FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

50 YEARS OF MATERIALS RESEARCH AND EDUCATION AT THE INSTITUTE I IN ERLANGEN 1965 – 2015

PREFACE

Prof. Dr. rer. nat. M. Göken

The Institute I of the Department of Materials Science & Engineering was officially established on August 9th 1965 by late Prof. Bernhard Ilschner. From 1984 to 2002 Prof. Haël Mughrabi was the head of the Institute and in 2002 I got the privilege to take over the responsibility for the Institute. It is now 2015 and more than 600 students have received their Diploma, Bachelor's, Master's,- or Doctoral degrees at the Institute. The Institute has been continuously growing over the years and has currently more than 30 PhD students working on their dissertation projects. This has been made possible through intensive cooperative research activities at the FAU, for example within the framework of the Cluster of Excellence »Engineering of Advanced Materials« or the SFB/Transregio on superalloys. New instruments and microscopes, for example the large chamber SEM in Fürth, have significantly improved our understanding of the deformation mechanisms in materials, allowing for a more goal oriented design of new materials and alloys. Recently, an atom probe system has been established at the Institute allowing insight to the chemical nature of materials down to the atomic scale.

In this chronicle we try to show some aspects of the current research and teaching activities at the Institute I, together with a small historic overview. However, such an overview never can be complete - rather it has to be selective, which makes it quite difficult to choose subjects. Therefore, please excuse if some aspects are missing or incorrect. Perhaps we can put those into the next newsletter.

I am very thankful to all who contributed to this chronicle, first of all to Prof. W. D. Nix and Prof. J. Hornegger, the FAU president, for their nice prefaces. This chronicle wouldn't have been possible without the great support from the group leaders at the Institute, Heinz Werner Höppel, Steffen Neumeier, Erik Bitzek, Arun Prakash, Doris Amberger, Benoit Merle, Peter Felfer and to Werner Langner. Special thanks go to Heinz Werner Höppel for putting the historic part together based on reminiscences by Fritz Pschenitzka. I am also very thankful to my predecessor Haël Mughrabi for his ongoing interest in the scientific work at the institute, for our friendship, and also for his support in the preparation of this chronicle and the 50th anniversary of the Institute.

Mathias Göken
Erlangen, October 2015

Mathias Göken, Haël Mughrabi, Karsten Durst, Steffen Neumeier, Bill Nix and Robert Singer, DGM meeting in Dresden in 2011 where Bill Nix received the Heyn Medal.

Bernard Ilschner, Bill Nix, Ilschner's daughters, and Nix's daughter, Cynthia, near Erlangen, October, 1973.

STANFORD
MATERIALS SCIENCE
AND ENGINEERING

WILLIAM D. NIX
Lee Otterson Professor of Engineering (Emeritus)
496 Lomita Mall · Durand Bldg., Room 117
Stanford University · Stanford, CA 94305–4034

Dear Mathias,

I am delighted to send you and your colleagues my warmest congratulations on your celebration of 50 Years of Materials Research in Erlangen at the Institute I of the Department of Materials Science and Engineering. I am so sorry I am not able to be there for this wonderful occasion.

It would have been so appropriate for me to be there to help celebrate, as I feel such a strong connection to your department. I knew the founder of your department, the late Bernard Ilschner, very well and I have followed your department under the subsequent leadership of Haël Mughrabi and yourself and its emergence as one of the best materials science departments in the world.

Nearly 50 years ago, in late 1965, Ilschner wrote to me at Stanford to propose that we stay in touch regarding our mutual interest in the mechanisms controlling creep of crystalline solids. He might have seen the paper that Barrett and I had published in late 1965. That began a connection to your department that has lasted for all of these 50 years. It led to the very intimate connections that I have developed with the materials science community in Germany. When I received the Heyn medal in Dresden four years ago (thanks to Robert Singer, you and your colleagues), I mentioned these connections and listed the large number of post-docs and visitors that I had had from Erlangen, including Jürgen Hausselt, Wolfgang Blum, and Robert Singer, in addition to Ilschner. I think I counted as many as 15 people from Germany with whom I had collaborated closely, including you.

The honor you and your colleagues bestowed on me with the Heyn medal was gratefully received, but quite unexpected. Below is a nice picture from that event.

Not long after Ilschner's first letter to me he started visiting Stanford when he could. The photograph below is of Ilschner at Twin Peaks on a windy day in San Francisco in about 1971. At about that time Ilschner began to discuss the possibility of my spending some time at Erlangen under a Senior Humboldt Fellowship that he thought I could get. Well, he did secure that fellowship for me and I was planning to accept it. But as the time drew near, I became more and more concerned about the effects of a sabbatical leave on the momentum of my research group at Stanford. I finally had to tell Ilschner that I would not be able to come after all, in spite of all that he had done for me. That was a

Bernard Ilschner on Twin Peaks in San Francisco in 1971.

very hard letter for me to write and for Ilschner to read. As a rather weak substitute, I did arrange to come to Erlangen in 1973 as a very small part of a vacation that I was taking with my wife, Jean, and daughter, Cynthia. The photograph below shows Ilschner and me, together with his two daughters and our daughter, Cynthia.

I well remember my first visit to Erlangen in 1973. With Ilschner (who was Rector at the time), Blum and Bernd Reppich, I had a series of very vigorous discussions about the mechanisms controlling creep of metals. I also remember the special sausage dinner we had, possibly somewhere in Nuremberg (in a basement restaurant, as I recall).

As mentioned above, my first connections to your department eventually led to a number of post-docs and visitors coming from Erlangen to Stanford. Hausselt came in the mid-1970's and Blum and Singer in the late-1970s. By that time I guess Stanford was a place for German Materials Scientists to come. I think Ilschner, Blum and Singer might have all been at Stanford at one time in 1979, when Ilschner and I were preparing our joint review paper on creep mechanisms for the International Conference on Strength of Metals and Alloys (ICSMA V), held that year in Aachen.

A steady stream of post-docs and visitors came from Germany in the 1980s and 1990s, all because of the connections I had with your department from the very beginning. Actually, many of those visitors could come to work with me because of the Senior Humboldt Fellowship that Ilschner had secured for me. Indeed, I was stunned to learn in the early 1990's that the Humboldt Foundation still considered me to be a Humboldt Fellow, even though I had never actually accepted the award. Their only question was: Is he now ready to come? Based on the literature that I receive, I think I am still regarded as a Humboldt Fellow, even after more than 40 years. Only Germans could do that.

Again, I am sorry I cannot be there for this great occasion. But many of my students, colleagues and friends will be there to help you celebrate, as I would have liked to do. Best wishes for a most joyful celebration.

With best personal regards to all of my friends at Erlangen,
Sincerely

Bill

Bill Nix

CELEBRATING 50 YEARS – PRESIDENT'S WELCOME

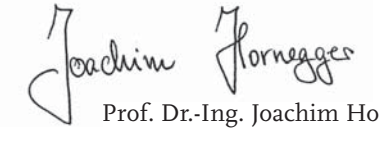
President of the FAU,
Prof. Dr.-Ing. Joachim Hornegger

I would have liked to come to the celebration myself, but unfortunately I am unable to attend. Therefore, as FAU's President, I would like to offer my congratulations in this commemorative programme.

Institute I of the Department of Materials Science and Engineering is celebrating its 50th anniversary, which actually makes it older than the Faculty of Engineering to which it belongs. This may seem contradictory, but the first chair of the Institute and a former rector of our University, Prof. Ilschner, joined the University in the autumn of 1965 as one of the first two professors of what was to become the new Faculty of Engineering.

I never had the pleasure of meeting Prof. Ilschner, the inspiring personality who laid the solid foundation for materials science that allowed the Institute to become so successful today. Prof. Ilschner, his successors and their teams established materials science as one of the most successful subjects at FAU. This is reflected in the latest edition of the renowned DFG Funding Atlas, in which the research field of materials science came in on top. In the context of a faculty which ranks in the top three in Germany for engineering, this is an even more impressive achievement. It is certainly no coincidence; we have outstanding staff who do excellent work – in our Cluster of Excellence, in DFG-funded research projects, in degree programmes such as Nanotechnology, and in international collaborations. The Institute's excellent reputation is underpinned by the many eminent speakers and guests in attendance at this golden anniversary celebration.

The Institute has received a special gift for its fiftieth anniversary, the atom probe which will be presented for the first time during the celebration. This is an important milestone for materials research in Erlangen and I am certain that the Institute will continue its high-level research in a promising future.



Prof. Dr.-Ing. Joachim Hornegger

CONTENT

MATERIALS RESEARCH AT THE INSTITUTE I – GENERAL MATERIALS PROPERTIES

Staff and students of the Institute I, summer 2015

MATERIALS RESEARCH

ORGANIZATION OF THE INSTITUTE

Professors and Group Leaders of the Chair

Prof. Dr. rer. nat. Mathias Göken (Head of the Chair)
Dr.-Ing. habil. Heinz Werner Höppel (Deputy Head)
Jun. Prof. Dr. rer. nat. Erik Bitzek (Modelling & Simulation)
Dr.-Ing. Steffen Neumeier (High Temperature Materials)
Dr.-Ing. Benoit Merle (Nanomechanics & Thin Films)
Dr.-Ing. Arun Prakash (Modelling & Simulation)
Dr.-Ing. Doris Amberger (Creep)
Jun. Prof. Dr. Peter Felfer (Atom Probe Tomography) since 1. September 2015

Members of the "Leitungskreis" during their regular meeting

Retired but still active Professors
Prof. Dr. rer. nat. Dr. h. c. Haël Mughrabi
Prof. Dr.-Ing. Wolfgang Blum

External Professors
Hon. Prof. Dr-Ing. Peter Weidinger (Brose Coburg)

Secretary and Administration
Kerstin Ebentheuer, Brigitte Saigge

Technical Staff
Werner Langner (Safety Officer), Richard Kosmala (metallography), Wolfgang Maier (mechanical testing), Lothar Sommer (workshop), Christina Hasenest (metallography), Jonas Harrer (mechanical testing), Steffen Iberl (apprentice)

Currently around 30 PhD students are working at the Chair on their dissertation projects. A list of these students including the topics of their projects is given in the research section. Furthermore many Master and Bachelor students are working on their thesis topics and many student assistants are supporting the scientific work at the chair.

EXPANSION OF THE INSTITUTE I

Since 1972 most of the research work has been carried out in the institutional building on the South Campus of the FAU at Martensstrasse 5 in Erlangen. In this building, an area of around 1350 m² is available for research and teaching activities of the Institute I. However, due to the growth of the Institute and the large instrumentation park, space became very limited during the recent years. New opportunities opened up with the reinvigoration of the abandoned Grundig industrial area in Fürth. As early as 2006, the Institute I participated with several other institutions from the University to create the Joint Institute of Advanced Materials and Processes (ZMP) which was settled in the Technikum I building in the premisses. The Institute is an interdisciplinary research facility in the field of materials science, mechanical engineering, chemistry and physics, aiming at developing novel materials. Current research areas include: Metal Powder Injection Moulding, Electronbeam-based Additive Manufacturing, Functional Carbon Allotropes, Rapid Prototyping of Ceramics, Laser-based Additive Manufacturing and Diamond Coatings. The Institute I is also responsible for the research area of Non-Destructive Testing of Materials and Devices, incorporating a one-of-a-kind large chamber scanning electron microscope installed in 2006. In 2014, this capability was complemented by the installation of a high-end Focused Ion Beam microscope on the Fürth premises of the ZMP.

