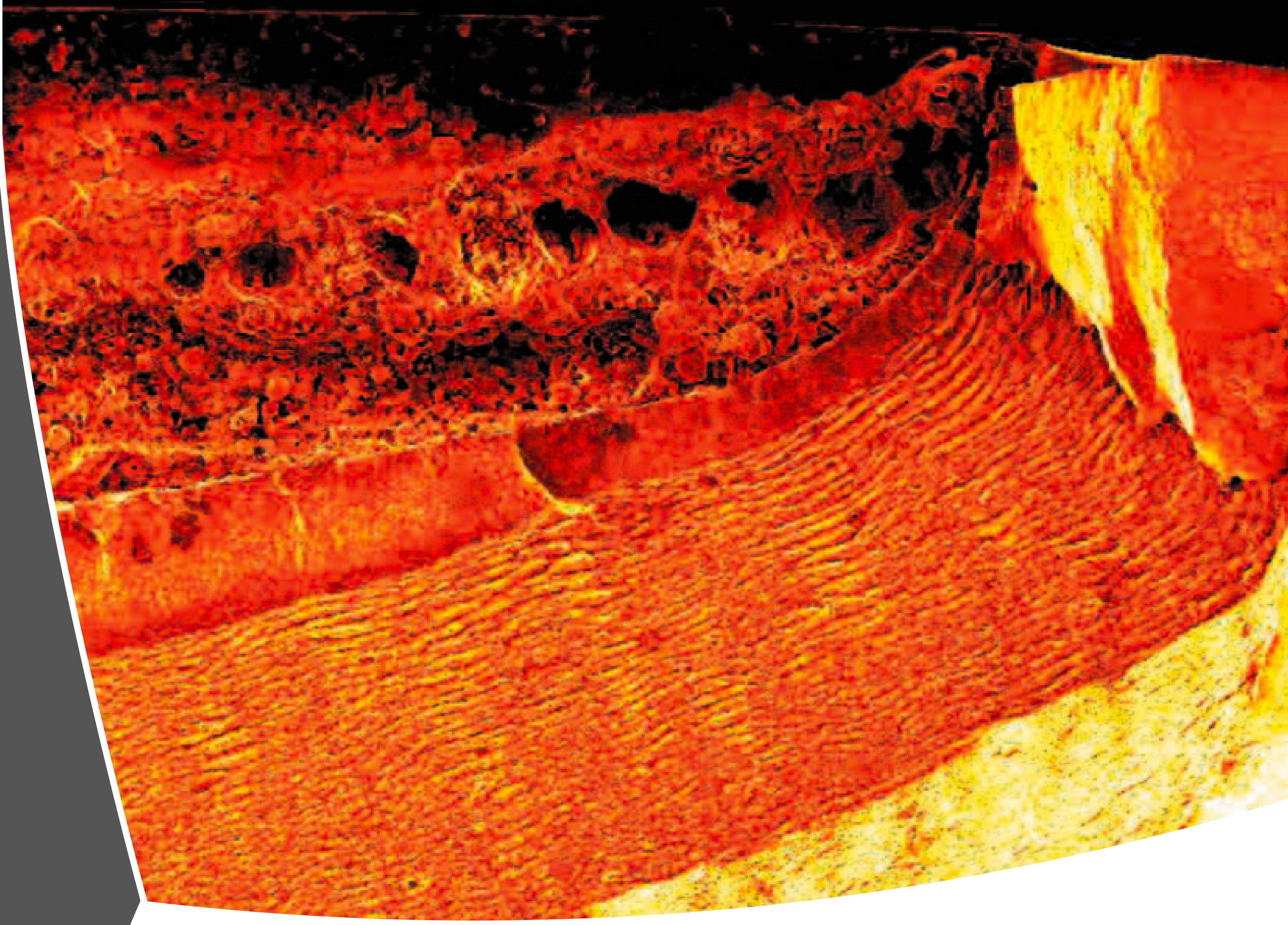


Institute of Materials Research

DLR

Institute of Materials Research

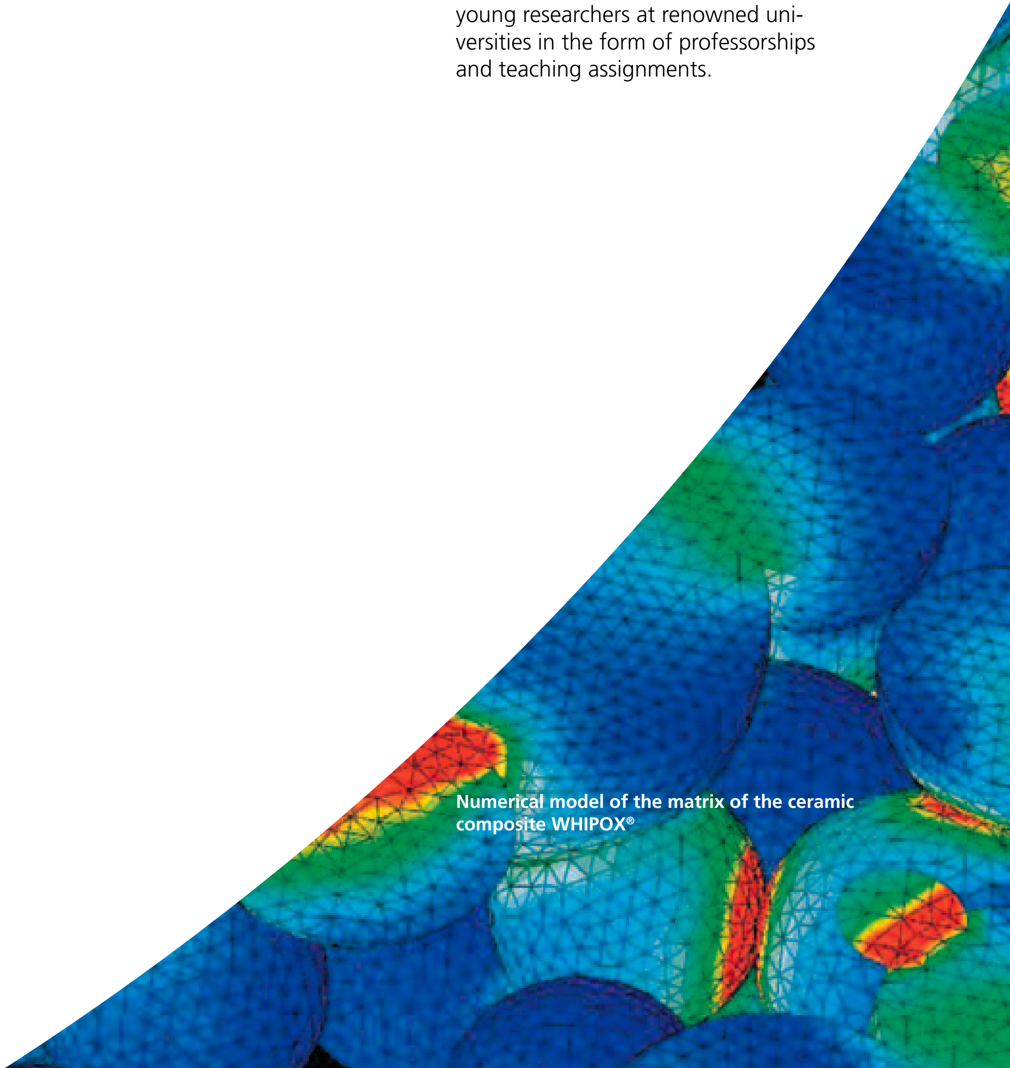
Materials technology – paving the way for complex component solutions

The main research focus of the Institute of Materials Research is the development of new material solutions and their processing techniques for applications in aerospace, in energy technology, and in automotive engineering.

In co-operation with DLR institutes as well as with national and international partners, the Institute of Materials Research is consistently working on fundamental and application-orientated topics.

The research portfolio spreads across the fields of metallic structures, hybrid material systems and intermetallics, ceramic matrix composites, thermoelectric systems and high-temperature and functional coatings. The development of numerical methods to simulate the behaviour of materials and components completes these competencies aiming at supporting the transfer of materials into industrial applications.

