

Press Release

CFRP hydrogen tanks for zero-emission and sustainable mobility

Surface pre-treatment, barrier layer, automated machining and assembly of cryogenic CFRP hydrogen tanks

At ILA 2026, Fraunhofer IFAM presents “HYTANK” project results on the efficient production of lightweight hydrogen tanks for zero-emission aviation

Researchers from Plasma Technology and Surfaces, Paint/Lacquer Technology as well as Automation and Production Technology at Fraunhofer IFAM, in collaboration with “HYTANK” project partners, developed groundbreaking, resource-efficient manufacturing and joining technologies for the production of large-format, double-walled hydrogen tanks made of carbon fiber-reinforced plastic (CFRP) – ranging from suitable surface pre-treatments and functional barrier layer up to automated production on a 1:1 scale, including machining and adhesive bonding assembly. The goal was to lay the groundwork for the future efficient production of lighter, leak-tight and – under cryogenic conditions – more reliable tank structures, e.g., for the aerospace industry.

Liquid hydrogen (LH₂) is considered a promising option for the aircraft engines of the future. However, the tanks required for this purpose have to meet extreme requirements: despite their minimal weight, they must remain permanently leak-tight and structurally sound at temperatures as low as -253 °C, while also withstanding mechanical and thermal stresses. CFRP structures generally offer favorable conditions for this, but place high demands on design, manufacturing and joining technology. In particular, cryogenic temperatures, pressure loads and the combination of different materials require tailored design and process concepts.

In the “HYTANK” project (“Development of coating, joining, and assembly processes for the manufacture of a CFRP LH₂ tank for emission-free flight”; funding code: 20W2214D), Fraunhofer IFAM addressed these challenges with an integrated approach covering key process steps – from the preparatory functionalization of surfaces to the development of barrier layer for increased leak tightness and vacuum stability, right through to the automated machining and assembly of the tank structures.

At ILA 2026 in Berlin (Hall C, Booth 280), the scientists present a true-to-scale model of the automated machining and assembly plant as well as a 1:1-scale original tank structure segment that has undergone surface pre-treatment and barrier layer.

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Surface pre-treatment: Improving adhesion in a targeted manner

To ensure that subsequent coating systems function reliably on CFRP structures, a consistently high level of adhesion to the substrate is required. A main focus of the R&D work within the "HYTANK" project was therefore on the appropriate pre-treatment of surfaces. The goal was a combined pre-treatment and coating process that improves the barrier properties of the CFRP structure, thereby permanently stabilizing the insulating vacuum between the inner and outer shells of a double-walled cryogenic tank. The focus is on enhancing the barrier effect against moisture penetrating from the outside as well as against outgassing products from the CFRP. For the barrier layer to function reliably, in addition to the actual barrier effect, excellent adhesion to the CFRP substrate is required. The challenge: Due to the manufacturing process, the CFRP surface has release agent residues that are critical for adhesion; these must be removed or specifically modified without damaging the matrix or exposing the fibers.

The project involved a comparative study of various pre-treatment methods, including vacuum suction blasting, atmospheric pressure plasma treatment, VUV irradiation and laser treatment. Three of these process variants proved to be fundamentally suitable. However, which solution is best suited in each individual case depends heavily on the specific application – for example, on component geometry, accessibility, available processing time, the CFRP material used as well as the type and amount of release agents applied.

Dry, non-contact or material-friendly processes show particular promise. Thus, **atmospheric pressure plasma treatment** increases wettability and adhesion without subjecting the surface to significant thermal or mechanical stress. **Vacuum ultraviolet (VUV) light irradiation** activates the surface by inserting polar functional groups, while **laser treatments** enable precise cleaning and activation.

The studies clearly showed that surface pre-treatment is a decisive factor in ensuring the reliable function of subsequent coatings on large-scale CFRP structures.

Barrier layer: Increasing leak tightness and stabilizing the vacuum

A second research priority of the project focused on coating solutions for cryogenic hydrogen tanks made of lightweight materials. Fraunhofer IFAM developed barrier layers that can reduce gas permeability in polymer-based tank systems. They are designed to minimize hydrogen leakage while also limiting the ingress of atmospheric gases – such as oxygen – or moisture. In this way, they could make a twofold contribution: on the one hand, by increasing the operational safety of the tank system and on the other hand, by supporting the maintenance of the heat-insulating vacuum in double-walled tank structures.

The coating systems developed are based on polymeric binders with integrated barrier pigments. By specifically designing the layer structure, the diffusion path for gas molecules is lengthened, thereby reducing permeation. A key advantage of these approaches is that they can generally be applied to complex geometries using established coating processes, making their transferability to industrial processes plausible.

Here, Fraunhofer IFAM contributed its expertise in application technology and coating development. This included, among other things, the transfer of layer systems to real tank geometries, process stability and behavior under cryogenic conditions. To evaluate performance, methods such as permeation measurements, cryocycling and SEM analyses were used.

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The results highlight the potential of barrier layer to increase the use of lightweight materials in hydrogen tanks, thereby reducing weight and energy consumption – not only in aviation, but prospectively also in other applications related to mobility and hydrogen infrastructure.