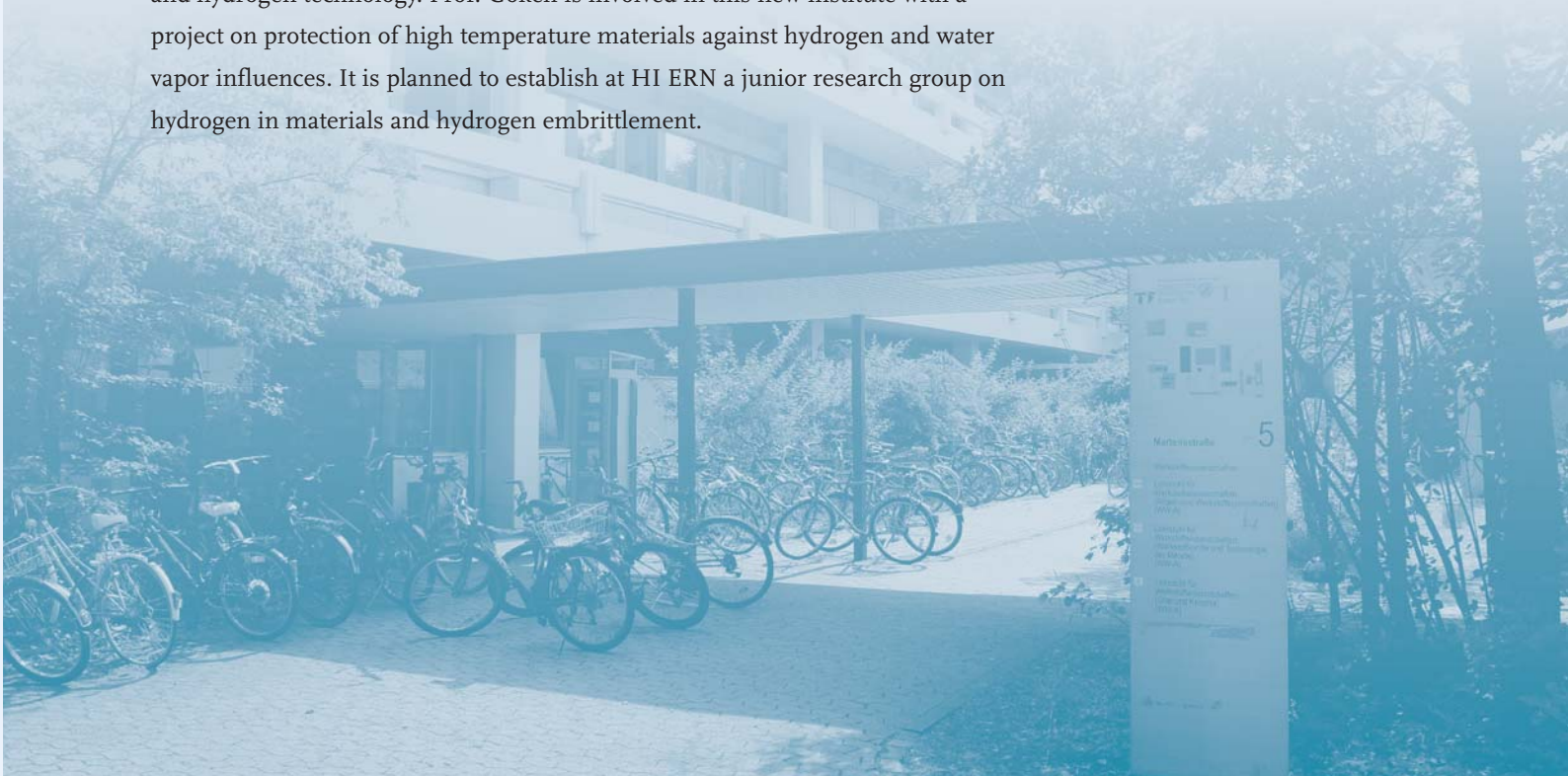
The expansion in Fürth continued in 2012, when a large part of the neighboring Technikum II building was leased for 10 years by the Department of Materials Science and Engineering of the University of Erlangen-Nürnberg. This provided the Institute I with a large hall very well suited for operating the nanomaterials processing equipment, as well as laboratory space for the X-Ray diffraction equipment and others. Along with the Institute I, the Technikum II is currently being used by the Institute 6 (group of Prof. P. Wellmann working on crystal growth) and Institute 8 (Simulation and Modelling, Prof. M. Zaiser) and a startup from the University called Crystal-N.

The Center for Nanoanalysis and Electron Microscopy (CENEM) is an interdisciplinary center of the Friedrich-Alexander-University Erlangen-Nürnberg aiming at the microscopic and analytical characterization of materials. The CENEM was

founded in 2010 by Prof. Göken as part of the cluster of excellence "Engineering of Advanced Materials" to provide a forefront research center for the versatile characterization of materials and devices with state-of-the-art instrumentation and expertise, and to intensify the interdisciplinary research. The CENEM is now a joint institution of the new Chair WW9 for Micro- and Nanostructure Research in the Department of Materials Science and Engineering (Prof. E. Spiecker), the Institute for Crystallography and Structural Physics (Prof. Tobias Unruh) and the Institute I. It provides access to a large range of experimental facilities within the fields of Electron Microscopy (transmission and scanning electron microscopes), Scattering Methods (X-ray diffraction and UV-Vis methods) and Scanning Probes (Atomic Force Microscopy and Nanoindentation). The large chamber scanning electron microscope located in Fürth and operated by the Institute I is also part of the CENEM. A new research building is planned in the Cauerstrasse close to the Materials Science buildings, where all the activities of the CENEM will be bundled together. Construction of this new interdisciplinary center for nanostructured films with an area of 4600 m² will start in 2016, and will offer further expansion possibilities for the Chair.

Entrance of the main building, Martensstraße 5

Directly next to the new research building, 3000 m² have been reserved for a building of the new Helmholtz-Institute Erlangen-Nürnberg for Renewable Energy Production, HI ERN. This Helmholtz Institute, established in 2013, is devoted to research on materials and processes for renewable energy, mainly for photovoltaics and hydrogen technology. Prof. Göken is involved in this new institute with a project on protection of high temperature materials against hydrogen and water vapor influences. It is planned to establish at HI ERN a junior research group on hydrogen in materials and hydrogen embrittlement.



GENERAL MATERIALS PROPERTIES

Institute I
General Materials Properties

Nano/Micro

Microstructure
(3D) FIB, SEM, TEM, AFM, APT
Local properties:
Nanoidentation
Bulge testing
In-situ deformation

Materials Properties

Fatigue (LCF to VHCF), TMF
Creep, deformation kinetics
Strength, hardness, tribology
Size effects
Thermal Analysis

Macro

High temperature materials
Intermetallics: TiAl, NiAl ...
Ni- and Co-base superalloys
Light metals (Al, Mg, Ti)
Oxide protection coatings, TBC
Hard metals and composites
Biomaterials

Materials Optimization and Processing

Microstructural optimization
(Nanocrystalline / UFG)
Heat treatments
Alloy development

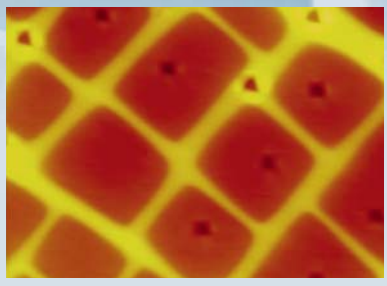
Method development
Atomistic modelling, DFT
Crystal Plasticity
FE-Simulation
Thermodynamic
(Thermocalc, Dictra)

Modelling & Simulation

Fracture mechanics
Interface dominated materials
Dislocation interactions
Amorphous materials
Nanomechanics

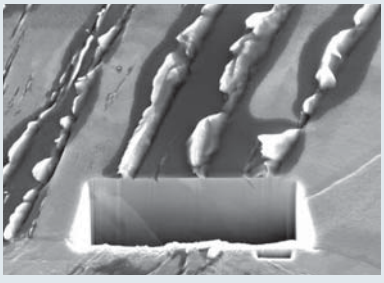
CURRENT RESEARCH PORTFOLIO

The overall research strategy of the Institute has been more or less constant over the years. We want to understand the correlations between the complex microstructure of materials and the mechanical behavior of these materials in order to use this knowledge to optimize the mechanical properties of materials. This includes the properties at high temperatures, cyclic deformation behaviour, creep performance and tribological properties. From the time of Bernhard Ilschner, a new integrative approach of materials research has been established, meaning that all different classes of materials from metals, to glasses, ceramics, polymers, composites etc. are studied in Erlangen. And in this sense, more or less all classes of materials are investigated at the Chair, including specialized materials like CaF_2, thermal barrier coatings and biomaterials. However, the main focus of the research activities at the Institute is still on metals and advanced alloys.

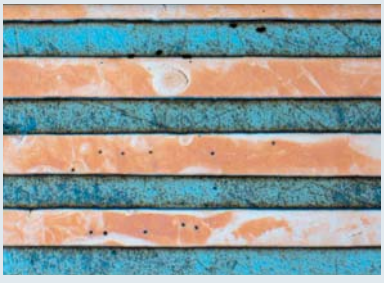


High Temperature Materials

Since optimization of properties and development of new materials strongly involves the processing and heat treatment techniques of materials, some processing techniques have also been established at the Institute. In particular, techniques for microstructural refinement such as accumulative roll bonding (ARB) and pulsed electrodeposition (PED) have been very well established in Erlangen. With the ARB technique, very fine lamellar metallic composites are produced, which is a new and very interesting topic. However, more conventional processes such as heat treatment of alloys are used intensively, especially for new high temperature materials. In collaboration with the Chair of Metals Science and Technology, casting of new alloys is also possible, which is for example very important for the development of new Co-based-superalloys ongoing at the Institute.

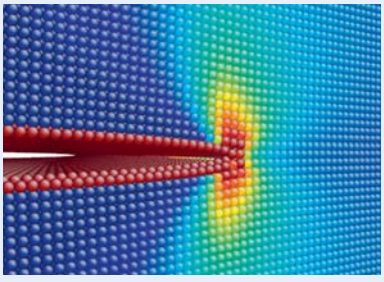


Creep & Fatigue



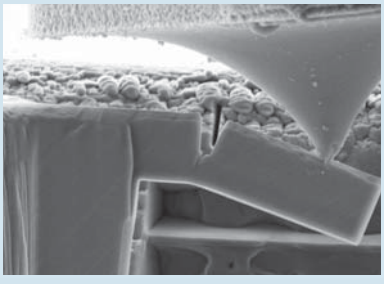
Nanocrystalline Materials

CURRENT RESEARCH PORTFOLIO



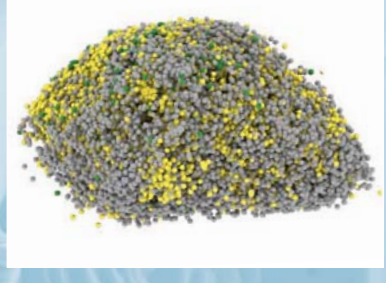
Simulation & Modelling

Although, the general research strategy has been more or less constant, the methods and microscopic techniques have been changed and extended enormously. Mechanical testing, in particular macroscopic testing of e.g. creep, fatigue behavior has always been an important aspect of the research strategy. More recently, micro- and nanoscopic testing with new methods like nanoindentation, microcantilever or pillar testing have become very prominent allowing for the measurement of properties at the microstructural length scale. Additionally, modelling of the mechanical behavior became very important in extension to experimental studies. Atomistic simulations gain access to the interaction of dislocations and other defects with interfaces and are also very important for a better understanding of the small scale mechanical behaviour.



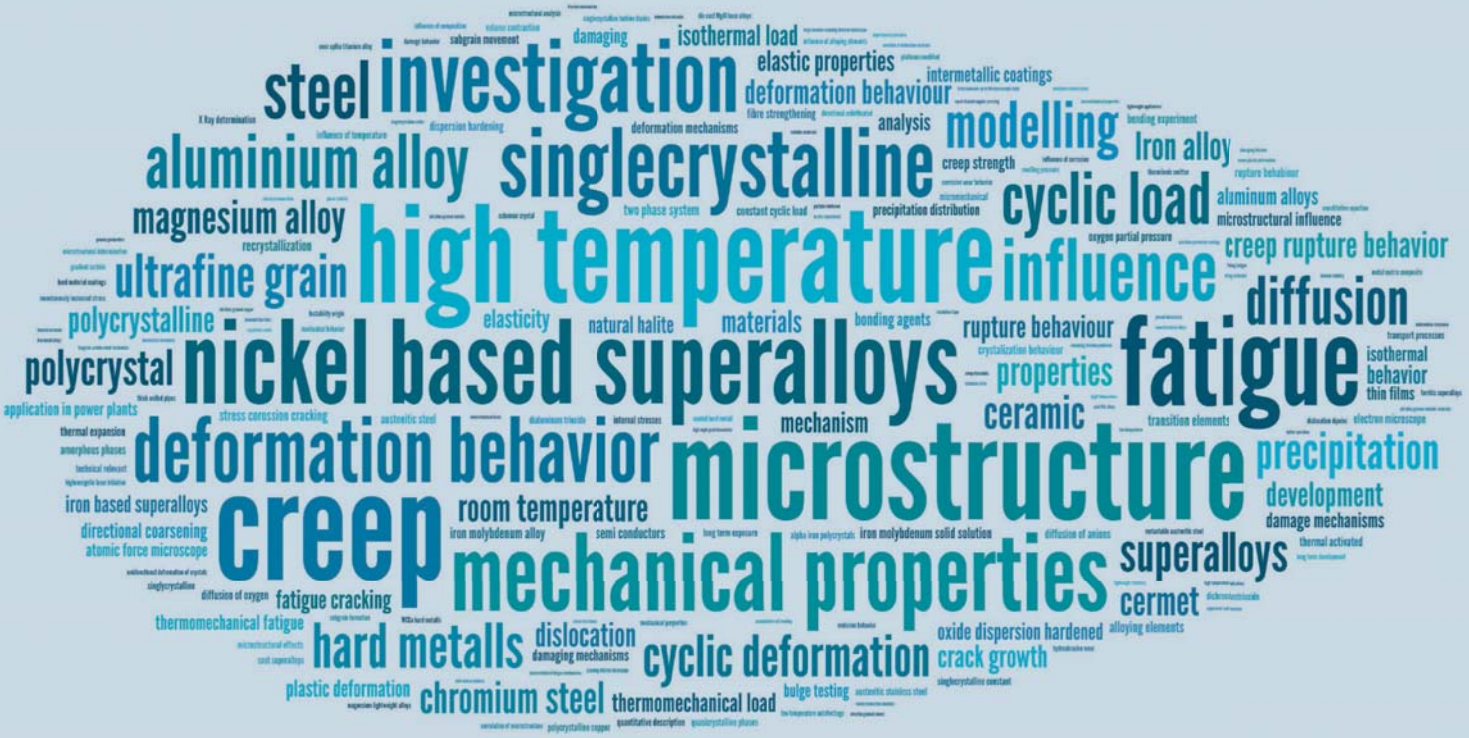
Nanomechanics & Thin Films

During the time when Haël Mughrabi was head of the Institute, Erlangen became well-known worldwide for research on the fatigue properties of materials. Although this still is a very active topic and many results on the fatigue properties of ultra-fine-grained and nanocrystalline materials have been achieved, the focus of the area has been changed to the very high cycle fatigue regime, and additionally, to more complex loading schemes like fretting, rolling contact and thermo-mechanical fatigue. The installation of the large-chamber scanning electron microscope in Fürth in 2006 allows for in-situ studies, where damage mechanisms can be directly studied online. The huge progress in the development of new microscopic techniques is in general very important for a full understanding of the microstructure. The Institute is equipped with a very modern microscopy lab, where all microstructural characterization techniques are available, from TEM and SEM to AFM and FIB instruments, enabling three-dimensional investigations. The new atom probe tomography (APT) instrument which has been installed recently, gains access to the chemical analysis on a more or less atomic scale.