In addition to scientific research the institute is actively involved in the education and advanced training of young researchers at renowned universities in the form of professorships and teaching assignments.



Numerical model of the matrix of the ceramic composite WHIPOX®

New coating systems are subject to complex processing and testing methods

High-temperature and Functional Coatings

The research and development work on major aero-engine components like compressor and turbine blades or combustion chambers offer a high potential for the future generation of aero-engines.

The further development of thermal barrier coatings is concentrated on the reduction of thermal conductivity, the rise of application temperature and the understanding of damage mechanisms as well as the extension of lifetime.

To be able to fully exploit the potential of modern titanium aluminides in compressors or low-pressure turbines effective oxidation protection and thermal barrier coating systems are further developed.

Moreover, thin and nano-structured functional layers are synthesized for life-time control of exhaust gas catalytic converters, for efficiency rise of high-temperature gas sensors and of reformer catalysts producing syngas and H_2. The developments not only aim at single components but also cover the integrated and intelligent design of thin layers as a basis for efficient multifunctional systems.

Component of the all-oxide ceramic matrix composite WHIPOX®

Structural Ceramics

Future energy-efficient and environmentally-friendly turbine technologies in aeronautics and power engineering require materials which combine the good high-temperature stability of ceramic materials with the non-brittle failure behaviour and thermal shock resistance typical of metallic systems. Similar requirements apply to reusable and cost-efficient thermal protection systems built into multiple-use re-entry space vehicles.

The all-oxide, long fiber reinforced ceramic matrix composite WHIPOX® (Wound Highly Porous Oxide ceramic matrix composite), an original development of the Institute of Materials Research, is an ideal solution for these requirements. WHIPOX® structures and components can be manufactured by an easy and cost-effective fabrication process.

The properties of all-oxide CMCs can be further tailored to requirements through functional coatings thus considerably expanding their application portfolio.

Also for metallic structures a reduction of the manufacturing costs as well as the structural weight is possible using new alloys and innovative manufacturing processes

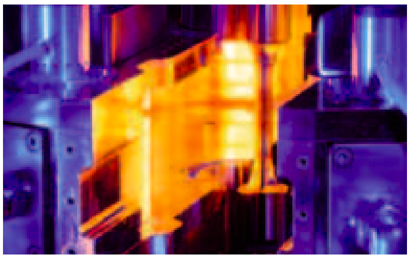
Metallic Materials and Structures

The research area of metallic materials and structures is focused on the investigation of innovative manufacturing processes and new alloys to further optimise both the manufacturing costs and the weight of primary structures of airplanes. In this context the "damage tolerance" properties are of special consideration. New and economical methods to determine the failure-relevant properties are developed and applied in this research area. The spectrum ranges from the micro-analytical characterisation of damage mechanisms at the level of the local microstructure to the assessment of the lifetime behaviour, crack propagation and remaining strength at the component level.

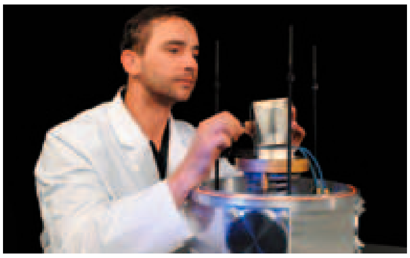
These experimental competencies are being complemented by numerical simulations that are used not only to model the behaviour of the specimen under testing conditions, but can also be used to bridge the gap to the real airplane structure. In particular stochastic methods are developed and applied.

For the manufacturing of cost-efficient, integral structures the process of friction stir welding is investigated. In this context the welding parameters, the microstructure of the weld seam and the strength and corrosion properties of friction stir welded joints are the topic of the investigations. In addition to that, procedures for non-destructive testing of friction stir welded joints are developed and applied.

