Press Release

StruBiPlate Project

Taking off with less weight: Fiber-composite bipolar plates for aerial mobility

In the StruBiPlate research project, Fraunhofer IWU investigated new manufacturing and structuring approaches for particularly lightweight bipolar plates made from carbon fiber-reinforced polymer (CFRP). The results point to promising ways of combining the advantages of established metallic and graphite bipolar plates in novel fiber-composite designs. Fuel cells for drones, small aircraft, and light helicopters could benefit in particular, since every kilogram saved matters in these applications.

Fuel cells generate electricity from hydrogen and oxygen in the air, continuously supplying energy to an electric propulsion system. For aerial mobility applications, weight and packaging space of a fuel cell system are critical. This is where the StruBiPlate collaborative project comes in: the goal was to develop novel, extremely lightweight fiber-composite bipolar plates with microstructured surfaces that perform electrical and fluid-flow functions.

Metal or graphite? Two established solutions with different strengths

Bipolar plates perform several functions simultaneously in a fuel cell stack. Among other things, their fine channel structures distribute the reactants and coolant. In the StruBiPlate project, the researchers therefore examined existing metallic bipolar plates and their characteristic channel geometries, as well as graphite bipolar plates as starting points for developing new structures.

In practice, metal and graphite represent two fundamentally different material concepts. Metallic bipolar plates primarily offer low component thickness, mechanical robustness, and excellent suitability for industrial manufacturing. By contrast, graphite offers good electrical conductivity and high chemical resistance in the fuel cell environment, but its mechanical properties require comparatively thick walls. For applications where weight is critical, this raises an interesting question: Can a new design combine the strengths of both approaches?

CFRP as a third option: intelligently combining structure and function

Carbon fiber-reinforced polymers offer considerable design freedom. CFRP combines high strength with low weight. It also provides direction-dependent thermal properties: fiber orientation and laminate layup can be tailored to control heat transport within the component.

This opens up possibilities that go well beyond simply replacing an existing material. One potential solution is a functionally integrated hybrid bipolar plate: the fiber composite provides a lightweight structural base and enables targeted thermal management, while metallic functional layers can be incorporated wherever specific surface, contact, or flow functions are required. This combination emerged as a particularly promising area for further development during the project.

Successful hybrid approach: metallic flow field meets CFRP

The IWU team initially investigated whether typical flow-field geometries could be embossed directly into CFRP prepregs. More than 35 individual trials with different process parameters provided important insights. The highest replication quality was achieved when the channels ran parallel to the carbon fibers. However, at bends running transverse to the fiber direction, the material's forming limits became apparent. The tests showed that typical flow-field structures cannot readily be embossed directly into CFRP. Therefore, the researchers took the concept a decisive step further: Why form the entire flow field from CFRP when fiber composites and metal can each be used where they perform best?

The new approach uses a flat CFRP base combined with a prefabricated metallic flow field. For this purpose, IWU cut flow-field contours from stainless steel and laminated them onto uncured, pre-impregnated carbon fibers (CFRP prepreg). A previously developed laser process increased the stainless-steel surface roughness approximately sixfold, promoting strong adhesion between the metal and the CFRP. The subsequent lamination process was successful with all five surface-roughening variants investigated. The “Mattiert N5” variant achieved the best results in terms of continuous bonding and flatness of the metal-CFRP composite.

Down to 0.01 millimeters from the CAD model

In parallel, IWU explored a second promising approach: directly structuring fully cured CFRP plates with ultrashort-pulse lasers. Differences in the thermal properties of the epoxy resin and carbon fibers initially complicated laser processing, but successive optimization steps significantly improved the results. Among other findings, rotating the laser paths by 37 degrees from one layer to the next improved both roughness and the flatness of the structured surface.

The team ultimately produced complete flow fields for bipolar plates. The average geometric deviation from the CAD model was initially no more than 0.04 millimeters and was reduced to 0.01 millimeters in the optimized process. A subsequent coating step also smoothed surface roughness peaks and produced more homogeneous surfaces.

Coating takes CFRP to the next level

Another important development concerns corrosion protection. Bipolar plates are exposed to demanding electrochemical conditions during operation. A project partner therefore coated the CFRP samples with a combined copper-nickel layer. Testing showed good passivation behavior. Testing confirmed good passivation behavior. Testing showed good passivation behavior. Out of the coated samples, one achieved corrosion current density and corrosion potential values comparable to titanium.

This finding highlights a promising path forward: CFRP does not need to meet all the requirements of a bipolar plate on its own. Instead, fiber composites, metallic functional elements, surface structuring, and coatings can be designed as an integrated system and combined for optimum performance.

From material testing to a complete stack

The project went beyond investigating individual samples. IWU manufactured bipolar-plate demonstrators, developed the required seals, and used them to build a prototype stack incorporating CFRP bipolar plates. A leak test of the assembled stack with nitrogen at 1.4 bar showed no pressure drop. Further leak tests, however, indicated that the pressure distribution across the cell layers requires more detailed analysis.