Atom Probe Microscopy

Nowadays, the research activities at the Chair for General Material Properties is organized in six different research fields: Creep and Fatigue, Nanomaterials, Nanomechanics & Thin Films, High-Temperature Materials, Modelling & Simulation and Atom Probe Microscopy. This is the result of internal growth as well as the participation of the chair in a large number of research programs that will be presented briefly also in the following.

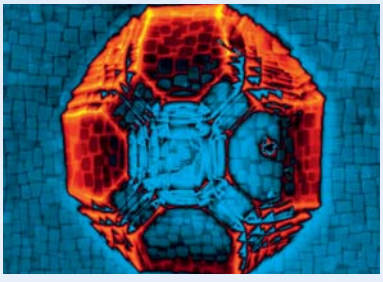


Wordcloud of PhD topics from 1972 until 2015

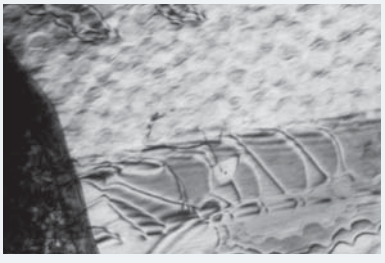
HIGH TEMPERATURE MATERIALS
NANOMATERIALS
NANOMECHANICS & THIN FILMS
MECHANICAL PROPERTIES, FATIGUE AND CREEP
MODELLING AND SIMULATION
ATOM PROBE MICROSCOPY

Steffen Neumeier, Mathias Göken

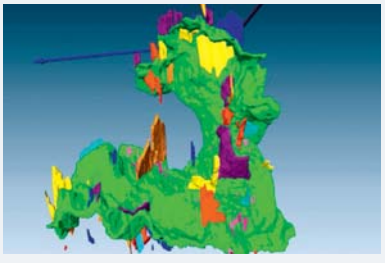
HIGH TEMPERATURE MATERIALS



γ/γ' microstructure of a Co-base superalloy with pore.



Microtwinning in a crept Co-base superalloy



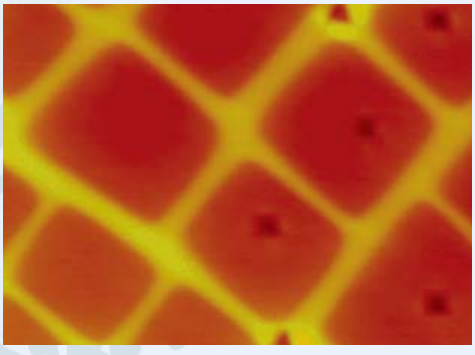
3D FIB tomography of a crack in a Ni-base superalloy

High temperature alloys are key materials for the aviation, automotive and power generation industries. They play an important role in our society and guarantee international mobility and global energy supply. The High Temperature Materials group carries out basic and application oriented research on various advanced metallic and intermetallic materials for high temperature applications. Over the last decades the Institute I has gathered a broad knowledge on high temperature materials and the research has always focused on the correlation between composition, microstructure and mechanical properties of advanced materials. Various mechanical testing methods and microscopy techniques at the institute combined with X-ray, synchrotron and neutron radiation sources are used for the characterization of hardness, fracture toughness, creep, fatigue and high temperature strength as well as the microstructure of materials such as Nickel-base superalloys, Titanium aluminides, NiAl-based protective coatings and thermal barrier coatings. Several years ago the group started also working intensively on novel precipitation strengthened Cobalt-base superalloys which were discovered in 2006. Our PhD student A. Bauer was the first to publish creep properties of this new class of high temperature materials. With a strong standing at the forefront of this research topic, the Institute I is looking forward to providing major contributions to this field and to putting this exciting class of materials into service.

The High Temperature Materials group collaborates closely with partners from aviation and automotive industry and several projects participate in the DFG funded Collaborative Research Center SFB/Transregio 103 “From Atoms to Turbine Blades” and the DFG-Research Training Group 1229 “Stable and Metastable Multi-phase Systems for Elevated Service Temperatures”.

RELATED RESEARCH ACTIVITIES

- Single crystal γ/γ′-hardened Co-base superalloys – alloy development, heat treatment strategies and mechanical properties, funded by the DFG within the Collaborative Research Center SFB/TR 103, Dipl.-Ing. Christopher Zenk
- Novel polycrystalline $L1_2$ hardened Co-base superalloys – Mechanical properties and deformation mechanisms, funded by the DFG-Research Training Group 1229, M. Sc. Lisa Freund
- Nickel-base superalloy Allvac 718Plus – Microstructure and mechanical properties of a new alloy for disc applications, Dipl.-Ing. Martin Pröbstle
- Influence of the alloying elements Niobium, Tantalum and Zirconium on the microstructure and mechanical properties of Titanium aluminides, M. Sc. Johannes Bresler
- Micro- and nanomechanical characterization of superalloys at elevated temperatures, funded by the DFG within the Collaborative Research Center SFB/TR 103, M. Sc. Markus Kolb
- High temperature protective coatings for application in hydrogen and water containing atmospheres, fundey by HI ERN, M. Sc. Sven Giese

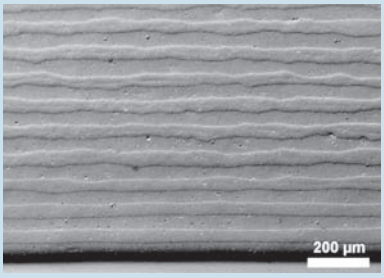


Nanoindentation in γ and γ'-phases of a Nickel-base superalloy.

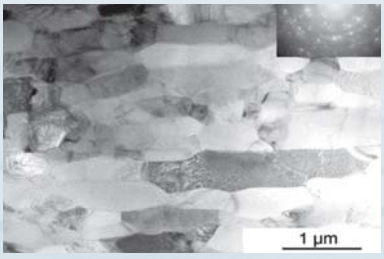
High-temperature fatigue testing of a Nickel-base superalloy

Heinz Werner Höppel, Mathias Göken

NANOMATERIALS



ARB laminate of AA60xx and AA50xx alloys



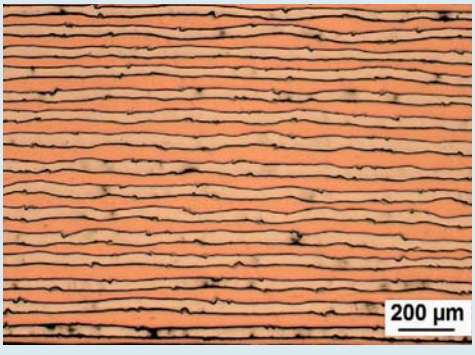
UFG microstructure of ARB process AA1050

The Nanomaterials group at the Institute of General Materials Properties mainly focuses on the production and characterization of ultrafine-grained (UFG) or nanocrystalline metallic materials. UFG materials have been investigated since the year 1999, when first fatigue experiments have been performed on UFG copper in collaboration with by R. Z. Valiev, one of the pioneers of severe plastic deformation (SPD)-processing. Nowadays, besides Pulsed Electro Deposition (PED), the main focus lies on the Accumlative Roll Bonding (ARB) process. This process allows the production of metallic UFG sheet-materials with grain sizes in the range of some hundreds of nanometers. The ARB-process is also intensively used to produce so-called nano-laminates, where different materials are repeatedly rolled together offering an extremely wide scope to tailor materials properties. By thorough characterization of the influence of the micro- and meso-structure on the mechanical properties, an optimized and tailored sheet design can be achieved. In this context, not only the structural characterization on different length scales is essential but also the possibility to correlate them with macroscopic and local mechanical properties.

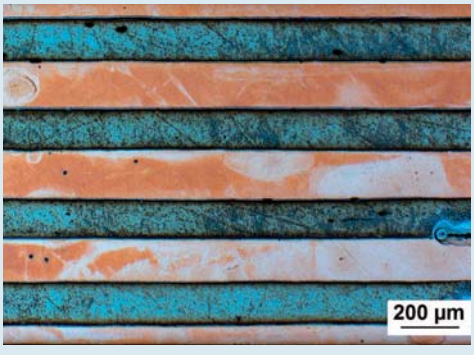
The Nanomaterials group collaborates closely with partners from other universities and from the aviation and automotive industry and several projects participate in the DFG funded Cluster of Excellence Engineering of Advanced Materials EAM.

RELATED RESEARCH ACTIVITIES

- Ultrafine-grained laminated metallic materials for new light-weight design, EAM, M. Sc. Frank Kümmel
- New light-weight materials by nanostructures at the macroscale, LuFo, M. Sc. Christopher Schunk
- Upscaling of the ARB-process: Potentials and Limitations, DFG, Dipl.-Ing. Mathis Ruppert
- Influence of sheet architecture on the mechanical properties of ARB-processed Laminates, DFG, Dipl.-Ing. Christian Krechel
- Tailoring materials properties of Aluminium alloys by ARB-processing, EAM, Dipl.-Ing. Tina Hausöl



ARB Cu/Al laminate, N6 ARB-layers

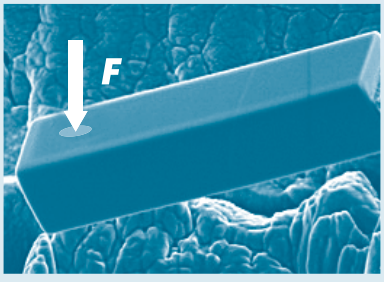


ARB Cu/Al laminate, N4 ARB-layers

NANO-MATERIALS

Benoit Merle, Mathias Göken

NANOMECHANICS & THIN FILMS



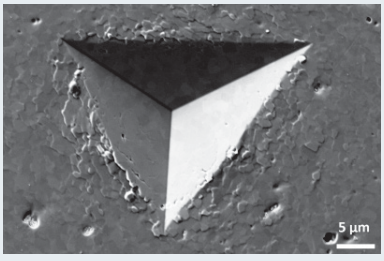
Small-scale testing of fracture toughness by bending beam

The nanomechanics group of the Institute I is using advanced test methods for exploring the fascinating world of the small-scale mechanical behavior of materials. Nanomechanical testing is used in order to characterize the local properties of inhomogeneous materials and to provice insights on mechanical size effects. Additionally, nanomechanical methods allow the characterization of samples too small or too thin for regular mechanical tests. A special emphasis in our research is put on thin films, which are not only ideal models for studying size effects, but are also of great practical interest due to their widespread applications.

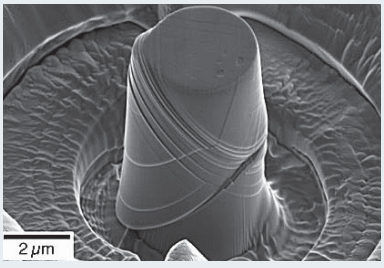
Nanoindentation is the most versatile and robust nanomechanical testing technique. It is usually used for measuring the local hardness and Young's modulus of a bulk sample. It's scope of application is steadily widening, including new procedures for testing time dependent deformation behavior, developed in Erlangen. Most prominently, a new strain-rate jump test method proposed by Maier, Durst and Göken in 2011 has found widespread application for determining the local strain-rate sensitivity of materials. The Institute I also contributed a novel stiffness-based method for performing long-lasting creep tests at elevated temperatures avoiding the influence of thermal drift. Current research is aiming at using nanoindentation for characterizing the fatigue properties of nanolaminates, leveraging the materials synthesis capabilities of the nanomaterials group.

The nano-scale testing methods are greatly complemented by Focused Ion Beam (FIB) techniques, another very important approach for testing properties of materials on the nanoscale. The FIB is used to mill extremely small samples such as micro-cantilevers and pillars, typically in the order of some micrometer from the materials of interest. These samples are then loaded either in compression or bending with a nanoindenter inside a SEM. Investigations of the bending process of notched micro-cantilevers even allows measuring the fracture toughness of such extremely small samples. The crack propagation can be monitored by continuously recording the stiffness of the beam. This allows the precise measurement of the fracture toughness of soft elastic-plastic materials. This technique was used to achieve better understanding why otherwise ductile metals behave in a brittle manner at the small scale.

