The Bark Project
Combining Science and Design to Elaborate New Models of Production for the Design Industry

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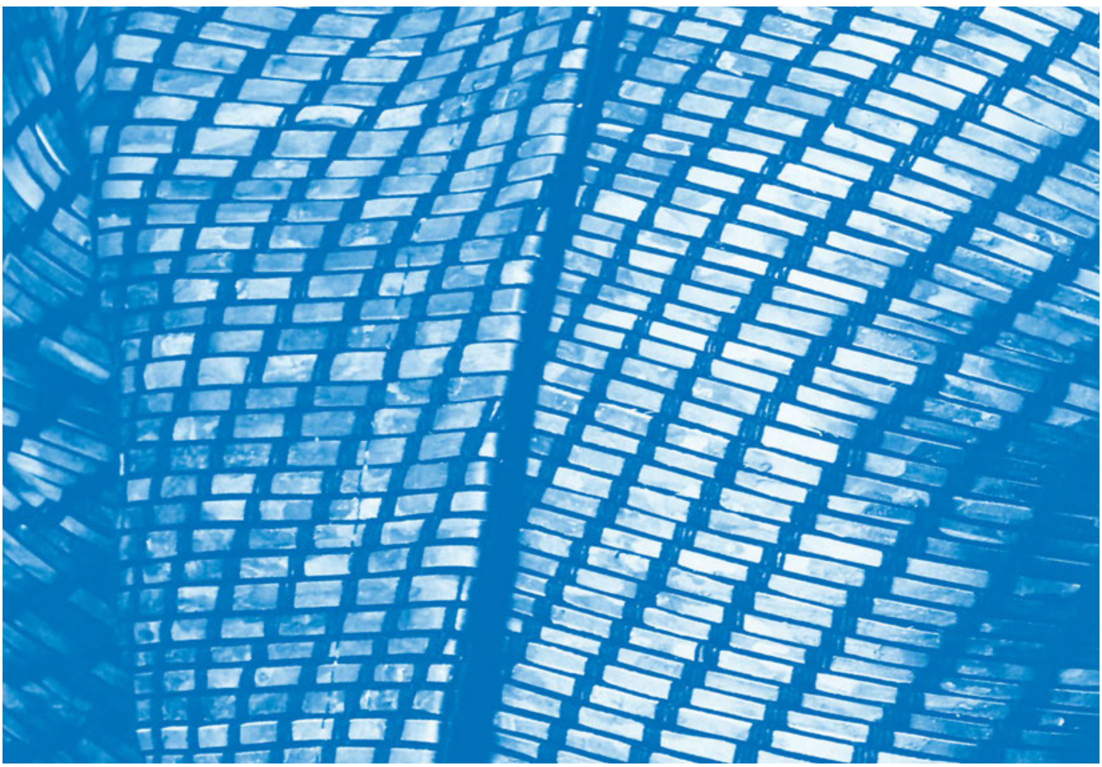

The use of wood and the evolution of human civilization are intrinsically intertwined. Trees, the “producers” of wood, are complex living organisms, and their harvest and processing does not only produce timber. The cambium, a meristematic tissue located between wood and bark synthesizes wood cells towards the inside and phloem cells to the outside. The living phloem together with older dead tissue forms the bark—the outer protective “skin” of the tree.[1] Bark makes up 10 to 20 percent of a tree[2] and is typically removed after harvest. Apart from niche applications of bark as a material, such as the use of cork from *Quercus suber* or of birch bark of *Betula* sp. for crafts, the majority of bark production is considered as waste by the wood industry. Large-scale bark use is thus mainly limited to the production of energy through incineration and mulching in horticulture. This means the potential to utilize the structure and properties of bark as a material that can be produced in large quantities is unexplored.

The motivation for the present project was to work with bark from local trees, to keep the bark as unmodified a state as possible and to make use of the inherent natural properties for different application scenarios.

The Bark Project is an example of a material-focused exploration using scientific and design methods as a possible new mode of developing more sustainable objects based on inner properties, structure and potential applications of waste materials of timber processing industries. The focus of this project is to establish and analyze the possible interactions between practice-based methods traditionally used in design and fundamental research in material science and engineering in order to develop sustainable design concepts and objects.

Selection Process of Bark Species

The broad variety of different barks (shape, thickness, development in growth) both within and between tree species makes each bark a material of its own, with unique characteristics. In a first step, nonendangered and local species in the area of Berlin and Potsdam were selected. To provide a sustainable model, another selection criterium was the economic

1 Nigel Chaffey, “Esau’s Plant Anatomy, Meristems, Cells, and Tissues of the Plant Body: Their Structure, Function, and Development. 3rd ed,” *Annals of Botany* 99, no. 4 (2007): 785–86.

2 Zoltán Pásztory et al., “The Utilization of Tree Bark,” *BioResources* 11 (2016): 7859–88.

relevance of trees. To give an example, in 2019, 83 percent of the harvested wood in Germany was softwood such as spruce, fir, Douglas fir, pine and larch.[3] Pine and larch were the selected softwoods; and birch, oak, beech and robinia were the selected hardwoods.

