BioSunShade

Adaptive Composite Structures Based on Natural Fiber-Reinforced Polymers with a PV-Functionalized Surface

Project Website

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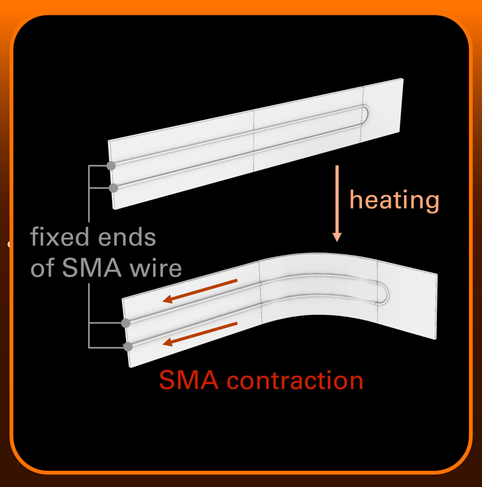
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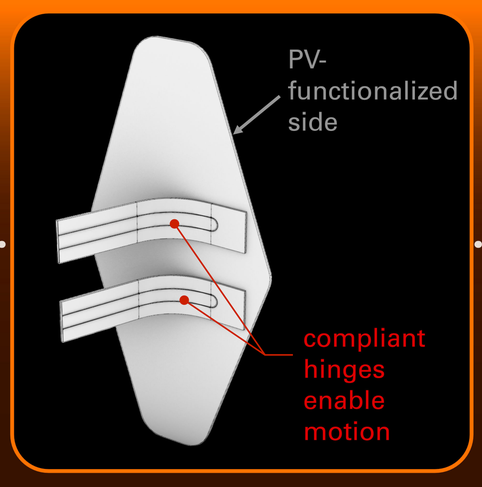
Novel hybrid yarn
A flax/CoPA hybrid yarn is developed for 3D weaving of quasi-UD fabrics. The yarn is made from staple fibers rather then filaments, allowing for precise control over the composite material's flexibility.



Energy-autonomous actuation
Shape memory alloy (SMA) wires actuate the hinge without motors or external power: PV supplies energy for SMA heating.
Figure: Hinge bending by SMA actuation.



Multifunctional module
All functions are embedded in one composite module. Compliant hinges enable motion actuated by SMA. The PV-functionalized plate provides shade and generates energy for the actuation and more.



Façade application
Self-sufficient modules track the sun, maximizing PV yield while adapting shading to daylight conditions.
Figure: Rendering of a built façade.



Buildings account for around 40 % of final energy consumption [1]. Highly glazed office buildings often require more energy for cooling than for heating [2]. External adaptive shading can reduce the energy demand for cooling of EU buildings by about 60 % (55 TWh per year) by 2050 [3]. However, today's systems rely on complex mechanical joints, motors, and gears that wear out and require maintenance. Compliant mechanisms made of fiber-reinforced polymers (FRP) replace these rigid-body joints by exploiting the elastic deformation of the material [4,5], while integrated shape memory alloy (SMA) actuators replace motors and gears and enable silent motion [6]. BioSunShade combines both with a partially bio-based material system in which renewable flax fibers replace energy-intensive glass fibers. Its thermoplastic copolyamide (CoPA) matrix enables thermal reprocessing and thus potentially improves recyclability compared to thermoset composites. PV-functionalized surfaces enable energy-autonomous actuation and supply surplus energy to the building.

Targets | **Recyclable material system** | **B2 fire class** | **>90° bending angle** | **22,000 cycles** | **+50% PV energy gain** | **Energy-autonomous**

Motivation for SMA actuation

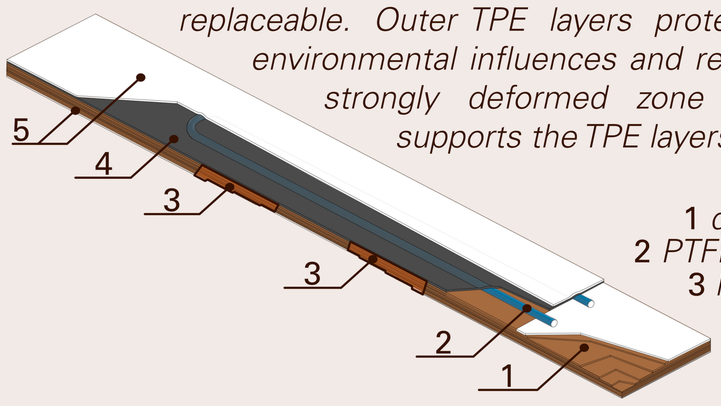
Previous FRP shading modules were actuated by pneumatic cushions, which require an air supply and achieved bending angles of about 90° [4,5]. SMA wires offer a very high work density and enable compact, silent actuation [6].