Over the last 15 years, the Institute I has accumulated a broad range of expertise on the mechanical behavior of freestanding thin films in the range 50 – 500 nm. These insights were mostly achieved through bulge testing with a custom-built setup. A unique feature of the custom-built bulge tester is its capability to be integrated in an Atomic Force Microscope (AFM) and hence allow for in-situ observations on the deforming sample. This in-situ operational mode was intensively used for investigating the fracture properties of thin films. Unlike ceramic films, the fracture toughness of ductile metals such as gold was found to be strongly dependent of the film thickness. The scope of the bulge test technique was further extended to the investigation of other mechanical properties which are usually not accessible by any other technique, such as the strain-rate sensitivity and the fatigue properties of thin films.

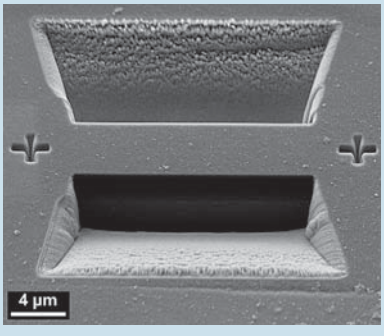


Nanoindentation in UFG aluminum



Micropillar compression in α-brass

Coatings on substrates are also intensively investigated at the Institute I. A major issue in the industry concerns the determination of the residual stresses present in these films. The Institute I has developed a robust method which allows its local measurement in the FIB microscope by stress relaxation. The gallium ion beam is used for milling two trenches in the surface of the sample. The relaxation of the lamella between the trenches then is precisely measured by means of digital image correlation analysis, from which the initial residual stress can be obtained. This method proved particularly useful for hard coatings, which can exhibit very high residual stresses above one gigapascal.



FIB-DIC technique to measure residual stresses of coatings

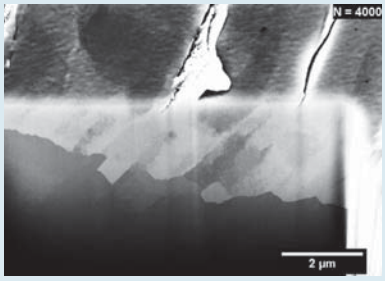
RELATED RESEARCH ACTIVITIES

- In-situ nanomechanics and thin films, funded by the Cluster of Excellence for the Engineering of Advanced Materials (research area A3), M. Sc. Eva Preiß, Dipl.-Ing. Johannes Ast
- In-situ investigation of the deformation mechanisms of materials at the small scale, funded by the graduate school GRK 1896, M. Sc. Jan Liebig, M. Sc. Carolin Puscholt
- Local investigations of the stress distribution in hard coatings, funded by the graduate school 1229, Dipl.-Ing. Markus Krottenthaler
- Development of a FIB-based method for the local measurement of residual stress, European IStress project, M. Sc. Lisa Benker

Heinz Werner Höppel, Doris Amberger

MECHANICAL PROPERTIES, FATIGUE AND CREEP

The group "Mechanical Properties, Fatigue and Creep" mainly focuses on the investigation of the mechanical properties and the related deformation behavior at various loading conditions. In this context, a deep understanding of microstructure–property correlations and the kinetics of plastic deformation has been kept in focus over the decades. Besides monotonic loading, the behavior under long-term creep conditions and under cyclic loading lies in the focus of the group. Accomplished investigations on the related damage mechanisms form the basis for tailored and mechanism based materials development/optimization.



FIB cut of PGB's in LCF fatigued Copper

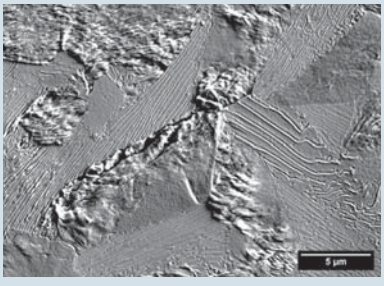
FATIGUE: In manifold technical applications structural parts as well as functional components are loaded not only statically but also cyclically. Since the cyclic endurance limit lies usually far beyond the monotonic yield strength, fundamental understanding of fatigue processes as well as a fatigue design are of extraordinary importance for engineering applications. Many pioneering concepts in this area as for example the composite model for describing the complex deformation behavior in soft and hard areas have been developed already by Haël Mughrabi and still intense research activities on the fatigue behavior of materials are ongoing. At the Institute we are concerned with fundamental fatigue mechanisms as well as applied problems. The main interest lies on the correlation between the mechanical properties under cyclic loading and the microstructural processes and damage mechanisms of metallic materials, compound materials, such as hard metals and material systems, and coatings on metallic substrates. Beside the investigations with conventional fatigue loading at room temperature and elevated temperatures, we are also concerned with investigations of the fatigue behaviour under thermo-mechanical loads as well as under fretting fatigue conditions.

Grain coarsening in UFG Copper during LCF loading

CREEP: The creep behavior of metallic materials is of high scientific as well as technological interest with a long tradition of research on this topic. As 50 years ago, we are still using self constructed creep machines in order to fulfill our particularly high requirements on the resolution of the strain measurements and on the stress constancy. The focus is put to the determination of the relevant creep mechanisms in technologically relevant alloys used for high-temperature applications in order to improve the materials further.

RELATED RESEARCH ACTIVITIES

- Damage mechanisms and microstructural influence on the Very High Cycle Fatigue Lifetime of metallic materials, DFG SPP 1466, Dipl.-Ing. Jochen Bach
- 'White-etching areas' in wind turbine roller bearing steels, BMBF, Dipl.-Ing. Tobias Ninnemann
- In-situ investigation of crack initiation and propagation in pure Cu and Nickel, M. Sc. Philip Goik
- High performance aluminium piston alloys: Isothermal fatigue properties, microstructure and thermal stability, BMBF, Dipl.-Ing. Matthias Korn
- New AlSi-alloys for cylinderhead applications, INI.FAU, Dipl.-Ing. D. Schwimmer
- Effekt of thermal (Over-)loading on the microstructure and mechanical properties of High performance aluminium piston alloys, BFS, M. Sc. Nicole Engl
- Optimization of the heat treatment of Al-Si- die cast alloys for structural applications in the automotive industry, INI. FAU, M. Sc. Holger Rammensee
- New high ductility Al-Si- die-cast alloys for structural applications in the automotive industry, AUDI AG and AMAG Casting, M. Sc. Robin Müller
- Improved precipitation kinetic by new Al-Si wrought alloys, AUDI AG and AMAG Rolling, M. Sc. Felix Glöckel
- Thermal stability and mechanical properties of copper alloys for applications at very high temperatures and cyclic loading amplitudes, Dipl.-Ing. Martin Kommer



Extrusions in C45E after VHCF loading

FATIGUE CREEP

Erik Bitzek, Arun Prakash

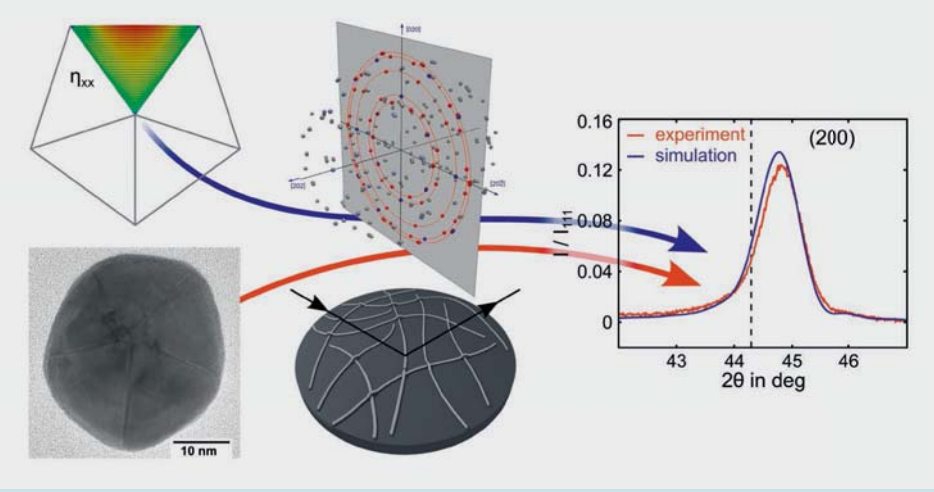
MODELLING AND SIMULATION

The Modelling and Simulation Group of Institute I conducts research into the elementary defects of the crystalline lattice (dislocations, cracks, interfaces, vacancies, ...) and on how the organization and interaction of these defects influences the mechanical properties of metallic materials. The group's activity also includes the modelling of mechanical properties of amorphous systems, like silicate and bulk metallic glasses. In all these studies, large-scale atomistic simulations and density functional theory (DFT) calculations are used to obtain detailed information on defect properties and on the mechanisms that lead to deformation and failure.

The focus of our research is to provide qualitative insights as well as quantitative information on the deformation processes at work at the atomic scale. These findings lead to better understanding and interpretation of experimental results, whilst simultaneously helping in the development of robust and reliable models for the prediction of deformation behavior and failure of materials. Insights from atomistic simulations are used in our group to develop multiscale models like crystal plasticity frameworks with the finite element method (FEM) and the fast Fourier transform (FFT) method. Such models bridge various length scales and facilitate the simulation of complex forming processes. Within collaborative research projects such as the SFB/Transregio 103 – "From Atoms to Turbine Blades", the atomistic simulations, furthermore, provide important input parameters for mesoscale simulation methods like discrete dislocation dynamics (DDD) or phasefield models.

The main research topics of the Modelling and Simulation Group, namely, *Nanomechanics and Small Scale Plasticity*, *Interface-Dominated Materials* and *Fundamental Aspects of Fracture* mesh well with the topics of experimental investigations at the Institute I, thereby successfully leveraging synergy effects. Through these close links to the experimental groups at our institute, the PhD students specializing in modelling and simulation are exposed early on to the experimental intricacies, enabling them to critically assess experimental results or suggest experimental investigations to validate their simulation-based predictions.

Recent highlights of our work include the development of an analytical model to explain the particular mechanical properties of five-fold twinned nanowires (see Figure right).



Strain state and microstructure of five-fold twinned nanowires and related diffractogram (Niekiel et al., ACS Nano 8, 1629 · 2014).

These nanowires are commonly used in flexible electronics, e.g., as transparent electrodes. Understanding their deformation and failure mechanisms has therefore important implications for the design of reliable, highly stretchable and bendable devices.

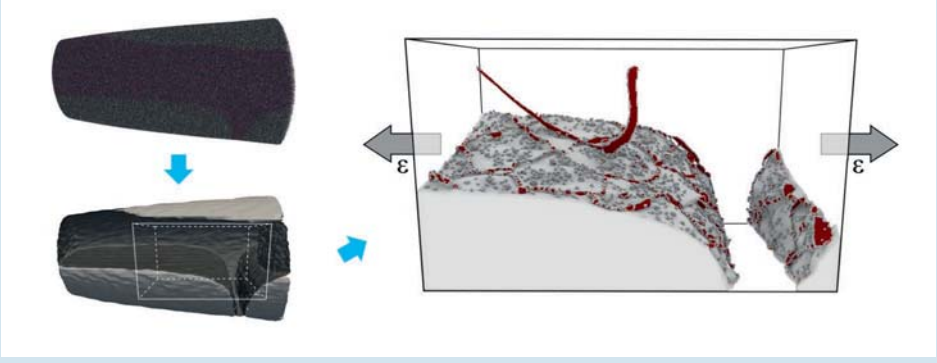
In studies involving fundamental aspects of fracture, we could show that the fracture toughness of grain boundaries can surpass the toughness of single crystals. This counterintuitive finding cannot be explained by the usual thermodynamic approach in continuum-scale fracture mechanics but can be explained by extending the concept of lattice trapping to bond trapping in grain boundaries. We also recently performed some of the first massively-parallel atomistic simulations of curved crack fronts. In contrast to the typical simulations using quasi-2D setups and periodic boundary conditions, the nanoscale penny-shaped cracks show pronounced crack tip plasticity and the interaction of dislocations emitted from different parts of the crack front with each other and the crack. These results are directly related to the crack front curvature and point to the importance more complex simulation geometries, ideally through digitization of experimental data, than the over-idealized scenarios often used in atomistic simulations.

MODELLING AND SIMULATION

Driven by these and other similar observations, we developed a novel methodology to construct atomistic simulation geometries based on real morphologies determined e.g. by atom probe tomography (APT), see Figure below. Experimentally-informed simulations on the interactions of channel dislocations with γ' precipitates allowed us for the first time to identify the atomic-scale details of many observed dislocation processes in Ni-base superalloys and to show the importance of local interface curvature on the interfacial dislocation network.