How to Link Science and Design

The main idea is to create "boundary objects." A boundary object describes the different use of information by different groups. The concept was introduced by Susan Leigh Star and James R. Griesemer in 1989 and was illustrated by the example of a natural history museum in California.[4] "[Boundary objects] have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds."[5]

The flexibility to interpret any object makes the theory of boundary objects to a possible connector of design experiments and scientific research. The collection of general data about different types of bark facilitates and stimulates the discussion between science and design, with the goal to determine relevant research directions and tailor-made bark use for different species.

The process itself, which is characterized by simultaneous scientific experiments, design techniques, and crafts, generates new knowledge about the material. The results are iteratively used for the further development of design experiments, scientific experiments, and design applications.

3 "Destatis Holzeinschlag 2019: 69 Millionen Kubikmeter," Statistisches Bundesamt, https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Wald-Holz/aktuell-holzeinschlag.html (accessed June 26, 2021).

4 Susan Leigh Star and James R. Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science* 19, no. 3 (1989).

5 Star and Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects," 393.

Fig. 1: Peeling bark.

Peeling Bark

Tree bark was not always treated as a waste material in the past. A review of literature on material culture revealed a long and diverse tradition of bark use since the Stone Age. Bark use is documented in the European rural periphery until the first half of the twentieth century, in particular in countries with a long history of timber production like Austria[6] and Finland.[7] In these regions, tree bark was harvested by peeling as a seasonal product. Even though the technique of peeling is rarely documented, some of the reported applications, like large layers of bark that were used to build seasonal alpine huts,[8] made clear that it is possible to remove large bark pieces. The aim within the Bark Project is to study large pieces of tree bark in order to create application scenarios reaching from small-scale objects up to architectural dimensions.

The first attempts to peel trees took place in Spring 2018 and soon it became clear that some trees such as beech cannot be peeled, while for others, peeling is only possible when trees are full with water. As a result, freshly peeled bark contains a large amount of water. The drying process leads to pronounced shrinkage and warping. Warping can be avoided by fixation of the wet bark between wooden boards until dry. The harvest of large pieces of bark allows design experiments for large-scale applications; it is also possible to get an overall picture of how macroscopic as well as microscopic structure and properties change along the tree—both with design and scientific experiments (fig. 1).

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

7 Ville Kokkonen and Florencia Colombo, *Man Matter Metamorphosis: 10000 Years of Design* (Helsinki: National Museum of Finland, 2018).

8 Hiltraud Ast and Georg Winner, "Historische Holzverwendung und Waldnutzung in der Schneebergregion."

Research on Structure and Properties

Compared to wood, bark is less well studied. This lack of knowledge is possibly a consequence of less economic interest and high variability of bark material properties. An understanding of properties requires detailed information about chemical composition, structural differences at several length scales and physical properties (thermal, mechanical, optical, ...). To get this data, materials characterization techniques such as imaging approaches (for example, light and electron microscopy, computer tomography), structural analysis (X-ray diffraction), chemical (wet chemistry) and mechanical tests (for example, tensile tests, nanoindentation) are applied. These insights allow for more targeted design experiments. By combining both scientific and design-based results, processing methods can be precisely adapted to the typical properties of different barks. In addition, fields of application are better defined, enabling more targeted and sustainable application (fig. 2).

Fig. 2: Research on structure and properties.

Fig. 3: Flat bark panel.

Densification

Standardization, such as by defined and homogenized sizes or mechanical properties, is a common method to facilitate the processing of materials. In order to transform tree bark into uniform and standardizable panels (fig. 3), various forms of compression processes were studied. The densification of two crosswise placed bark pieces with specific heat and pressure conditions led to flat bark panels with a smooth surface and mechanical stability. It is conceivable that the heat melts substances in the bark, which act as glue. In this way, a purely bio-based material without additional adhesive but reproducible appearance and mechanical properties was created.

Fig. 4: Pressed bark in 3D shapes.

Experiments with Three-Dimensional Geometries

In a second step, the potential to create three-dimensional geometries was explored as these experiments open up new possibilities for 3D elements frequently required for many industries such as transportation design or packaging industry. Metal molds with different geometries were produced and bark pieces were pressed into the predefined shapes. The experiments showed that bark can be pressed into 3D shapes (fig. 4) with the cambium facing in both directions. More critical is the fiber direction, which should follow the curvature of the mold. The method works best for oak, pine and larch. While larch and pine show a very smooth surface, oak results in a possibly high-strength material due to its large fiber content.

Fig. 5: Mirror pine bark treated with a water-glycerine solution.

Flexible Bark

Freshly harvested tree bark is full of water and at least partly flexible. The drying of bark causes not only geometric deformations but also stiffening, hardening, and increased brittleness. While numerous applications rely on stiff, hard and strong materials, others, such as textiles for different uses, require flexibility. Since we know that leaves can be preserved and protected from crumbling by treating them with glycerin,[9] a similar approach was explored for bark. Glycerin keeps water molecules in hygroscopic materials and prevents them from drying.[10]

In an experiment, mirror bark of pine (*Pinus sylvestris*) was immersed in a mixture of glycerin and water and it was possible to maintain flexibility (fig. 5).[11] In terms of applications for flexible bark, historical examples provide inspiration: Already 8,000 years ago tree bark was used for clothing in China.[12] Nowadays bark textiles are still present in Central America and Uganda.[13] While the mentioned examples are nonwoven textiles, in European peripheries, especially in Finland, birch shoes or even whole suits of birch bark were created by weaving until the 1870s.[14]

9 A. K. Babu et al., "Review of Leaf Drying: Mechanism and Influencing Parameters, Drying Methods, Nutrient Preservation, and Mathematical Models," *Renewable and Sustainable Energy Reviews* 90 (2018): 536–56.

