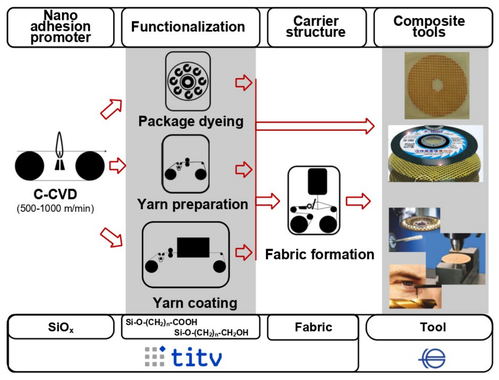
Textilforschungsinstitut Thüringen-Vogtland e. V.

Development of a Technology for Consolidating and Functionalizing Natural Fiber Yarns for Fiber-Reinforced Composite Components Using C-CVD

Research project 01|F23471N

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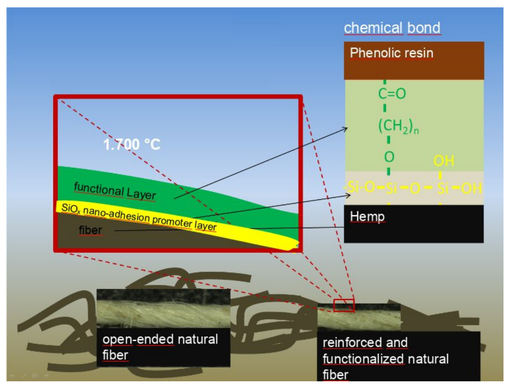


Fig. 1-2: Schematic diagram of deposition process and functional layer

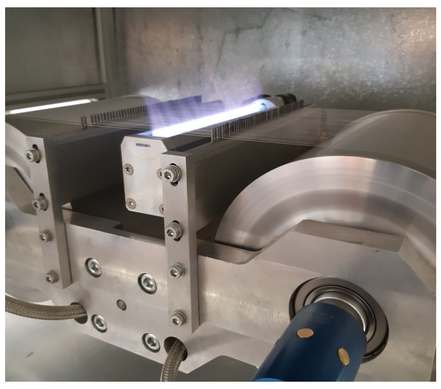
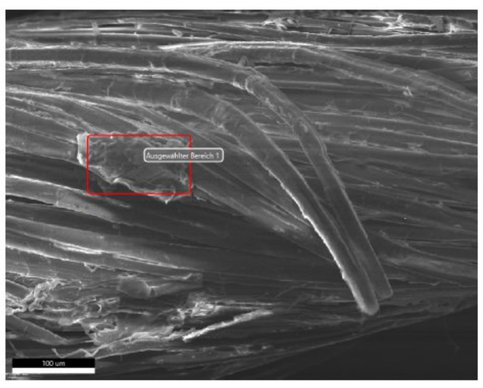


Fig. 3: C-CVD system with active flame



eZAF Quant Result - Analysis Uncertainty: 9.39 %

Element	Gewicht%	MDL	Atom%	Error %
A 16_26 | Probe 8 | Bereich 11 | Ausgewählter Bereich 1				
C K	70.3	0.06	77.0	8.6
O K	26.9	0.09	22.1	10.6
Na K	0.2	0.06	0.1	16.4
Mg K	0.1	0.04	0.1	19.3
Al K	0.2	0.04	0.1	11.8
Si K	0.1	0.04	0.0	26.7
K K	0.1	0.08	0.0	25.0
Ca K	0.9	0.10	0.3	10.3
Cu K	0.5	0.29	0.1	34.2
Au M	0.7	0.16	0.0	17.6

Fig. 4: REM-EDX analysis of a silicon particle on a thread: on the left, an REM image showing the detected Si particle; on the right, a tabular presentation of the elemental composition in % by weight

Introduction

Woven or non-woven fabrics based on glass or carbon fibre materials are used in the manufacture of lightweight components due to their excellent mechanical properties, such as high tensile strength and stiffness. The handling of glass fibres during manufacturing and processing is increasingly regarded as a critical issue due to abrasion and the particles released as a result. Such particles are usually respirable, thus penetrating the body, causing health hazards. In addition, the sharp-edged fracture structure of glass fibres poses a potential risk of skin penetration, which can lead to mechanical irritation and injury to the skin.
As an alternative, natural fibre yarns with high mechanical strength are produced. Owing to their fibrous structure and surface properties, these yarns bond well with coating materials and form excellent composite properties with polymer matrices. Yarns produced from renewable materials, such as flax fibres, are characterized by a significantly increased life cycle assesment compared to conventional reinforcing materials. Initial studies also show that such nature-based reinforcing materials may have the potential for biodegradability or fermentability under suitable conditions.