RELATED RESEARCH ACTIVITIES

- Schädigungsmechanismen und mikrostrukturelle Einflussgrößen auf die Ermüdungslebensdauer metallischer Werkstoffe im VHCF-Bereich. DFG PP1466, Dipl.-Ing. Johannes J. Möller
- Modelling Early Stages of Fracture and Crack – Microstructure Interactions. EAM SG2, Dipl.-Spec. Polina Baranova
- Atomistic simulation of mechanical properties of nanostructures and interfaces. GRK1896, M. Eng. Zhuocheng Xie
- Plastic deformation, crack nucleation and fracture in lightweight intermetallic composite materials. EAM A3, M. Sc. Tobias Klöffel
- Atomistic simulations of elementary dislocation processes in coherent and semi-coherent γ/γ' –microstructures. DFG SFB/TR 103, M. Sc. Frédéric Houllé
- Influence of Topological Anisotropy on the Mechanical Properties of Silicate Glasses. DFG PP1594, M. Sc. Sudheer Ganisetti
- Modelling of FIB-induced artefacts and the effect of in-homogeneities and anisotropic elasticity. EU FP7 iSTRESS, Dr. Julien Guénolé

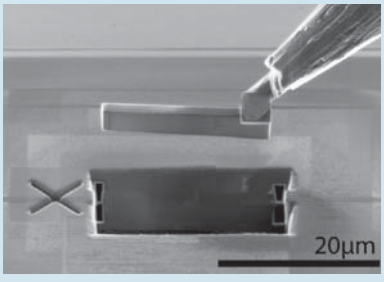


Experimentally informed atomistic simulation of dislocation-precipitate interaction based on APT data of a Ni-base superalloy (A. Prakash et al., Acat Mater. 92, 33 (2015)).

Peter Felfer

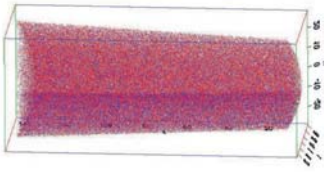
ATOM PROBE MICROSCOPY

The atom probe microscopy/tomography (APT) group ist the newest addition to the Institute I. It is centered around the new acquisition of a Cameca LEAP 4000 X HR, a latest generation atom probe. This is an instrument that can carry out single atom mass spectrometry at the nm scale and below in three dimensions on up to tens of millions of atoms in one experiment from metals, semiconductors, ceramics and geological materials. By its mass spectrometry principle, it is equally sensitive to all elements of the periodic table and even their isotopes, greatly expanding our capabilities to understand materials on the nanoscale even with very dilute additions. Since the atom probe works by pulsing off single ions from a needle shaped specimen with a sub 100 nm tip radius, specimen preparation is one of the key factors in the experimental process. For metals, this can very often be achieved by electropolishing of wire-shaped blanks, cut out from bulk materials. In order to perform analysis on specific features in bulk materials, or from nanomaterials, access to FIB based preparation is available (Figure top).



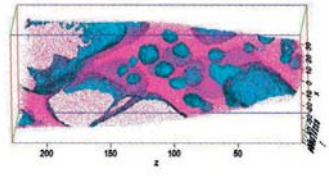
FIB-based lift-out of an atom probe sample from a phase interface in a TiAl intermetallic alloy

Having only operated for since early September 2015, the atom probe is already producing invaluable data for the research on TiAl intermetallic alloys (Figure middle) and next generation Co-based superalloy (Figure bottom). Below, are visualizations of the data produced.



3D reconstruction of the atom distribution at a phase interface in a TiAl intermetallic alloy

Apart from supporting the research on metallic and intermetallic materials at the institute, the atom probe group will also focus on advanced sample preparation methods including targeted preparation and nanomaterials including nanoparticles and further develop the computational analysis tools needed to link the resulting data to theory and simulation.



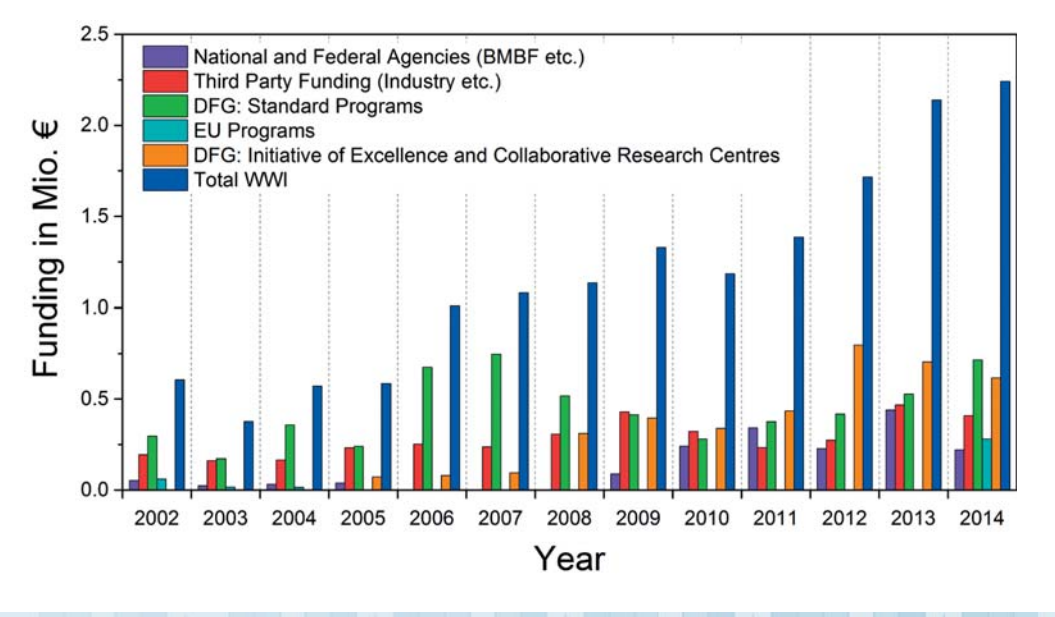
Experimental results from Co-Al-W alloy, showing γ' percipitates in a γ-matrix (blue: isosurface at 40% Co, pink: Cr atoms)

RELATED RESEARCH ACTIVITIES

- APT and TEM analysis of precipitation processes in Al-Mg alloys, M. Sc. Steffen Lamm

THIRD PARTY FUNDING

The growth of the Institute is well reflected not only in the high number of PhD-students but also in the increasing amount of total funding. In 2014 2.2 Mio € have been acquired, which was again an all-time high in the history of the Institute. We are also very proud to keep over the years a good balance between funding related to more technological background, like direct founding from industry, BMBF-projects, etc. and funding for fundamental research from the DFG and similar organizations. We are also very happy to succeed to be part of the DFG-funded Cluster of Excellence Engineering of Advanced Materials and of the Collaborative Research Center SFB/TR103 on high-temperature materials. Moreover, in 2014 we succeeded for the first time to take part in the joint European research project ISTRESS. The more technological projects allow us to transfer fundamental knowledge to technological applications. Thus, our major goal is to consolidate at the high level by still keeping the balance between funda-mental and more applied research.



Third party funding at Institute I

COOPERATIVE RESEARCH PROJECTS

CLUSTER OF EXCELLENCE

Engineering of Advanced Materials

The **Cluster of Excellence "Engineering of Advanced Materials"** funded by the excellence initiative of the German government was established in 2007 at the University of Erlangen-Nürnberg as the only cluster devoted to Material Science in Germany. Not only was this a recognition of the leading position that Erlangen had enjoyed in materials science research during the past years, but it has also provided a strong boost for keeping the equipment to the highest international standards by providing an extensive funding for new acquisitions. The Cluster of Excellence is a joint initiative of the Technical Faculty (mostly Materials Science and Engineering, Chemical and Biological Engineering, Electrical and Mechanical Engineering departments), the Faculty of Sciences as well as other academic and industrial research partners (mostly the Max Planck and Fraunhofer Institutes and Neue Materials Fürth). The interdisciplinary research is organized in 7 research areas. The Institute I is especially committed to the "Nanoanalysis and Microscopy" as well as "Lightweight Materials" topics. These research areas encompass the research activities carried on the novel micromechanical characterization of materials as well as the development of innovative foil materials by Accumulative Roll Bonding (ARB). The entire materials science department has greatly benefitted by the funding associated with the excellence initiative. Prof. Göken and the Institute I have been pivotal in the acquisition of a state of the art aberration-corrected Transmission Electron Microscope and the construction of a vibration-proof building to house it (part of CENEM, see above). In 2015, the first Atom Probe device in South Germany was successfully commissioned at the Institute I, and the EAM cluster initiated the creation of a new Junior Professor position at the Institute I for further developing this research field. Last but not least, the Institute I is also a founding member of a new structure that was established in 2013 in Erlangen and which is intended as a long term continuation of the interdisciplinary work initiated by the EAM cluster: the Helmholtz Institute for Renewable Energy Production.

E A M ENGINEERING OF ADVANCED MATERIALS

SEBM for new materials

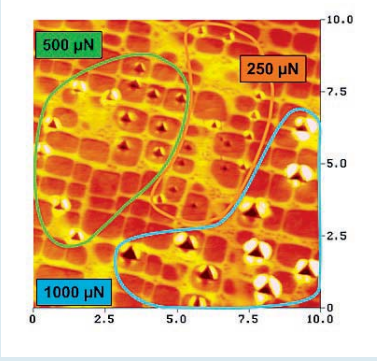
German Class for researchers from abroad

SFB/TRANSREGIO 103

From Atoms to Turbine Blades – A Scientific Approach for Developing the Next Generation of Single Crystal Superalloys

SFB/Transregio 103
SUPERALLOY SINGLE CRYSTALS

Single crystal Ni-base superalloys represent key materials for turbine blades in modern gas turbines for aero engines and power plants. International mobility and global energy supply rely on this fascinating class of high temperature materials. Improvements in efficiency and emissions demand new concepts in single crystal technology, which require progress in different areas of expertise. Amongst others, a basic understanding of all aspects of alloy design and performance is needed. This comprises the role of heterogeneities on the dendrite and on the precipitate scale. It includes the exact role of alloying elements (especially: d-shell elements). It is important to understand how microstructural and atomistic parameters affect thermodynamic equilibria, the evolution of microstructure during processing and high temperature deformation. The focus is on creep deformation mechanisms, microstructural stability (nucleation and growth of new phases, coarsening of the γ/γ′ microstructure), castability (porosity, parameters of the dendritic structure) and surface integrity (oxidation and coatings). New alloys are expected to have a better performance while making most efficient use of fossil ressources. They should also reflect the availability of strategic elements such as Re. Within the SFB/Transregio 103, the Ruhr-Universität Bochum and the FAU are the main collaborative partners. They join forces with the Max Planck Institut für Eisenforschung (MPIE, Düsseldorf), the Deutsche Forschungszentrum für Luft und Raumfahrt (DLR, Köln) and the Forschungszentrum Jülich (FZ Jülich). The SFB is coordinated by Prof. G. Eggeler (RUB) and Prof. R.F. Singer (FAU), who both are former members of the Institute I.



Nanoindentation in a Ni-base superalloy

In addition to Ni-base superalloys, a special effort is made to explore the high temperature properties of new Co-base superalloys with γ/γ′ microstructures. Co is an element quite similar to Ni, however, with a 40°C higher melting point. Since the discovery by a Japanese group in 2006, which showed the possibility of γ′ strengthening by a ternary $Co_3(Al,W)$ phase, this new class of superalloys has become very attractive. The SFB offers to explore the properties of this new alloys in a broader sense including oxidation, thermophysical data, processing, etc. The acivities in the SFB concerning Cobalt-base superalloys are coordinated by Institute I.

More detailed knowledge of materials properties and microstructure through use of new test procedures, either mechanical measurements (like miniaturized creep and fatigue testing and nano metrology) or characterization methods (high resolution, aberration corrected transmission electron microscopy, 3D atom probe) are further topics. These new techniques will help to identify elementary processes which govern the formation of new phases, the microstructural coarsening of the γ/γ′ microstructure and the interaction of deformation and damage mechanisms. The results will contribute to improvements in high temperature design and refurbishment strategies. Materials modelling, bridging all scales from atomistic to mesoscopic and macroscopic modelling, is applied to materials processing as well as high temperature behaviour.

Members of the SFB/Transregio 103 at the interaction week in Erlangen

At Institute I three projects under the supervision of Prof. M. Göken, Prof. E. Bitzek and Dr. S. Neumeier focus on nanomechanical testing of superalloys at elevated temperatures, atomistic simulations of fundamental dislocation processes in Ni-base superalloys and the development and investigation of single crystalline Co-base superalloys.

COOPERATIVE RESEARCH PROJECTS

GRADKO – DFG RESEARCH TRAINING GROUP 1229

Stable and metastable multi-phase systems for elevated service temperatures (2006 – 2015)

Stabile und metastabile Mehrphasensysteme bei hohen Anwendungstemperaturen
DFG-Graduiertenkolleg 1229

The materials and coatings used at elevated temperatures typically are nano-scaled multiphase or composite materials with complex microstructures. The main research idea of this graduate school was to combine research activities on different classes of materials like metals and ceramics for applications at high temperatures and to derive common aspects and synergies between these typically separated fields. Correspondingly, the research program of the graduate school was divided in four fields: Ceramics and composites, metallic alloys, oxidation and coatings and new methods & simulations. In total 14 projects at the Universities in Bayreuth and Erlangen were funded from 2006 to 2015 in two rounds over 4.5 years with a total financial sum of 8.5 Mio € by the DFG. At Institute I Ni-based superalloys with rhenium and ruthenium, new polycrystalline γ'-strengthened Co-base superalloys, thermal barrier coatings and bond coats have been important topics in the research training group. The continuous improvement of such materials requires a good knowledge on the mechanisms of how the different alloying elements operate. New electron microscope methods like the 3D-focused ion beam tomography or nanoindentation techniques have been used and introduced at Institute I. This research program was a joint research initiative between the Universities in Bayreuth and Erlangen, which are situated within close proximity in northern Bavaria. Both Universities have a high expertise in materials science and engineering and this research program has led to a strong intensification of cooperative research activities between both Universities. Also the interaction between students has been intensified by a joint educational program. The research training group has been coordinated by Prof. Mathias Göken for the University in Erlangen-Nürnberg and Prof. Uwe Glatzel for the University in Bayreuth. The linkage of both Universities was facilitated by a red mini bus, which was typically used for traveling between Erlangen and Bayreuth once a week.

