-0186-2

24 Reeves, C. M. (2015). Head and Shoulders Above the Rest: Birch-Bark Hats and Elite Status in Iron Age Europe. (Master of Science). University of Wisconsin-Milwaukee

25 Nae Vegan Shoes. (2021) The astonishing versatility of cork. Retrieved from: https://www.nae-vegan.com/en/the-astonishing-versatility-of-cork_672.html?idb=100

26 Burggrafburggraf. (2023). Cork bags and backpacks. Retrieved from: https://burggrafburggraf.de/

27 Silva, S. P., Sabino, M. A., Fernandes, E. M., Correlo, V. M., Boesel, L. F., & Reis, R. L. (2005). Cork: properties, capabilities and applications. International Materials Reviews, 50(6), 345-365. doi:10.1179/174328005X41168 https://www.tandfonline.com/doi/abs/10.1179/174328005X41168

28 Janker, K. (2021, 22. April 2021). Fast, Faster, Super Fast Fashion. Süddeutsche Zeitung. Retrieved from https://www.sueddeutsche.de/wirtschaft/fast-fashion-marken-deutschland-1.5272604

29 Wahnbaeck, C. (2019, 20.10.2019). Ultrafast Fashion Wo Zara und H&M zu langsam sind Spiegel. Retrieved from https://www.spiegel.de/wirtschaft/unternehmen/ultrafast-fashion-wenn-zara-und-h-m-zu-langsam-sind-a-1290385.html

30 Igini, M. (2022). 10 Stunning Fast Fashion Waste Statistics. Retrieved from https://earth.org/statistics-about-fast-fashion-waste/

Consequently, we require materials that are both easily recyclable and compostable.

The design prototypes created as part of the doctoral thesis of "The Bark Project" represent a vision that ideally inspires other designers to further explore the potential of tree bark in various disciplines. An example of this is the collection "Space In Between" by Johanna Hehemeyer-Cürten, which was created as part of her master thesis.
The project consists of a basic collection named "Durable Companions" and experimental pieces titled "Temporary Companions". While the focus of the basic collection is on durability and timelessness, the experimental pieces are inspired by red carpet fashion and costume design – garments and accessories that are only worn a few times. The materials used for this purpose were developed from industrial by-products that are fast compostable, locally sourced, and can be easily integrated into a biological life cycle. In this context, building on the first two jacket prototypes of "The Bark Project" ❏ ILL-05, a third prototype was created ❏ ILL-06.
The weaving technique developed for the second prototype was adjusted once again, and greater flexibility was achieved through the use of thinner strips of bark. Additionally, the jacket's cut was significantly altered to allow for greater freedom of movement, transforming it into a vest (similar to a kimono) consisting of a long, draped rectangle ❏ ILL-06.

The flexible pine bark, due to the moisture stored in it by glycerin, possesses a special luminosity and a wide range of colors from orange, beige, brown to green, grey and black. In the woven vest, this color complexity is utilized for a gradient effect ❏ ILL-07. This is emphasized by using a weft-faced twill weave, where the upper side of the fabric is predominantly composed of weft threads (bark), while the warp threads (cotton) primarily lie on the underside.

The jacket prototypes demonstrate how the dry and brittle bark of the pine tree can be transformed into a flexible fabric in just a few steps. While preserving its ability for natural composting, the material properties change to enable further processing into fashion products such as the described vest.

The development and establishment of new materials can be a lengthy process, wherein economic feasibility plays a significant role alongside design and material engineering.

Workshop: Possible Applications for Tree Bark

In a one-day workshop, students had the opportunity to develop new techniques for designing and processing bark. The goal of the course was to provide students with the opportunity to work with tree bark in all the workshops at the University of the Arts Bremen. The course started with an overview of the structural composition of bark, followed by the hands-on part. The provided materials were pieces of bark from oak, pine, birch, and larch trees. ❏ ILL-08, as well as flexibilised pine bark.