10 Babu et al., "Review of Leaf Drying."

11 Charlett Wenig et al., "Advanced Materials Design Based on Waste Wood and Bark," *Philosophical Transactions* (2021).

12 Dawei Li et al., "The Oldest Bark Cloth Beater in Southern China (Dingmo, Bubing basin, Guangxi)," *Quaternary International* 354 (2014): 184–89.

13 Samson Rwawiire, George William Luggya, and Blanka Tomkova, "Morphology, Thermal, and Mechanical Characterization of Bark Cloth from *Ficus natalensis*," *ISRN Textiles* (2013).

14 Ville Kokkonen and Florencia Colombo, *Man Matter Metamorphosis*.

Fig. 6: Bark jacket: The first prototype (non woven). Charlett Wenig (Material), Johanna Hehemeyer Cürten (Design), Model (Friedrich Reppe).

Bark Jacket – The First Prototype

Bark is the protection of the tree stem from environmental impacts. Driven by the question whether these protective properties can be transferred into textile applications for humans, the concept of a first prototype for a jacket was developed.

The bark jacket (fig. 6) is a tailor-made nonwoven garment of flexible pine bark. This design experiment was done in cooperation with fashion designer Johanna Hehemeyer-Cürten.

This experiment revealed bark-related material characteristics, which need to be considered for future manufacturing. While it is possible to sew bark across its longitudinal fiber directions, parallel seams lead to fractures of the material. The haptic of bark appears similar to leather but bark is stiffer. The model reported that the wearing comfort is worse than leather and the jacket feels like a stiff object. To overcome this problem, another fabrication method for using flexible bark as clothing or applications requiring high flexibility had to be considered.

Weaving Experiments

To increase fracture resistance and the flexibility of bark, weaving experiments were performed on a manual weaving chair (fig. 7). The idea was to make use of the better strength properties along the fiber direction, to increase flexibility and to create a fabric with more homogeneous properties in different directions. The application of different weaving techniques and patterns expands the design space for fine tuning material properties even more. The cooperation with fashion design was a determining role in this process. In order to find suitable weaving patterns for the woven jacket, different weaving techniques have been tested and evaluated.

Bark Jacket Woven

The woven bark jacket (fig. 8) is the first application of woven flexible bark (again in collaboration with Johanna Hehemeyer-Cürten). The problems of sewing and cutting of the first bark jacket were solved and the wearing comfort was improved by an increased flexibility. A twill weave, a pattern of diagonal parallel lines by passing the weft thread over one or more warp threads and then under two or more warp threads, providing good flexibility, was used.[15] Twill is popular in denim or furniture fabrics because it is very durable, more pliable and has a better wrinkle recovery.

Conclusion and Outlook

The Bark Project is an ongoing research project. Basic research on the structure and properties of barks of different species, developmental aspects, as well as how bark changes with the age of a tree and along the stem axis are still missing. It is expected that a better understanding of the raw material will trigger further developments toward a sustainable bark use in future interdisciplinary collaborations.

15 Anni Albers et al., *On Weaving: New Expanded Edition* (Princeton: Princeton University Press, 2017).

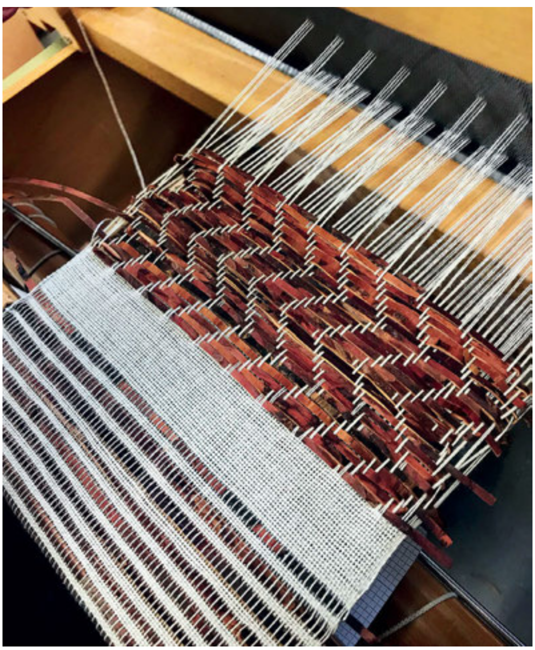

Fig. 8 (top): Bark jacket, second prototype (woven). Charlett Wenig (Material), Johanna Hehemeyer Cürten (Design), Model (Lee Zihern).

Fig. 7 (bottom): Weaving experiments.