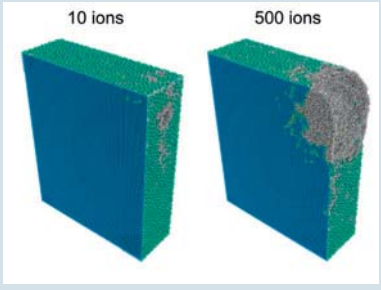
Graduates and associate PhD students of the Research Training Group in front of the red mini bus.

However, this mini bus was also used intensively for conference visits and excursions within whole Europe and by this became well known to many people in the community. The general topic of multi-phase high-temperature materials also allowed to create a very attractive educational program. Different material classes, processing techniques, analytical methods and theoretical models have been taught to the graduate students. A number of world-wide contacts allowed the incorporation of numerous well accepted international scientists within the graduate program. The PhD students Steffen Neumeier, Carolin Held (née Pfeiffer), Alexander Bauer and Lisa Freund from Institute I could spend some time abroad during a foreign research stay of up to three months during their PhD work at the Universities of Baltimore, USA, and Cambridge, UK. This was a very successful element in the graduate program and helped to intensify international cooperation. A very prominent aspect of the educational program has also been the yearly summer schools, which were held at different places in the nice Franconian surrounding.

The summer schools were supported by the members of the industrial advisory board, which allowed strengthening the application background. The research results have been published over the years in more than 200 publications in international journals and conference proceedings. We are grateful to the German Research Foundation, DFG, for their generous financial support of the research training group over the last years, which eventually made these research results possible.

Members of the Research Training Group with external guests from the Cambridge University during the Summer School 2011 at the Castle in Pommersfelden.

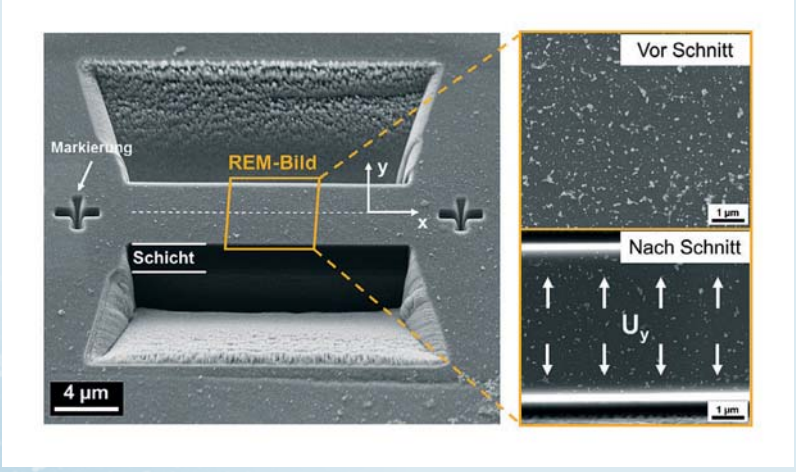
iSTRESS



Atomistic simulation of focused ion beam milling (J. Guénolé).

The **iSTRESS** project is part of the 7th framework program of the European commission as a large scale integrating collaborative project. Having as an objective the pre-standardization of incremental focused ion beam (FIB) micro-milling for intrinsic stress evaluation at the sub-micron scale, it involves numerous partners from different European countries, from both academia and industry. Two research groups are working on this project at the Institute I. In the Nanomechanics & Thin Films Group experiments are conducted on the stress measurement via digital image correlation (DIC). Using atomistic simulations, the Modelling and Simulation Group of Institute I studies the elementary mechanism of damage formation by ion irradiation and their effect on stress relaxation. The ultimate goal is to combine the insights from modelling and experiments to develop guidelines under which conditions the FIB-DIC method will provide reliable measurements of residual stresses.

Partners of the iSTRESS project.

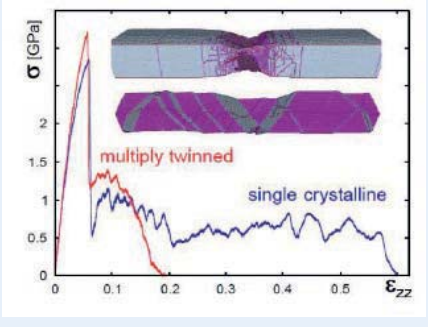


Measurement of the displacement field after FIB-milling in the H-bar geometry

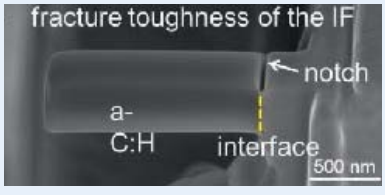
DFG RESEARCH TRAINING GROUP 1896

In-Situ Microscopy with Electrons, X-rays and Scanning Probes

This newly established research training group in 2013 strongly combines the expertise from the faculty for natural science with engineering aspects at the FAU and is based on the many activities in the interdisciplinary research center CENEM. Its main objective is to combine advanced complementary nanocharacterization methods to study the properties of functional nanostructures and nanostructure networks, as well as the important role of the mechanical properties of interfaces, in particular those between nanostructures. By this unique combination, the overall 12 PhD candidates funded by the DFG obtain a comprehensive, method-spanning and interdisciplinary training in the application of these tools to materials and device development. The Institute I participates with three projects in this research training group. Nano- and micromechanical tests in the TEM and SEM/FIB are used to study the role of interfaces on the plastic deformation in complex compounds, and bulge tests are used to study the strength and toughness of very thin films. The experimental projects are supplemented by a special simulation project, which studies the plastic deformation and failure of nanostructures and networks at the atomic scale.



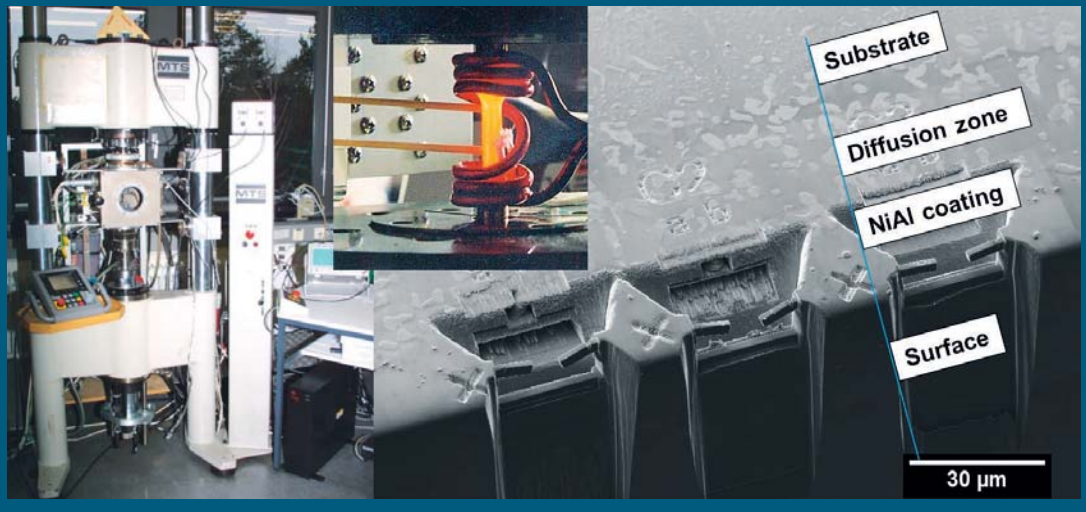
Stress-strain curve and deformation morphology of single-crystalline versus five-fold twinned nanowires (F. Niekiel).



Measurement of fracture toughness at a-C:H interface

INSTRUMENTATION AND EQUIPMENT

Understanding the mechanical behavior and optimizing the mechanical properties of engineering materials on all length scales is one of the key topics of the Institute. Therefore many techniques for measuring the mechanical properties on the macroscopic and microscopic scale are available at the institute. On the macroscale, fatigue, creep or thermomechanical fatigue properties are measured next to the strength under compression or tension. New nanomechanical testing procedures allow measuring the properties directly on the microstructural length scale as shown here with microcantilever tests on high temperature coatings. In most projects, we combine nowadays testing on the microscopic scale, to measure properties of individual phases and other microstructural constituents with nanoindentation or other nanomechanical tests, to get a better understanding of the bulk mechanical behavior. Many test equipments have been developed and built at the institute, to meet the high requirements and test protocols which are necessary for gaining a better understanding of the complex mechanical behavior.

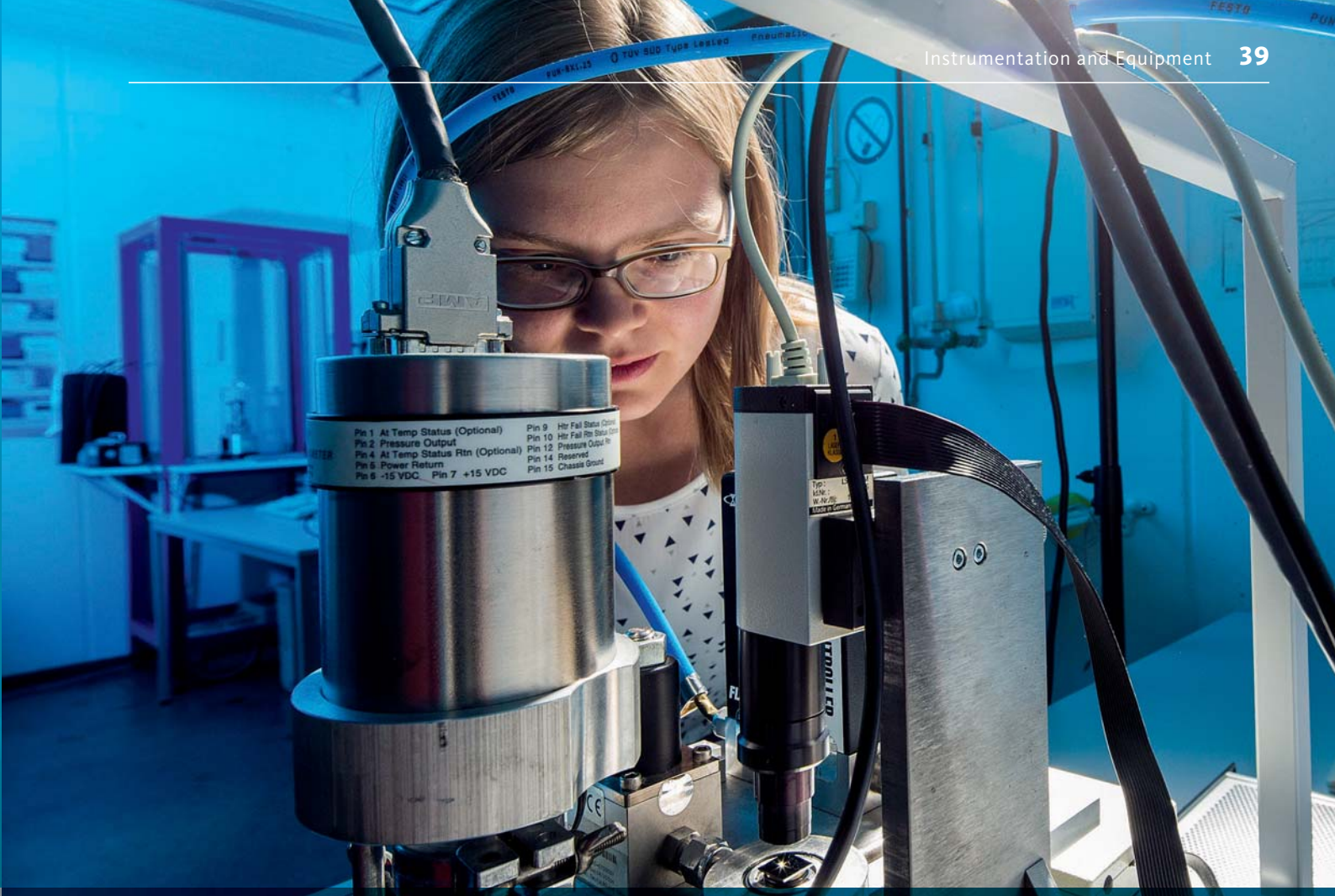


Instrumentation	Special remarks
Nanoindenter G200	up to 200°C; CSM
Nanoindenter XP	CSM
Bulge Test	thin films < 400 nm
MTS 880 and 810 servohydraulic setup	up to 1000°C and 100 kN, TMF, LCF, Vacuum
Roell Amsler 10HFP5100 mechanical oscillator	up to 140 Hz, Vacuum, fretting fatigue setup
Roell Amsler Rolling contact fatigue (RCF) apparatus	bearing currents, magnetic fields, temperature, variable speed ramps and static mechanical load
Ultrafast-MCI ultrasonic fatigue setup	laser interferometreic measurements, frequencies from 2 to 20 kHz
Netzsch TMA Hyperion 402	up to 1000°C, small scale mechanical testing
Compression creep testing	3 pneumatic machines, constant stress, up to 1100°C
Tensile creep testing	8 machines, up to 1000°C
CAMECA LEAP 4000X HR Atome Probe	
Bruker Dimension 3100 AFM	contact-, tapping-, magentic- and fluid mode
Zeiss Crossbeam 1540 FIB/SEM	EDS, EBSD
FEI Helios NanoLab 600i FIB/SEM (@ ZMP)	EDS, EBSD, STEM
Large Chamber SEM (@ ZMP)	2 m³ Chamber, EDS, BSD, in-situ fatigue testing
Philips CM200 TEM	double tilt holder, STEM, EDS
Carl Wezel Quatro Roll Stand	250 mm width, max
Instron 4505 Tensile testing	1-100 kN, RT-1200°C
Instron 4505 Compression testing	1-50 kN, RT-1400°C
High Performance Workstation for 3D Visualization	128 GB RAM, 20 TB hard disk space, high end grafic cards
High Performance Compute Cluster (shared with RRZE)	300 TFlop/s