Solution

The processability and mechanical properties of natural fibre yarns are specifically improved by means of a **C-CVD** (combustion chemical vapour deposition) treatment. In this process, the yarns are passed through a flame fed with precursors several times for short periods. During the thermal treatment, surface impurities and loosely adhering components, such as waxes or other natural constituents, are removed. At the same time, components leaching from the natural fibre structure are reduced or transformed by the controlled thermal treatment. Components from within the fibre are released and are either removed by the flame or melted, thereby causing the fibres to bond together. This results in additional consolidation of the yarn structure without any significant reduction in yarn diameter or damage to the underlying fibre structure being observed.
The **C-CVD** treatment achieves various effects. Singeing the yarn leads to a significantly reduced number of protruding fibre ends, thereby improving textile processability. The tensile stress applied to the yarn during the process, combined with the simultaneous thermal setting, increases yarn compactness, enhancing tensile strength and reducing elongation. The addition of precursors, such as organosilanes, also enables targeted functionalisation of the surface.

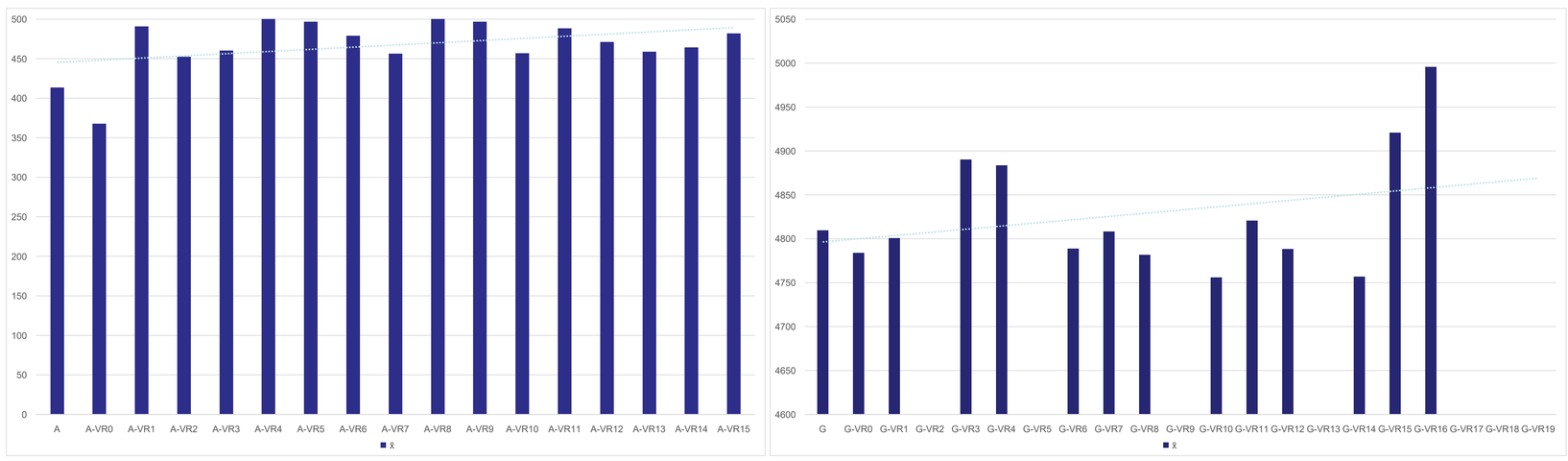


Fig. 5: Overview of the measured maximum tensile strengths (FH) of natural fibre yarns as a function of the C-CDV treatment. The y-axis shows the maximum tensile strength in cN, whilst the x-axis identifies the individual samples within each test series. The trend lines plotted illustrate the treatment-dependent increase in yarn strength.

Results, applications, outlook

The formation of inorganic deposits on the individual fibres was confirmed by SEM-EDX analysis. In particular, silicon-containing structures were identified, which are attributed to the formation of silicon oxide phases (SiOx). This surface modification increases fibre-to-fibre friction, thereby improving the internal strength of the yarn whilst also promoting the adhesion of subsequent coatings.

The aim of the project is to develop a process for strengthening and functionalising primarily bio-based natural fibre yarns. In addition enhanced mechanical properties, the C-CVD treatment specifically creates a defined surface structure with adhesion-promoting properties.

This enables the development of high-performance yarns that are both processable and suitable for permanent coating. Fabrics containing the functionalized yarn are suitable for applications in lightweight construction. The transfer of the developed yarns into lightweight components, including component manufacture, processing and mechanical testing, is being conducted in collaboration with the project partner institute. GFE Gesellschaft für Fertigungstechnik und Entwicklung Schmalkalden e.V., which is responsible for component manufacture, processing and performance evaluation.
The production of a coated grinding disc is planned as a demonstration of the natural fibre yarns developed in the project. The aim is to demonstrate that the functionalized yarns can be used as a reinforcing component in a technically sophisticated composite component, while offering a resource-efficient alternative to conventional glass-fibre-reinforced systems. Furthermore, the use of natural fibre yarns can help to reduce potential health risks.

Acknowlegements
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