The results demonstrate interesting processing methods that utilize various properties of bark.
The experiments shown in Figure 09 ❏ ILL-09 and Figure 10 ❏ ILL-10 share a common approach. The principle resembles a historical method of roofing, where bark was used as shingles.
Pine bark was cut into small rectangles, with the longer side cut along the direction of the fibers. Both experiments used glycerin treated bark. Bark pieces were secured with stitches on one end. The combination of fixed and loose points makes this processing principle highly interesting for design applications that include shape changes, air or light permeability.

The material experiment in Figure 11 ❏ ILL-11 shows a piece of flexibilised pine bark that has been rolled up and tied with another piece of pine bark and yarn. The shape resembles floaters used for fishing. Until the 1940s, fish lures were made from tree bark in the Scandinavian countries[31]. The cambium (inner side) of the bark is rolled outward.

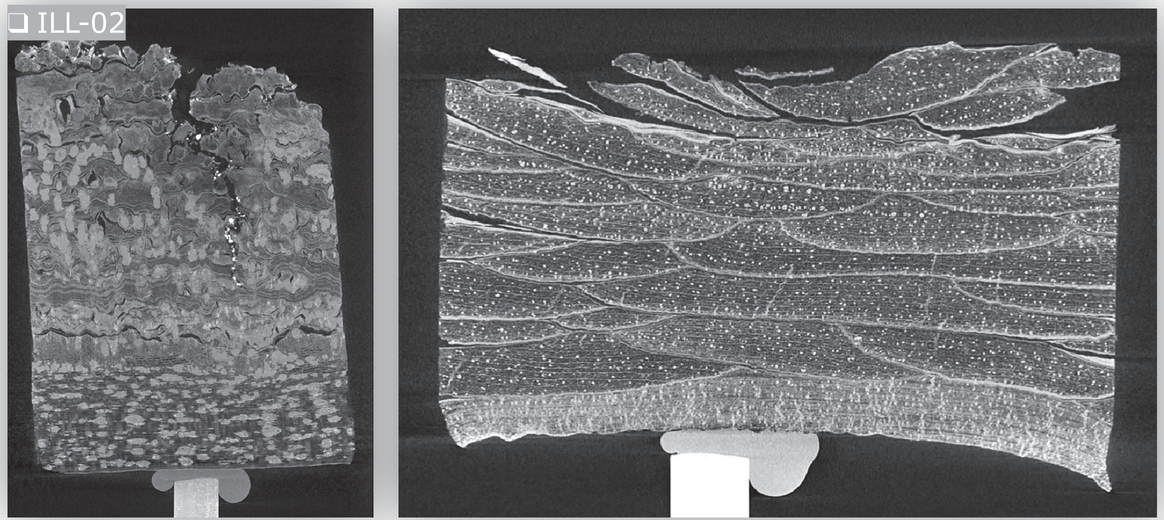
Tensile tests on pine bark showed that glycerin treated bark is significantly more flexible compared to dry bark. However, the initial experiments with the bark jacket ❏ ILL-03 showed that the material is still too rigid for many fashion applications. The problem of lacking flexibility is evident in many materials used in design. To achieve greater flexibility, materials like tree bark can be processed into textiles similarly to the processing of other fibrous materials such as cotton or flax. Crocheting is one of the many possible processing techniques. The experiment in Figure 12 ❏ ILL-12 demonstrates how flexibilised bark was cut into long strips along the grain direction of the bark. This gives the material higher tensile strength compared to cutting it against the grain. By crocheting single bark strips were transformed into a textile structure with higher tensile strength and improved flexibility. This type of processing makes flexibilised bark interesting for textiles in fashion. Given the considerable length of bark, this principle could also find application in architecture.

