Press Release

Fraunhofer IST coordinates new "CyPro" research project to optimize thermal and thermochemical treatment processes

More energy-efficient production without compromising quality

Thermal and thermochemical surface treatments are important processes in industrial manufacturing. They make tools and components, for example, harder and more resistant to wear and fatigue, and can improve their corrosion resistance; however, these processes are also very energy-intensive. The new joint research project "CyPro – Cyber-Physical Production Systems for Increasing Energy Efficiency and Ensuring Quality in Thermal and Thermochemical Treatment Processes," which is coordinated by the Fraunhofer Institute for Surface Engineering and Thin Films IST and launched on July 1, 2026, is investigating how energy consumption can be optimized in the future while maintaining consistent component quality.

Considering energy consumption and component quality together

A particular challenge in thermal and thermochemical treatment processes is that process parameters, energy consumption, and component quality are closely interconnected. Reducing energy consumption must not come at the expense of the required component properties. The "CyPro" project addresses precisely this intersection. The goal is to develop a cyber-physical production system (CPPS) designed to continuously collect and correlate data generated by processes, energy consumption, sensors, and production. In addition, the use of optical emission spectroscopy is planned, among other methods, to monitor the state of the plasma in real time.

Based on the collected data, explainable AI models will be developed to map the relationships between process parameters, energy consumption, and quality characteristics. The plan is to take into account, for example, the nitriding hardening depth, the formation of compound layers, and the corrosion resistance of the treated components. In contrast to purely data-driven "black-box" approaches, this will make it possible to understand how changes in process control affect energy consumption and component properties.

Furthermore, the data-based models are to be supplemented by physics-based modeling, such as thermodynamic and simulations supported by CFD, in order to investigate, among other things, heat flows, phase transitions, and waste heat potentials within the plant and its periphery. This approach is intended to enable the evaluation of energy losses based on both data and physics. In addition, a planning tool based on reinforcement learning is intended to

eventually take into account not only individual process parameters but also order sequences, plant utilization, throughput times, and peak loads. The plan is to make the information obtained available in real time via a dashboard and to enable predictive recommendations for plant operation.

Plasma nitriding as an industrial demonstrator

The methods will initially be developed and tested using plasma nitriding as an example. A plasma nitriding system at Fraunhofer IST will serve as the industrial demonstrator; key measurement campaigns with defined reference batches will be conducted on this system, and process, energy, and quality data will be collected and evaluated. The treated components will be characterized with regard to relevant surface-layer and functional properties so that, on this basis, the sensor technology, data models, and other components of the planned CPPS can be gradually integrated and validated under realistic production conditions.

Approximately 24 MWh in annual savings potential

An initial assessment of the plasma nitriding system's potential indicates the possible scale of savings: approximately 24 MWh of energy per year could potentially be saved in germany in the long term. According to the estimate, about 17 MWh of this results from the recovery and utilization of waste heat, and another 7 MWh from optimized process control.

The project will now investigate how these potentials can be technically realized and utilized under realistic production conditions. For manufacturing facilities and contract processors, this could result in lower electricity and operating costs, reduced peak loads, and lower CO_2 emissions. At the same time, more precise monitoring and control of the processes should help reduce the risk of quality deviations and costly rework.

As the project progresses, the plan is to transfer the insights gained from plasma nitriding to other thermal and thermochemical processes, particularly PECVD coatings and gas nitriding. In addition, the study will examine the extent to which the developed methodology can be applied to other industrial furnace systems characterized by high temperatures, long process times, and significant waste heat flows. In the long term, the CPPS could also enable cross-plant production planning, in which multiple heat treatment facilities could be operated in an energy-optimized, load-flexible manner that maximizes grid benefits.

About the project

“CyPro – Cyber-physical production systems for improving energy efficiency and ensuring quality in thermal and thermochemical treatment processes”

Project partners:

- Fraunhofer Institute for Surface Engineering and Thin Films IST (Coordination)
- Institute for Machine Tools and Manufacturing Technology (IWF), Technical University of Braunschweig
- Institute for Thermodynamics (IFT), Technical University of Braunschweig
- TLK-Thermo GmbH
- PLASUS GmbH
- EKS InTec GmbH

Project advisory group:

- PVA IVS
- Rübig
- Denso
- Oerlikon

Project duration: 01. June 2026 – 31. May 2029

Funding reference:

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Fig. 1 Duplex treatment system at the Fraunhofer IST. © Fraunhofer IST



Fig. 2 The duplex treatment system at Fraunhofer IST, shown with the unit open. © Fraunhofer IST

The Fraunhofer Institute for Surface Engineering and Thin Films IST is an innovative partner for research and development in surface technology, with expertise in the associated product and production systems. The aim is to develop customized and sustainable solutions: from prototypes, through economic production scenarios, to upscaling to industrial magnitudes – and all this whilst maintaining closed material and substance cycles. The Fraunhofer IST is one of the seventy-five institutes of the Fraunhofer Society, one of the world's leading organizations for applied research.

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