FRAUNHOFER IWU

PRESS RELEASE

Integrating Electrical Functions Directly into Components via 3D Printing: Robust and Filigree with WEAM

At Formnext 2025, the Fraunhofer IWU will present the latest generation of the WEAM tool (Wire Encapsulating Additive Manufacturing). This technology opens up entirely new possibilities: components can be manufactured with a wide range of integrated electrical functions, offering significantly better performance for sensing and load-bearing tasks compared to paste-, ink-, or powder-based printing methods. The key lies in the use of standard wires and cables, which, due to their homogeneous alloy and constant conductor cross-section, ensure perfect electrical properties.

The decisive advantage is the precise control of electrical properties through the choice of alloy, conductor diameter, and trace layout, combined with the continuous rotation of the tool. This allows for functions such as power and data lines, integrated sensors for proximity, load, fill levels, temperature, or EMC shielding, as well as coils, to be directly applied to existing components or invisibly integrated through subsequent processes. At Formnext, Fraunhofer IWU will present a series-ready WEAM printhead integrated into a product of the manufacturer CR3D. In four implementation examples, Lukas Boxberger and his team will demonstrate the industrial benefits of WEAM.

Example 1: Radome Heating to Protect RADAR Sensors in Automobiles: - Maximum Design Freedom, Perfect Function, Low Material Usage

Radomes, a combination of RADAR and Dome, are weather-resistant structural shells that encase antennas in order to protect them from external influences while remaining transparent to radio waves. They must remain ice-free in extreme weather conditions to reliably operate radar and sensor systems. Previous solutions rely on heating foils or wires embedded using ultrasound, which can only withstand moderate deformations and therefore don't allow for every design. As a demonstrator component, Fraunhofer IWU used the WEAM process to apply heating conductors directly onto a foil, which was then shaped and integrated as a demonstrator into the part for automotive supplier Nissha. The advantage of WEAM is that the wire stays exactly in place even after back-injection molding—there are no functional losses or delamination issues. Material consumption is very low, while still ensuring a very high heating performance.

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Integrated heating wires in radomes could provide an energy-efficient deicing solution, contributing to greater range in battery-electric vehicles. In vehicles, such heating wires could be integrated into armrests, side panels, or the backs of front seats, significantly reducing the energy demand compared to traditional interior heating systems. In addition to the automotive industry, military vehicles and drones could benefit from reliable sensors in snow, ice, and extreme temperatures. In aircraft, anti-icing protection could help reduce maintenance efforts while increasing safety. In many industrial applications, sensor covers for autonomous systems could guarantee reliable performance under adverse conditions.

Example 2: Highly Flexible, Stretchable, and 3D-Formable PCBs

With WEAM, it is possible to apply complex trace layouts on a 0.1 mm-thick thermoplastic polyurethane (TPU) foil. The traces can be fully or partially coated with plastic, depending on electrical requirements (e.g., breakdown resistance). For contacts, the coating can be omitted. Traces can cross each other while remaining electrically insulated. TPU combines the properties of plastic, such as formability and chemical resistance, with those of rubber (elasticity, flexibility). PCBs made this way can withstand a very high degree of three-dimensional deformation, where conventional flex or stretch PCBs with ink, paste, or powder-based traces would fail.
Furthermore, WEAM offers the option to combine different alloys and layouts on one surface to integrate sensors, actuators, and data/power lines at the foil level. The polymer coating can be adapted according to electrical requirements. For perfect contact, the coating can be omitted due to its high insulation properties. Again, the design freedom is virtually unlimited. When using a "TPU melt adhesive film," the printed PCB or wiring harness can be directly "ironed" onto a variety of materials (textiles, nonwovens, carpets, wood, metals, etc.). Numerous application areas are conceivable:

- **Wearables**: Electronics that can be seamlessly integrated like a second skin—offering more comfort, fewer break points, and new design options.
- **Interior/Construction**: Form-flexible surface heating systems, power lines, Shy-Tech applications (with as unobtrusive an integration as possible) in component-integrated sensors/actuators.
- **Automotive**: Interior components with integrated electronics or intramodule wiring; the need for wiring harnesses could decrease, with greater design freedom and reduced weight. Additionally, modular solutions could be possible.
- **Defense**: Potential for sensor films for load and deformation detection, integration of actuators for unlocking mechanisms, intramodule connections, better-protected PCBs, and complex-shaped radar antennas.