NANOINDENTATION TESTING

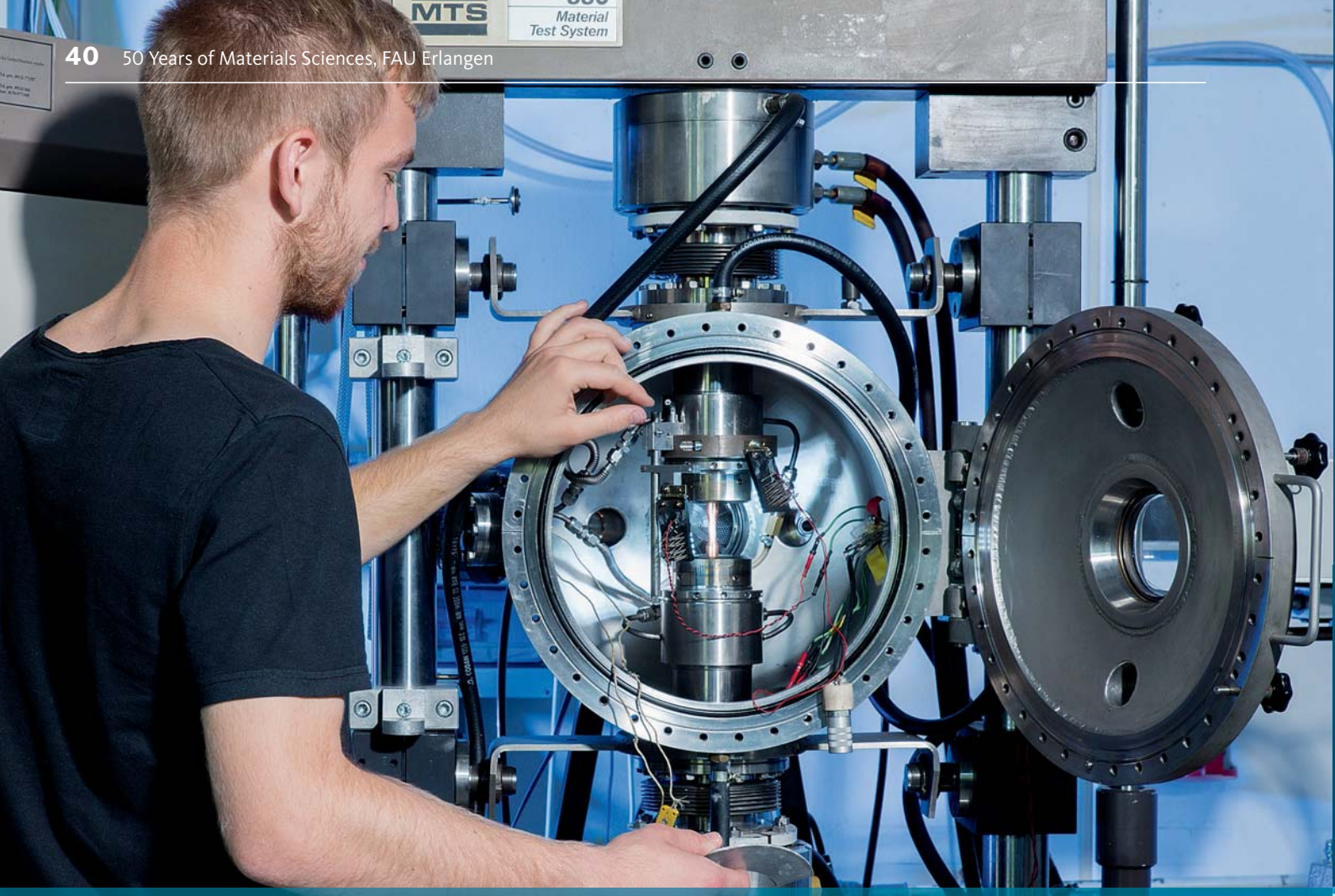
The Nanoindenter G200 and Nanoindenter XP are two related nanoindentation systems built by Keysight. They offer a high degree of automation, which allows for a high throughput of measurements and a wide range of applications. A special highlight of these systems is the availability of the CSM option, which enables a continuous determination of the hardness and Young's modulus over the indentation depth. The G200 platform is also well suited for elevated temperature testing up to 200°C, as well as scratch testing and AFM imaging. It has a very wide application field and is virtually used for characterizing all materials dealt with at the Institute I. The technical knowledge that has been gathered over the years was derived benefit from in order to implement new testing methods. Worth mentioning is the strain-rate jump test method developed by Verena Maier during her PhD in order to measure the local strain-rate sensitivity of various materials. This very successful novel method was taken over by Keysight for commercial application. Together with Benoit Merle, Verena Maier also implemented a CSM-based method allowing long-term creep measurements.

At the Institute I, a Hysitron Triboscope indentation head is combined to a Bruker Multimode AFM stage. The typical operational sequence consists into imaging the surface of the sample in AFM mode, selecting a spot of interest and performing indentation there. The nanometer-precise lateral positioning makes the system ideal for investigating the hardness and Young's moduli of phases as small as 500 nm. Currently, the main application is the investigation of cobalt-based high-temperature alloys.



BULGE TESTING

The bulge test technique has stood in focus of the micromechanical research at the Institute I since 2002. Three successive generations of PhD students (Elmar Schweitzer, Benoit Merle and Eva Preiß) have intensively used and improved this technique. Over the years, two fully functional devices were built and continuously improved. They are currently operated for measuring the mechanical properties of thin films in the thickness range 10 – 400 nm. The investigated materials range from gold, copper and silver to nitrides and oxides. Basic measurements include the determination of the internal stress and Young's modulus of the films, but the devices can also provide measurements of fracture toughness, strain-rate sensitivity, as well as fatigue properties.



THERMOMECHANICAL FATIGUE TESTING SETUP

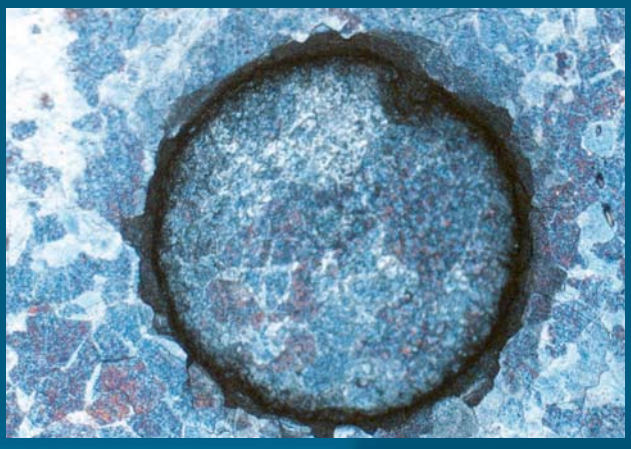
The 880 servohydraulic setup from MTS allows the mechanical characterization of samples at temperatures up to approximately 1000°C in air or under high vacuum. Loads as high as 100 kN can be used. The current setup is the results of successive improvements that have taken place over several decades. The main application at the Institute I is currently the low cycle fatigue characterization of high temperature materials. All in all, three similar machines (MTS 880 and MTS 810 setups) are available at the Institute I.

ULTRASONIC AND HIGH CYCLE FATIGUE TESTING

The Ultrafast MC1 ultrasonic fatigue machine offers unprecedented opportunities to test samples in the ultrahigh cycle fatigue regime within a reasonable lapse of time. The experimental setup was devised at the University of Kaiserslautern and is based on the excitation of a sample to its resonant frequency by a piezo-actuator. The system is equipped with a 500 kHz data measurement card, which allows in combination with a laser interferometric measurement system a very precise determination of displacement amplitude and number of fatigue cycles. The setup is typically operated in a pulse/pause mode to prevent unwanted specimen heating and so effective frequencies from 2.5 to 10 kHz can be reached. Damage evolution can be monitored by frequency, temperature or dissipated energy. Single amplitude and variable amplitude tests can be done with the MC1-System. The setup is heavily used at the Insitute I for investigating the effect of heat treatment, carbon content and microstructure on the very high cycle fatigue behavior of steels.

The Roell Amsler 10HFFS10V setup uses an electrical drive to generate a high frequency mechanical oscillation. This setup can be used to perform tensile, compression and bending experiments at frequencies up to 140 Hz. In order to allow specific investigations, the experiments can be performed under vacuum, under a specified mean stress or a lateral friction force. The setup is intensively used at the Institute I for the high cycle fatigue characterization of a wide range of materials.

INDENTATION CREEP TESTING



Next to its conventional creep testing setups, the Institute I purchased in 2012 a compact setup aimed at investigating millimeter small samples. The Netzsch TMA Hyperion 402 uses an electromagnetic actuation providing up to 3 N force and ensures a reliable measurement of the displacement with an accuracy of a few nanometers. The tests can be performed in controlled environment between -150°C and +1000°C. The setup is used to study the local creep properties of materials.

WEAR FATIGUE SETUP

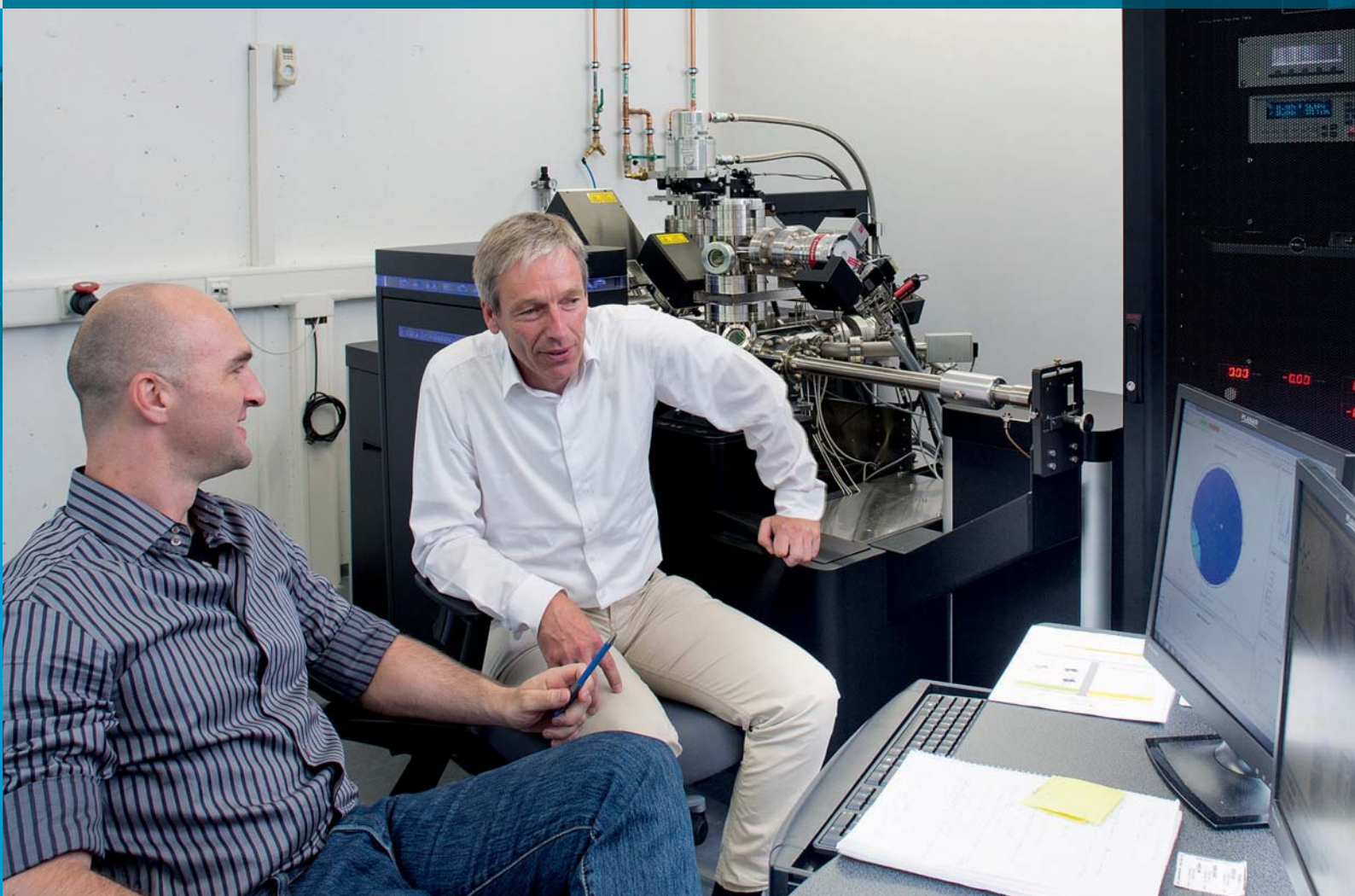
Within the scope of clarifying the white-etching crack (WEC) development in roller bearings, a rolling contact fatigue (RCF) with an open design been developed, which allows imposing and examining a high amount of different loadings. The apparatus consists of two modules. The first part is the actual RCF-module (bearing driving unit with mechanical and electric loading unit), which was developed and built in house. The second part is a commercial 50 kN resonance system of the company Zwick Roell. Both modules are mechanically coupled, so that the mechanical oscillations of the resonance system can be transmitted into the bearing sample during RCF-testing. The setup allows the application of bearing currents, magnetic fields, temperature, variable speed ramps and static mechanical loads. The lubrication is realized by a minimal lubrication system, introducing the oil discontinuously with pressurized air pulses. The applications at the Institute I especially involve the examination of interdependencies between the different loading types and their correlation to WEC-formation. With this setup, the interactions between electromagnetic impact on the chemical reaction layer formation (lubrication additive based) and related electric potentials have been successfully investigated.