Manufacturing: Automated machining and assembly of large-scale tank structures on a 1:1 scale

Finally, the “HYTANK” R&D activities relating to process-reliable manufacturing and assembly of large-volume CFRP hydrogen tanks complete the research project. For this purpose, Fraunhofer IFAM developed technologies for the mechanical machining of functional areas, for the precise positioning of the joining partners and for automated adhesive application. The goal was the controlled joining of the subcomponents to form a closed inner tank. The developed processes were tested on large-scale components at a 1:1 scale.

A comprehensive assembly concept was developed for a double-walled tank approximately six meters long, featuring an inner and outer tank, an integrated internal structure and insulation. Due to the large component dimensions, non-rigid CFRP cylinders, tight tolerance requirements, and long curing times, a precisely aligned and scalable assembly concept was required. For this reason, a **modular assembly system on linear axes** with parallel handling and joining processes was selected, as it enables precise, robust, prospectively scalable handling of the sensitive CFRP tank structures.

In addition, a **validation platform** featuring linearly movable mounting systems was developed and metrologically qualified. This platform allowed for the investigation of key factors influencing the joining process – such as the stability of the structural adhesive, the adjustment of overlap and gap ratios as well as the squeezing behavior of the joining partners – under controlled conditions. At the same time, the significant influence of form and positional tolerances on process stability became apparent.

A customized system was also developed for **adhesive bonding**, which required special automated process control. A custom-developed robot-guided end-effector with roller guidance and a spring mechanism ensured a constant nozzle distance on curved joining surfaces, thereby supporting reproducible adhesive application. After application, the joining partners were automatically positioned relative to one another and joined via a rail system on the assembly line. Heating mats then accelerated the curing of the adhesive.

The results show that automated machining, positioning and adhesive bonding processes for large-format CFRP LH₂ tank structures are fundamentally feasible. For industrial implementation, robust strategies for tolerance management, reproducible gap adjustment and reliable adhesive application must be further developed.

Conclusion | Perspective

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As part of the “HYTANK” R&D project, Fraunhofer IFAM developed key technologies for the future resource-efficient production of hydrogen tanks, e.g., for the aviation industry: tailored surface pre-treatments, functional barrier layers as well as automated machining, joining and assembly processes. Together, these approaches help make large-format, high-strength CFRP LH₂ tank structures lighter, more leak-tight and better manageable in industrial production – including applications in other industries, such as shipping and hydrogen infrastructure.

Funding

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Project partners

- Airbus Operations GmbH (Consortium Leader)
- Broetje-Automation GmbH
- Deutsches Zentrum für Luft- und Raumfahrt e.V.
- Faserinstitut Bremen e.V.
- FFT Produktionssysteme GmbH & Co. KG
- Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
- Technische Universität Dresden

Further information

- **Trade fair**
Find out more – visit us from June 10 to 14 at ILA 2026 in Berlin, Germany, at the Fraunhofer Aviation Joint Booth (Hall C, Booth 280)
➔ <https://www.ifam.fraunhofer.de/en/Events/ila-2026.html>
- **Video**
“HYTANK”: Developing CFRP LH₂ Tanks for Zero-Emission Flight
➔ <https://www.youtube.com/watch?v=H3zpoAHd7Y8>
- **Websites**
➔ www.ifam.fraunhofer.de/en/stade
➔ <https://s.fhg.de/dbi>
➔ <https://s.fhg.de/Z64>

Photos

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www.ifam.fraunhofer.de/en/Press_Releases/Downloads.html



Figure 1 | Caption
"HYTANK" – Contactless atmospheric-pressure plasma pre-treatment of a CFRP surface (© Fraunhofer IFAM).

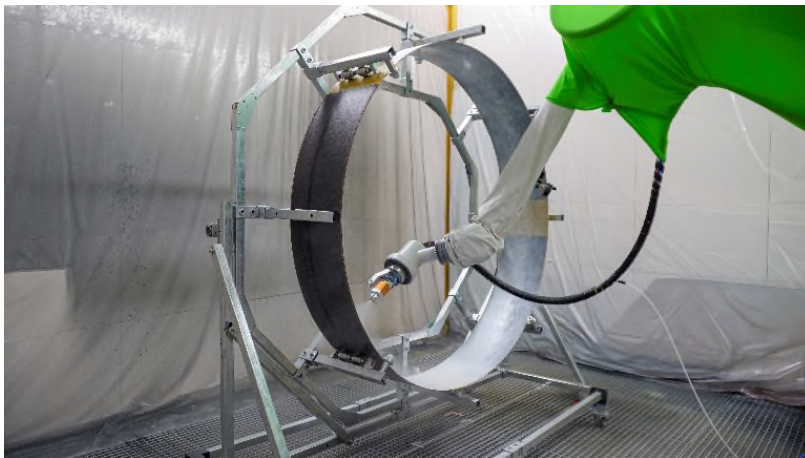


Figure 2 | Caption
"HYTANK" – Automated application of the barrier layer using a painting robot and a conventional automatic spray gun (© Fraunhofer IFAM).



Figure 3 | Caption

“HYTANK” – A milestone toward the future serial production of lightweight CFRP hydrogen tanks for aviation – a flexible, modular, automated assembly line (FFT Produktionssysteme GmbH & Co. KG; © Fraunhofer IFAM).

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