Model to demonstrate different blade designs in hybrid and MMC technology



Test facility for thermomechanical testing of high-temperature materials



Test facility for thermoelectric modules

Hybrid Material Systems and Intermetallics

Any material is marked by its specific properties and advantages. The best materials selection depends on the requirements of the component. Due to the increasing complexity and manifold requirements for components the choice of a material is often related to penalties under certain conditions. To avoid this drawback an intelligent combination of different materials to a hybrid material system can be preferred in such a way that the specific advantages of each material can be obtained.

An example for such a hybrid material system are metal matrix composites (MMC) or fibre metal laminates. The fibres are increasing the strength and stiffness while the metal contributes toughness and integrity in the case of fibre failure.

Titanium aluminides are intermetalic alloys with titanium and aluminium as mean alloying elements. Titanium aluminides are promising materials for high temperature and structural applications of the future. The Institute of Materials Research is collaborating with well-known German aeroengine companies for the optimisation and understanding of titanium aluminides. The research work is concentrated on microstructural characterisation und the relationship of microstructure and mechanical properties.

Experimental and Numerical Methods

The research activities aim at making high performance materials for aerospace applications more predictable. Therefore, experimental and numerical methods are combined and further developed.

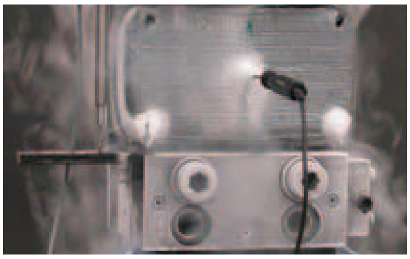
The typical workflow starts with characterising the material by means of microscopic analysis and (micro)mechanical tests on the microstructure level, which includes features from nanometre up to centimetre scale. Using this experimentally achieved data, numerical models are developed. With these models the behaviour of laboratory specimens and generic components under realistic loading conditions is simulated, and the calculations are validated through the respective laboratory tests.

Special non-standard test facilities are developed and manufactured in-house, for example test rigs for thermomechanical fatigue testing of internally cooled specimens, which represent gas turbine blades for aero-engines.

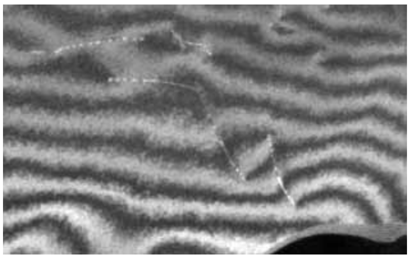
Thermoelectric Materials and Systems

Thermoelectric generators are widely known as very robust and reliable electrical power supplies for deep-space probes and planetary landers. The ”Thermoelectric Materials and Systems“ department is developing materials and technologies for thermal-to-electric energy conversion aimed at a wide application temperature range. Terrestrial use encompasses energy recovery in motor vehicles by means of exhaust heat-to-electricity power conversion, autarkic residential heat supplies and low-current power sources. The spectrum of methods in the department comprises materials synthesis, contacting and integration techniques, materials and system characterisation as well as numerical simulation and model-based system dimensioning.

Powder technology including suitability for upsizing to industrial manufacturing methods represents a key point here. The long-standing tradition in method development of functional characterisation is focussing on the material properties in the upper temperature range as well as precision measurements on thermogenerator modules. A main target is the development and implementation of standards for thermoelectric reference materials and measuring procedures.



Testing setup for cryogenic tests at -196°C



Dark field transmission electron micrograph of dislocations in a γ–TiAl alloy

Mechanical Testing of Materials

The team “Mechanical Testing of Materials” characterises materials for all departments of the institute as well as for external customers. Different mechanical test are performed under uni- and biaxial conditions. Experiments in air, vacuum and in corrosive environments as well as tests at different temperatures (-196°C up to 1400°C) are possible. Testing equipment for complex requirements is developed and established by this team. In-service fatigue and fracture mechanics experiments with various materials are the main focus of the team.

The investigation of crack growth behaviour including determination of crack initiation, evaluation of the threshold for crack propagation (ΔK_{th}), monitoring of da/dN - ΔK-curves, determination of crack growth resistance curves and the critical stress intensity factor are part of the work.