31 Rapala. 2021. Our History. Retrieved from https://www.rapala.com/ eu-en/content/rapala-general-information/ our-history. html?fdid=rapala-general-information&id=1, accessed 29.3.2021

Figure 13 ❑ ILL-13 shows a color offprint from a piece of oak bark. The characteristic outer side of the bark was coated with black color and then pressed onto a piece of paper. Tree barks differ in many factors such as: appearance, structure and thickness. The composition of bark also determines the appearance of the bark surface.

In the experiment shown in Figure 14 ❑ ILL-14, flexible pine bark was cut into a thin strip along the grain direction. This strip of pine bark was then looped and secured on both sides with a cotton thread. The experiment combines flexibility and stiffness. By compressing the structure, it can be deliberately compressed. It is likely that the bark possesses sufficient internal tension, allowing the structure to relax once the pressure is released. This principle is of interest for applications such as upholstered furniture or seat surfaces or cushioning packaging materials, where temporary compression or deformation of surfaces is relevant.

The described experiments are a selection of possible processing methods using tree bark. They demonstrate how techniques such as crocheting, folding, looping or sewing can be used to harness and modulate material properties such as anisotropy for specific use cases. Possible applications range from fashion to packaging all the way to architecture. This workshop showcased the various possibilities for processing tree barks and the potential that this material holds for the future.

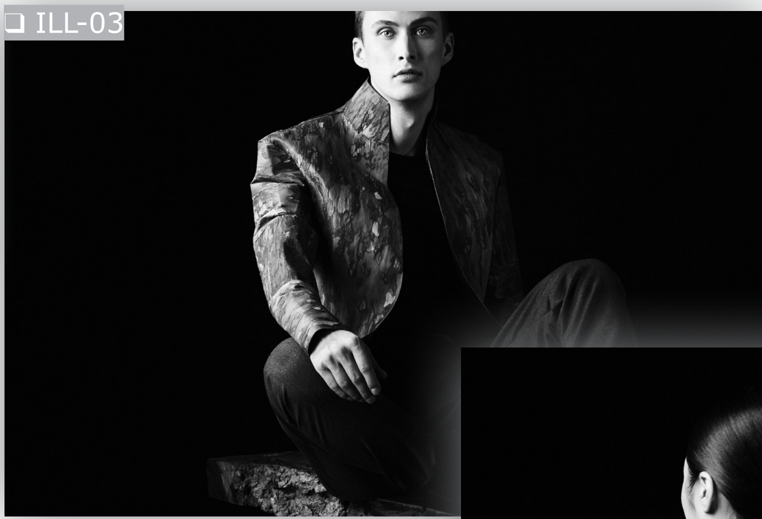


Micro-computer-tomographic images of birch and larch bark.

Peeling pine bark with a wooden wedge.

Jacket made from pine bark and leather shoes with bark applications.

❑ ILL-03



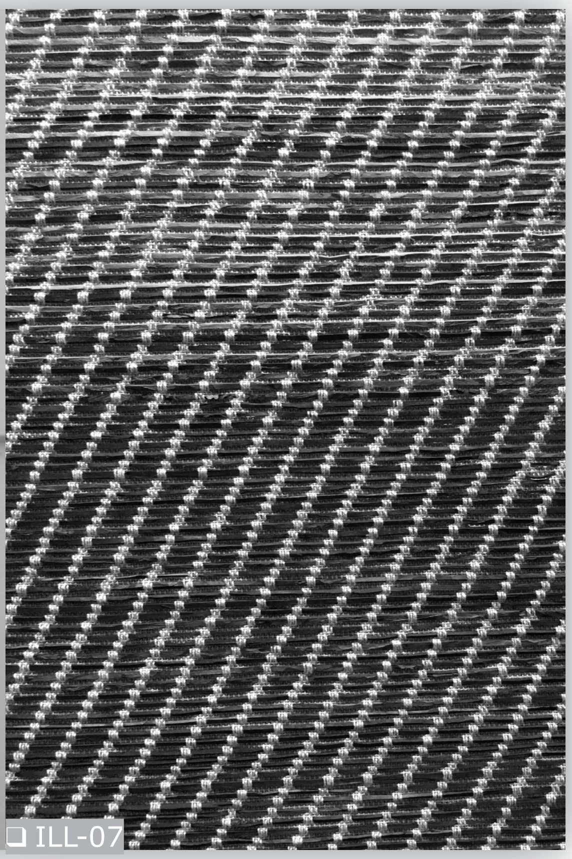
❑ ILL-04

Pine bark has been sewn into a skirt with riveted seam.

