Fraunhofer Institute for Silicate Research

Das Fraunhofer ISC forscht in verschiedenen Bereichen zu Keramiken und CMC. // The Fraunhofer ISC conducts research in various areas of ceramics and CMC.

The Fraunhofer Center for High Temperature Materials and Design (HTL) at the Fraunhofer Institute for Silicate Research ISC is a leading research facility dedicated to the development of high-temperature materials and advanced processes, with a particular focus on ceramic matrix composites (CMC). The HTL operates across three locations—Bayreuth, Würzburg, and Münchberg—with around 100 employees and more than 4,700 square meters of state-of-the-art laboratories and pilot production facilities, enabling comprehensive R&D and industrial projects.

Full Process Chain for Ceramic Matrix Composites (CMC)

HTL's core expertise lies in the complete process chain for producing CMC components. This includes the development of ceramic reinforcement fibers, textile processing, matrix formation, and final thermal treatment. CMCs are valued for their superior fracture toughness and damage resistance, which make them ideal for applications subjected to extreme thermal and mechanical stresses. The HTL employs a range of materials, such as oxide and non-oxide reinforcement fibers including glass, carbon, silicon carbide, and aluminum oxide fibers. Special fiber coatings are also developed to enhance corrosion resistance and ensure optimal fiber-matrix adhesion.

Laval nozzle of C/SiC (LSI) @ HTL

For matrix materials, HTL uses advanced methods such as the Liquid Silicon Infiltration (LSI) process for non-oxide CMCs, creating a robust matrix structure by infiltrating silicon into fiber preforms. Oxide CMCs are produced using aqueous suspensions of ceramic powders, which are then transformed into ceramic through high-temperature processes.

Pilot-Scale Production and Scaling Capabilities

One of HTL's significant strengths is its capacity to scale prototypes and lab samples into larger components, up to approximately 500 mm in diameter. This is supported by specialized equipment, including a fiber pilot plant in Bayreuth that enables the production of ceramic reinforcement fibers on a ton scale. Additional facilities include a CNC-controlled winding unit and a fully automated 5-axis machining center, which allows precise finishing of CMC components.

At the Center for Textile Fiber Ceramics (TFK) in Münchberg, HTL develops custom textile processing techniques for reinforcement structures. Techniques such as weaving, braiding, and knitting allow for 2D and 3D fiber structures tailored to specific mechanical requirements. This textile expertise enables HTL to create fiber preforms optimized for high-stress, high-temperature applications.

Partial segment of a mixer made of OFC mixer made from silica fibers and oxide ceramic matrix @ HTL

Partial segment of a mixer made of GMC (geopolymer matrix composite) with basalt fibers @ HTL

Additive Manufacturing and Material Design

Alongside traditional manufacturing methods, HTL integrates additive manufacturing to produce complex ceramic and metal components. Using materials like aluminum oxide, zirconium oxide, and silicon carbide, HTL can create intricate shapes through 3D printing. New additive manufacturing techniques are also developed in-house for ceramics and metals, combined with simulation-driven material design to optimize properties during the design phase.

Thermo-Optical Measurement (TOM) Systems and Quality Assurance

For quality assurance and process optimization, HTL has developed advanced thermo-optical measurement systems (TOM) that accurately characterize material behavior under extreme conditions. These TOM systems, such as TOM_ac and TOM_fiber, are tailored to high-temperature applications and allow HTL to analyze thermal and

mechanical stability in detail. In addition, HTL utilizes non-destructive testing methods like computed tomography and mechanical testing to ensure reliability and quality in all components produced.

Applications and Industry Partnerships

HTL's innovations find applications in aerospace, automotive, energy, and high-temperature technology industries. As one of the few research centers in Europe to offer a complete technology chain for CMC production, HTL collaborates extensively with industry partners to provide tailored solutions that range from fundamental research to pre-series production.

The CVT exists in its current form with about 50 employees since 2006. The motto is: "Gas to Solid", which is often implemented together with other partners. The field of activity of CVT is high-performance ceramics. Using its own patantized CVI process, CVT mainly produces C/C materials, primarily high performance C/C materials for friction applications. The strength of CVT is the matching of the morphology of the matrix to its needs. As the world's leading manufacturer of C/C friction materials produced by r-CVI and an expert in chemical vapor deposition (CVD) processes, CVT has the ideal technical prerequisites to successfully handle development tasks and experimental work. In doing so, CVT relies on cooperation at eye level between manufacturers and customers on a technical scale.

In summary, Fraunhofer HTL provides a comprehensive platform for R&D, focused on high-temperature materials, additive manufacturing, and complete process integration for CMCs, supporting applications across numerous demanding industries.