The next challenge: turning strong individual technologies into a robust overall system

This is where the next stage of research begins. The project results demonstrate several technically promising building blocks: precisely laser-structured CFRP surfaces, successfully laminated metal-CFRP hybrids, suitable surface pretreatments, and corrosion-resistant coating systems. The challenge now is to integrate these technologies reliably into a fully functional fuel cell for long-term operation. The laser process also needs to become significantly more efficient. At the demonstrator stage, machining just one side of a flow field took several hours. For future series production, CFRP ablation would also require an enclosed process chamber to contain the resulting contamination.

StruBiPlate therefore does not yet provide a ready-to-use solution for series production, but it establishes a solid technological foundation for a new class of particularly lightweight bipolar plates. Future research can now focus specifically on sealing, coating, electrical insulation, structuring, and cost-effective manufacturing. This approach offers considerable potential for aerial mobility: Combining lightweight fiber composites with metallic functional elements and tailored surfaces could enable bipolar plates designed specifically for the weight and packaging constraints of small aircraft, helicopters, and drones.

Project information

Federal Ministry of Research, Technology and Space

Project: WIR! – GRAVOmer – StruBiPlate, "Microstructured Fiber-Composite Laminates as a Key Element of Lighter, More Efficient Fuel Cells for Aeronautical and Mobile Applications". As part of the project, Fraunhofer IWU led the StruKo subproject, "Functional Structural Design and Consolidation Strategies for the Efficient Implementation of Complex Fiber-Composite Structures." Funding reference: 03WIR2017C Funding provider: BMFTR. Project partners**:** Connova Deutschland GmbH, SWG Sächsische Walzengravur GmbH, Forschungs- u. Transferzentrum Leipzig e.V. an der HTWK Leipzig; associate partner: HZwo e.V.

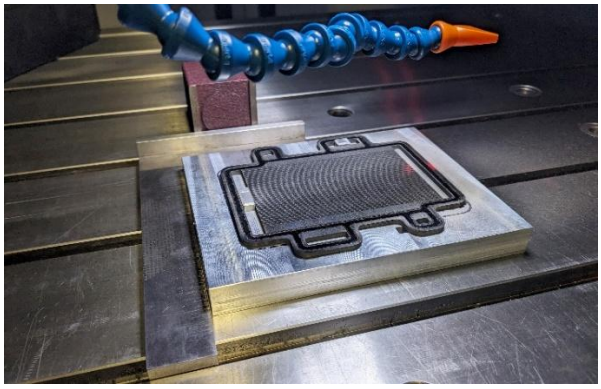


Abb. 1 Laser-structured bipolar half-plate © Fraunhofer IWU

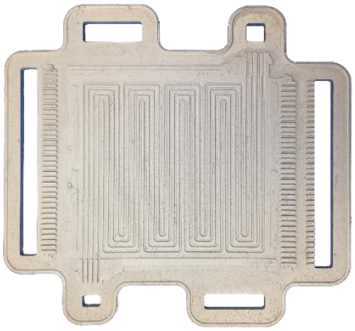


Abb. 2 Laser-structured and coated bipolar half-plate © Fraunhofer IWU

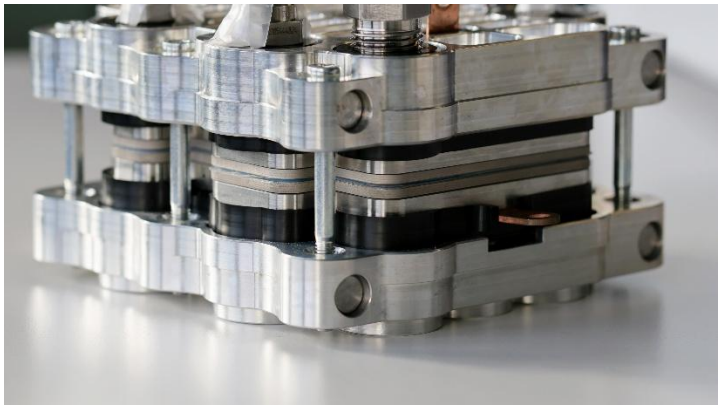


Fig. 3 OSS 050 2.0 open-source project stack (ALF TUC) with CFRP bipolar plates © Fraunhofer IWU

The **Fraunhofer Institute for Machine Tools and Forming Technology IWU** is an innovation-driven partner for research and development in production engineering. Around 600 highly qualified employees work at our locations in Chemnitz, Cottbus, Dresden, Leipzig, Wolfsburg, and Zittau. We unlock potential for competitive manufacturing, across industries like automotive, aerospace, electrical engineering, and precision engineering. Our research and contract research encompass the entire manufacturing ecosystem, from individual components to processes, methods, complex machine systems and human interaction.

Contact

Andreas Hemmerle
Fraunhofer Institute for Machine Tools and Forming Technology IWU
Spokesperson
Phone +49 371 5397 1372
andreas.hemmerle@iwu.fraunhofer.de
www.iwu.fraunhofer.de