Model in the front wearing the woven bark jacket.

❑ ILL-05

❏ ILL-06

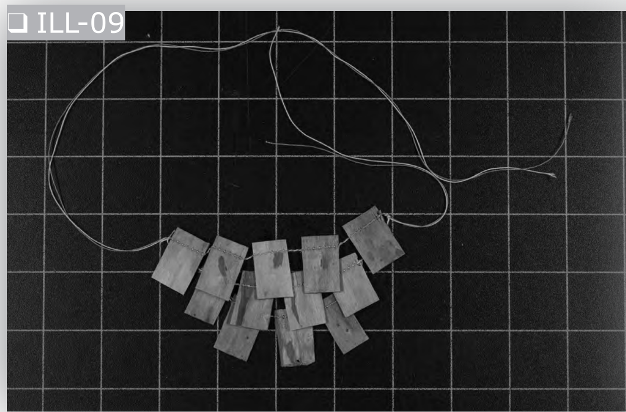


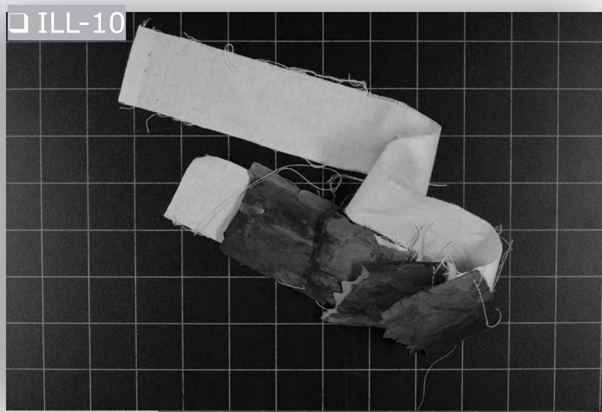
❏ ILL-07

Vest made from pine bark

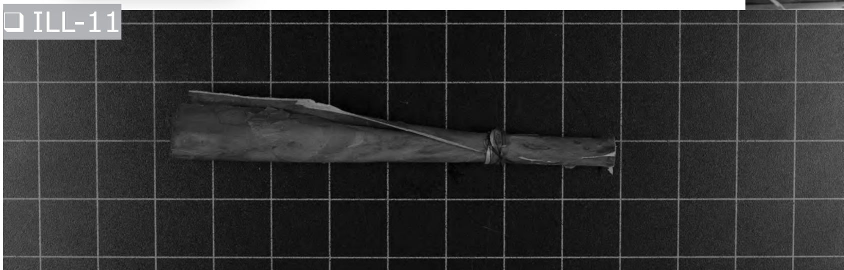

❑ ILL-08

Oak bark and birch bark were cut into narrow strips against and along the fiber direction.