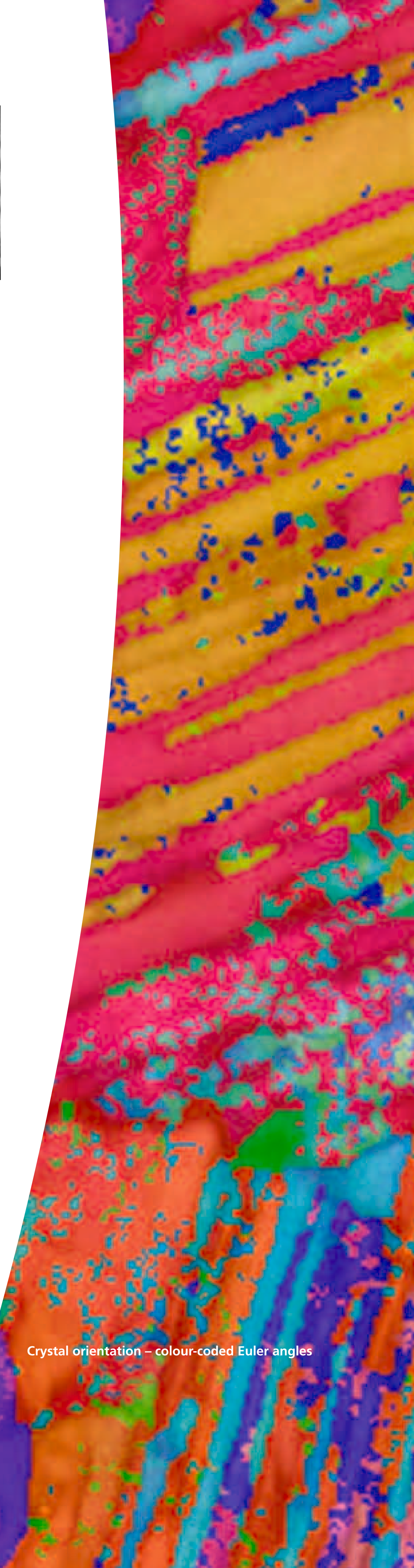
The evaluation and data analysis includes the mechanical results as well as fracture surface investigations.

Microstructural Research and Metallography

The macroscopic properties of materials are determined by their microstructure, which spans from the arrangement of the grains to the atomic structure including inclusions, internal interfaces and faults. Furthermore, the spatial orientation of the microstructure in relation to a component part is important. Thus, preparation, documentation and analysis of the microstructure are required for purposive materials research.

The results of the micro-structural characterisation lead to the understanding of the processes which are important for the properties, the production as well as the damage mechanisms of the materials investigated.

Microstructure investigations are carried out by means of light as well as scanning and transmission electron microscopy. For phase and texture analysis, X-ray diffraction methods are used. Indispensable for microstructure investigations is an effective and artefact-free preparation of the samples, which is performed by our metallographic laboratory.



Crystal orientation – colour-coded Euler angles

DLR at a Glance

DLR is Germany´s national research centre for aeronautics and space. Its extensive research and development work in Aeronautics, Space, Energy, Transport and Security is integrated into national and international cooperative ventures. As Germany´s space agency, DLR has been given responsibility for the forward planning and the implementation of the German space programme by the German federal government as well as for the international representation of German interests. Furthermore, Germany’s largest project-management agency is also part of DLR.

Approximately 6,900 people are employed at fifteen locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen, and Weilheim. DLR also operates offices in Brussels, Paris, and Washington D.C.

DLR’s mission comprises the exploration of the Earth and the Solar System, research for protecting the environment, for environmentally-compatible technologies, and for promoting mobility, communication, and security. DLR’s research portfolio ranges from basic research to innovative applications and products of tomorrow. In that way DLR contributes the scientific and technical know-how that it has gained to enhancing Germany’s industrial and technological reputation. DLR operates large-scale research facilities for DLR’s own projects and as a service provider for its clients and partners. It also promotes the next generation of scientists, provides competent advisory services to government, and is a driving force in the local regions of its field centers.

Institut für Werkstoff-Forschung_GB_06/2011

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