Example 3: PFAS-Free High-Temperature Flexible Conductors

WEAM enables the production of thermoplastic flexible conductors or PCBs that are heat-resistant up to 260°C (and up to 300°C for short periods). Until now, this was only achievable with polyimide (PI) material, which is coated with fluorine-containing substances to fix metallic conductors. With WEAM, this coating is unnecessary because the conductor is fixed using the same material as the foil substrate.
The "bonding with identical materials" offers advantages such as excellent mechanical stability (the conductor remains intact even under high bending stresses), low material consumption for electrical insulation, and, not least, high recyclability due to material purity. Therefore, WEAM can be considered a sustainable solution for high-temperature applications.
In the automotive and aerospace sectors, such solutions are ideal for areas near engines or in engine compartments, where high temperature resistance and low weight are required. In defense, electronics could be designed to be robust and durable in extreme environments. The mechanical engineering and robotics industries could benefit from long-lasting, environmentally friendly wiring for high-load areas, as well as delicate surface heating systems.

Example 4: Drones I Component Housing with Integrated Electrical Functions

Using a drone housing with integrated electrical functions as an example, Fraunhofer IWU demonstrates that with WEAM, the housing itself becomes the Printed Circuit Board (PCB), or the PCB becomes the housing. Functions such as sensors, actuators, electromagnetic shielding, or inductive charging coils can be directly integrated for optimized energy transfer: Electromagnetic shielding in this solution is no longer bound to fixed mesh sizes, providing consistent protection even with complex shapes.
Functional component housings offer clear advantages in a variety of applications. In power tools and outdoor electronics, housings must withstand extreme stress, they should protect against water ingress, and resist impacts. Integrated sensors could be used for user recognition or for measuring load. In defense, cost-effective, durable automation solutions and local, on-demand manufacturing could be envisioned. Consumer products could be made more compact, offer additional features in less space, while being produced cost-effectively, and benefit from a longer lifespan.

+++ Additional 3D printing solutions presented at Formnext will be published on our press portal starting November 12 +++

Fig. 1 Radome Heating, produced via the WEAM process. Key advantages: maximum design freedom, perfect function, low material usage
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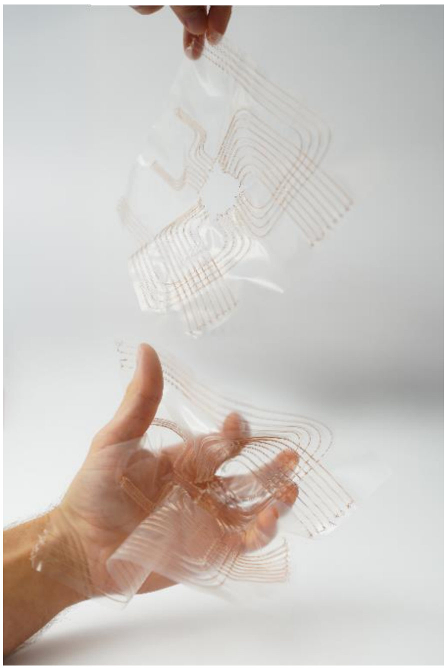

Fig. 2 Highly flexible, stretchable, and 3D-formable PCBs – WEAM printing of a 0.1 mm diameter copper trace on a 0.1 mm thin thermoplastic polyurethane film
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Fig. 3 PFAS-free high-temperature flexible conductors
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Fig. 4 EAM used for printing drones: Component housing with integrated electrical functions
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Fig.5 Rendering of the Formnext booth: Fraunhofer IWU printed all its furniture in-house (light elements: biocompostable plastic; dark elements: recyclable PP)
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