System simplicity

Pneumatic actuation requires a compressor, valves, and an air distribution network across the façade. SMA actuation only needs the electrical wiring already used for building-integrated PV: Fewer parts can fail, none can leak.

Hinge design for the flax/CoPA system

The flax/CoPA fabric is combined with functional layers fulfilling a specific tasks. A stiffness gradient concentrates the deformation in the compliant hinge zone. The SMA wire runs in an embedded PTFE tube (Bowden principle): It can slide freely, is shielded from the laminate and remains replaceable. Outer TPE layers protect the composite from environmental influences and reduce stress peaks in the strongly deformed zone [4,5]. A polyester net supports the TPE layers during actuation.



1 *quasi-UD flax/CoPA fabric*
2 *PTFE tube guiding SMA wire*
3 *layered stiffness gradient*
4 *polyester net*
5 *TPE layers*

Façade demonstrator with sun-tracking modules

BioSunShade is designed as a lightweight shading system that can be retrofitted to existing façades. Natural fibers and a recyclable thermoplastic matrix reduce the environmental footprint of the modules. Integrated PV supplies the energy for SMA actuation, and sensors allow the system to track the sun and regulate shading autonomously, without external power supply or building automation. Surplus energy can be fed into the building.

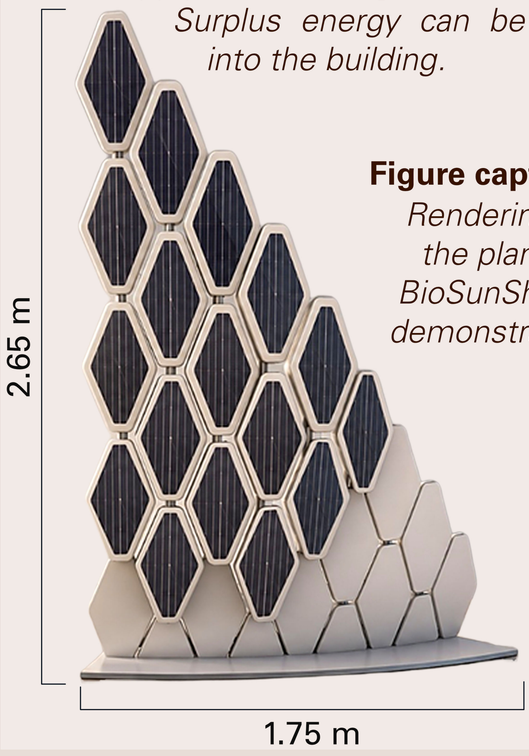


Figure caption
Rendering of the planned BioSunShade demonstrator.

Hybrid yarn and 3D weaving

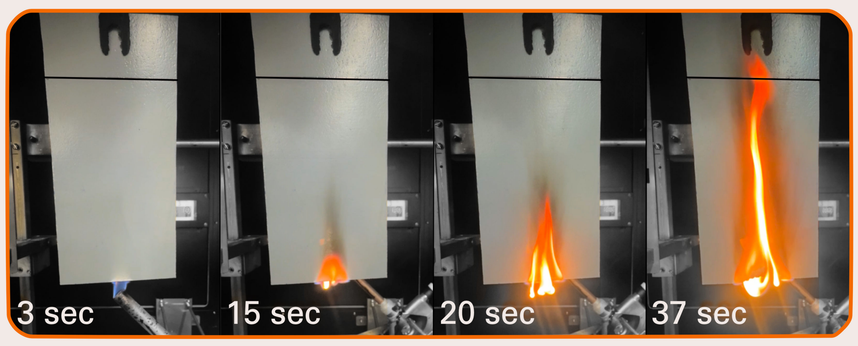
Cottonized flax and CoPA fibers were processed by rotor spinning into a hybrid yarn (100 tex, flax fiber mass fraction 66.4 %). Blending at fiber level distributes the matrix evenly both across and along the yarn axis and ensures short flow paths during consolidation.

Using CoPA yarn as warp, a quasi-unidirectional 3D fabric was woven with reinforcing fibers in the weft direction only.



Flammability

The flammability of two-layer flax/CoPA laminates with TPE layers was assessed in a small burner test based on DIN 4102-1. All specimens (n = 4) passed edge flame exposure, since the line is not reached by the flame at 20s, indicating class B2, normal flammability.



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DITF Deutsche Institute für Textil+Faserforschung

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