❑ ILL-09


❑ ILL-10

flexibilised pine bark

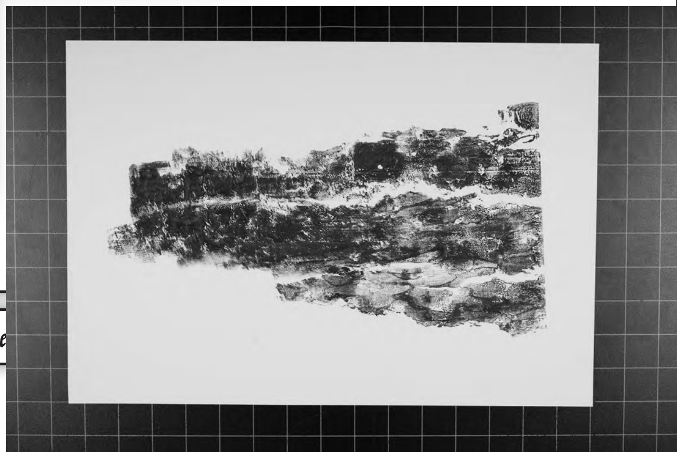

❑ ILL-11

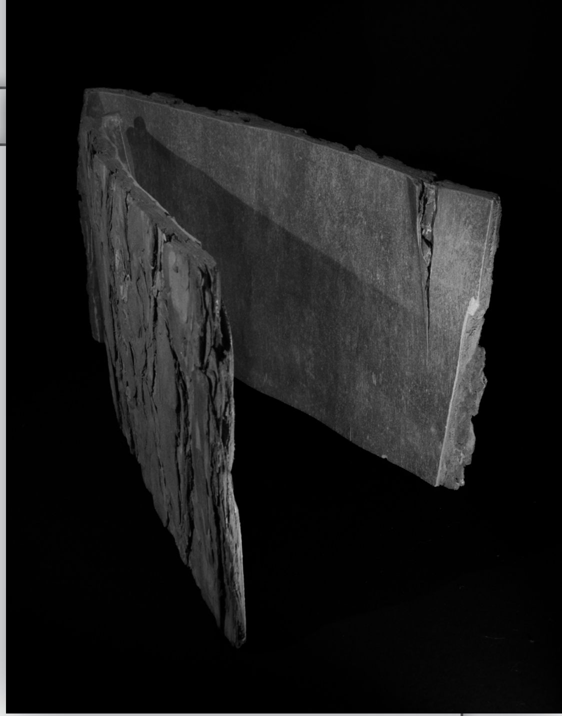
❏ ILL-12

flexibilised pine bark

❏ ILL-13

Color offprint showing oak bark.





❑ ILL-14

flexibilised pine bark

Image Credits

ILL-01

Peeling pine bark with a wooden wedge.
Copyright: Johanna Hehemeyer-Cürten, Max Planck Institute of Colloids and Interfaces.

ILL-02

Micro-computer-tomographic images of birch and larch bark.
Copyright: Charlett Wenig, Max Planck Institute of Colloids and Interfaces.

ILL-03

Jacket made from pine bark and leather shoes with bark applications.
Copyright: Studio Patrick Walter, Max Planck Institute of Colloids and Interfaces

ILL-04

Pine bark has been sewn into a skirt with riveted seam. Copyright: Studio Patrick Walter, Max Planck Institute of Colloids and Interfaces

ILL-05

Model in the front wearing the woven bark jacket. The model can bend her arms. The jacket of the model in the background is much stiffer. Copyright: Studio Patrick Walter, Max Planck Institute of Colloids and Interfaces

ILL-06

Space In Between: Vest made from pine bark and a bag sourced from a compostable composite material.
Copyright: Johanna Hehemeyer-Cürten

ILL-07

Detail Vest.
Copyright: Johanna Hehemeyer-Cürten

ILL-08

Oak bark and birch bark were cut into narrow strips against and along the fiber direction. Copyright: University of the Arts Bremen

ILL-09

Flexibilised pine bark was threaded with a cotton thread.
Copyright: University of the Arts Bremen

ILL-10

Flexibilised pine bark sewn onto a piece of fabric.
Copyright: University of the Arts Bremen

ILL-11
Rolled up flexibilised pine bark.
Copyright: University of the Arts Bremen

ILL-12
Crocheted flexibilised pine bark.
Copyright: University of the Arts Bremen

ILL-13
Color offprint showing oak bark.
Copyright: University of the Arts Bremen

ILL-14
Flexible pine bark connected in loops.
Copyright: University of the Arts Bremen