PNEUMATIC CREEP TESTING DEVICE

The Institute I operates custom-built pneumatic mechanical testing machines designed for creep testing at high temperature in both compression and tensile directions. The heating chambers allow testing at temperatures as high as 1100°C under a constant stress. The displacement is recorded from outside the heating chamber by a laser displacement sensor or directly at the sample via LVDTs. The devices are mostly used for the characterization of high temperature nickel and cobalt based superalloys. Next to this, also conventional compression creep testing machines and tensile creep testing machines are operated.

MICROSCOPY AND ANALYSIS
ATOM PROBE MICROSCOPY

Atom Probe Tomography is the most advanced technique currently available for analyzing the chemical composition of a specimen with an atomic resolution. It consists into progressively vaporizing a fine needle made of the material to analyze. During the whole process, the chemical nature of each single ejected atom is determined by a position informed time of flight mass spectroscope, whence a 3D reconstruction of the original specimen showing individual atoms can be achieved. The Institute I operates since July 2015 a state of the art LEAP 4000X HR built by CAMECA. Compared to previous device generations, this setup offers a wide field of view, allowing for specimens as large as 150 nm to be imaged, together with an improved mass resolution. Unlike with a usual electrical pulse, the use of an UV laser for heat vaporization allows the investigation of non-conductive materials. The Atom Probe is used for the characterization of all materials investigated at the Institute I. It allows identifying the diffusion and segregation processes of specific elements taking place during the fabrication of nanomaterials such as ARB and ECAP materials, high temperature superalloys, as well as multilayer thin films.



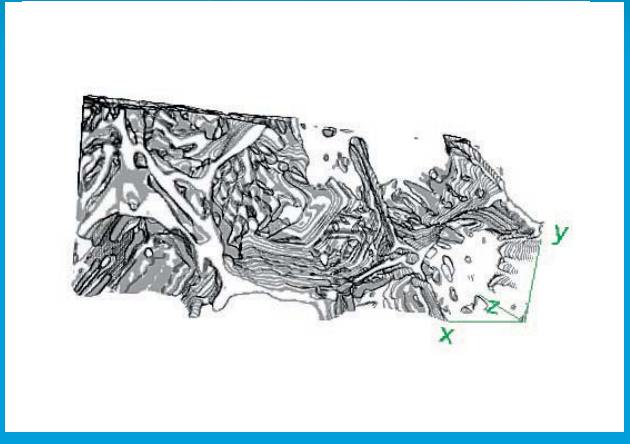
ATOMIC FORCE MICROSCOPE

This Dimension 3100 is a robust commercial setup from Bruker, which is used on a daily basis for investigating sample surfaces. The AFM supports the following operation modes: contact, tapping, magnetic, fluid. It is therefore possible to investigate a broad range of samples for topography, friction and magnetic properties.

Bildunterschrift

FOCUSED ION BEAM

The availability of a Focused Ion Beam workstation is increasingly considered a key factor for enabling cutting-edge research in materials science. The Institute I is currently operating two such devices. Next to the Zeiss Crossbeam 1540 which is in operation since 2006, a state-of-the-art Helios NanoLab 600i has been commissioned end of 2012 and is operated in share with our parners at the ZMP. This device is not only equipped with a powerful gallium ion gun aimed at structuring samples, but also with a broad combination of analytical detectors such as EDS, EBSD and even STEM. Basically every project at the Institute I relies on these devices for material characterization. They also allow the fabrication of miniaturized samples required for novel micromechanical testing methods or 3D tomographic reconstructions.

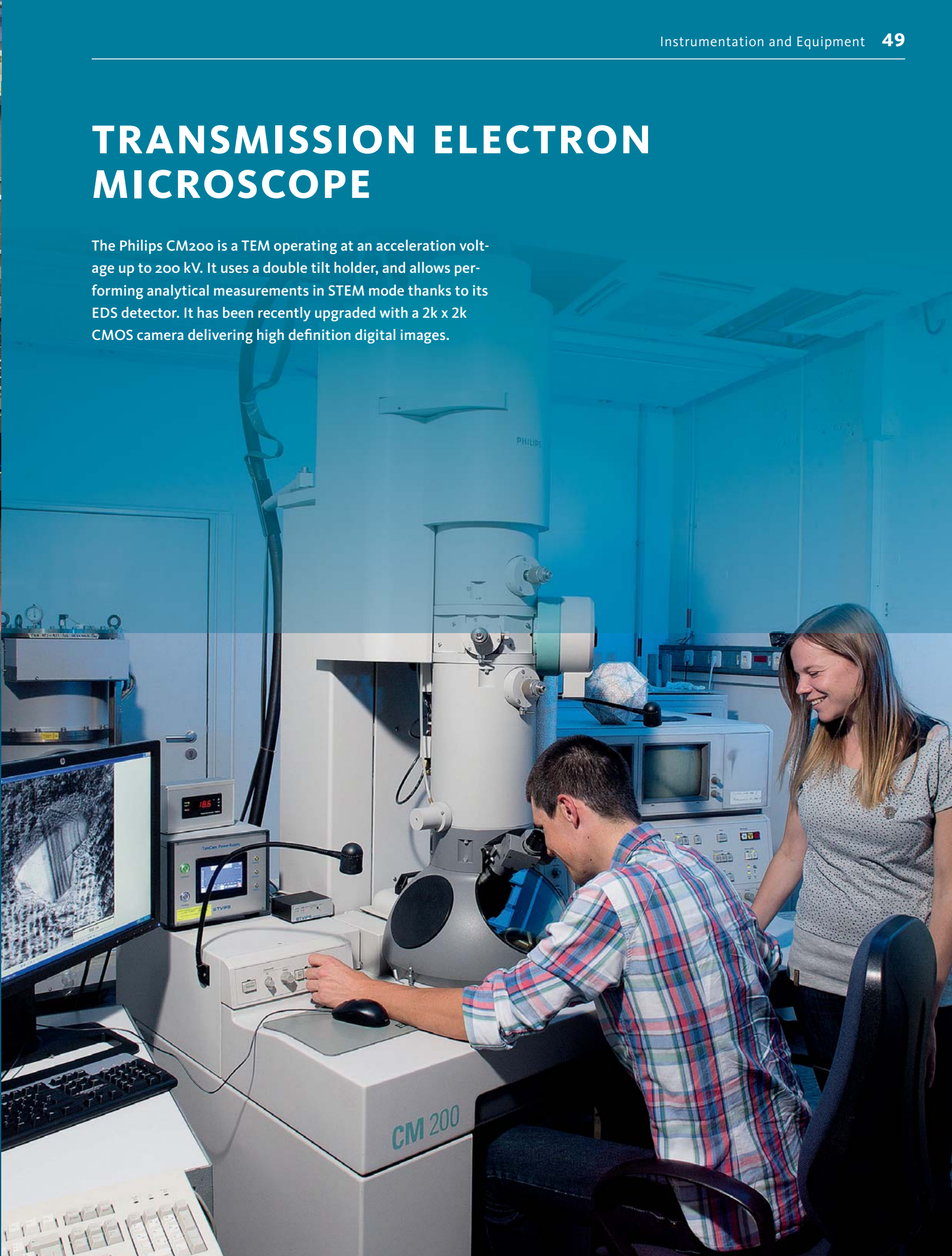


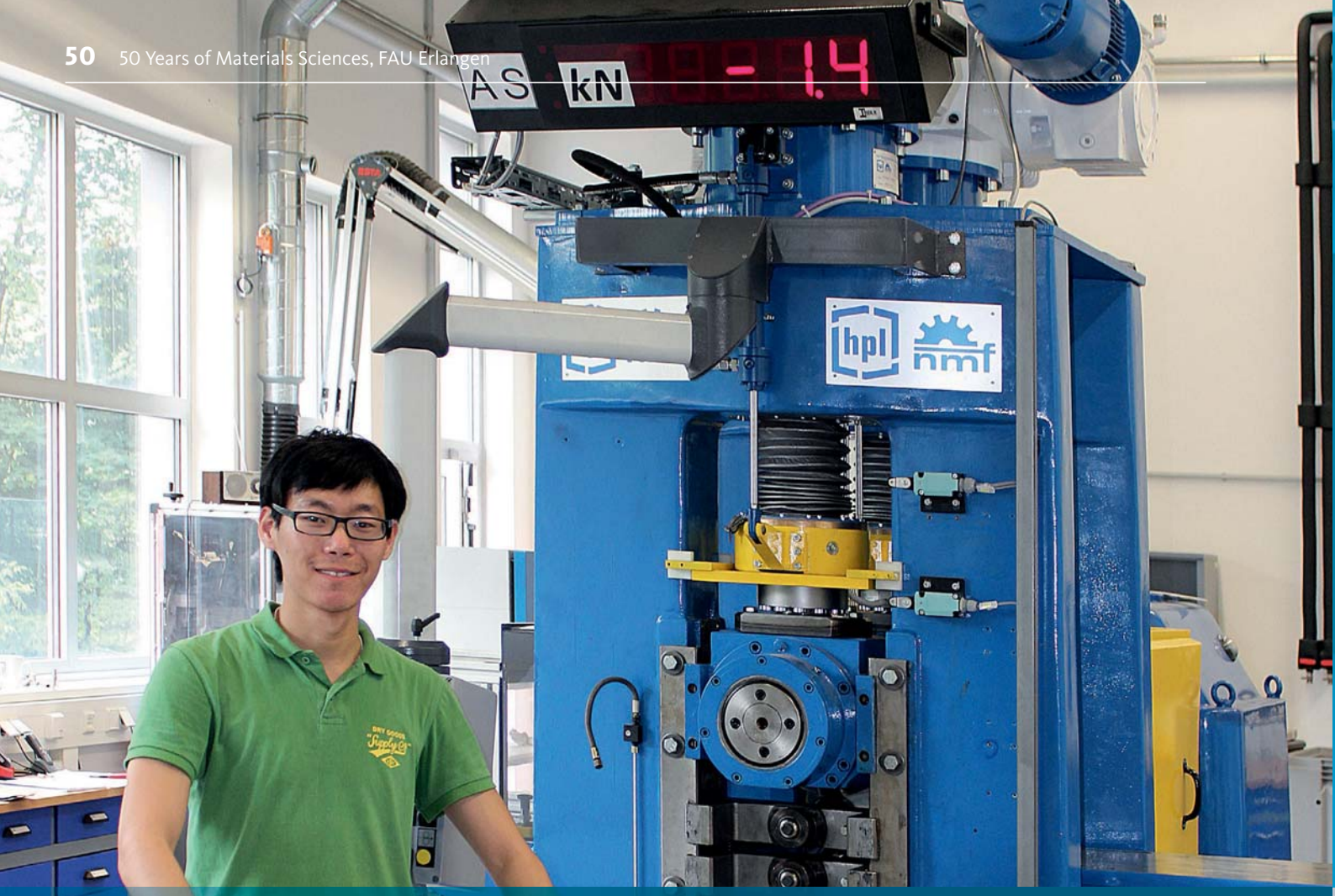
LARGE CHAMBER SCANNING ELECTRON MICROSCOPE

The large chamber SEM is a unique instrument that has been operated in Fürth since 2006 and continually optimized since. The remarkable 2 m^3 chamber is large enough to fit a full size servohydraulic machine inside it. The newly redesigned electron gun assembly offers a lot of flexibility to inspect samples from every possible angle. It also combines several analytical detectors, such as EDS and BSD. Currently, the large chamber SEM is used for in-situ fatigue tests, as well as interrupted monitoring of large industrial components.

TRANSMISSION ELECTRON MICROSCOPE

The Philips CM200 is a TEM operating at an acceleration voltage up to 200 kV. It uses a double tilt holder, and allows performing analytical measurements in STEM mode thanks to its EDS detector. It has been recently upgraded with a 2k x 2k CMOS camera delivering high definition digital images.





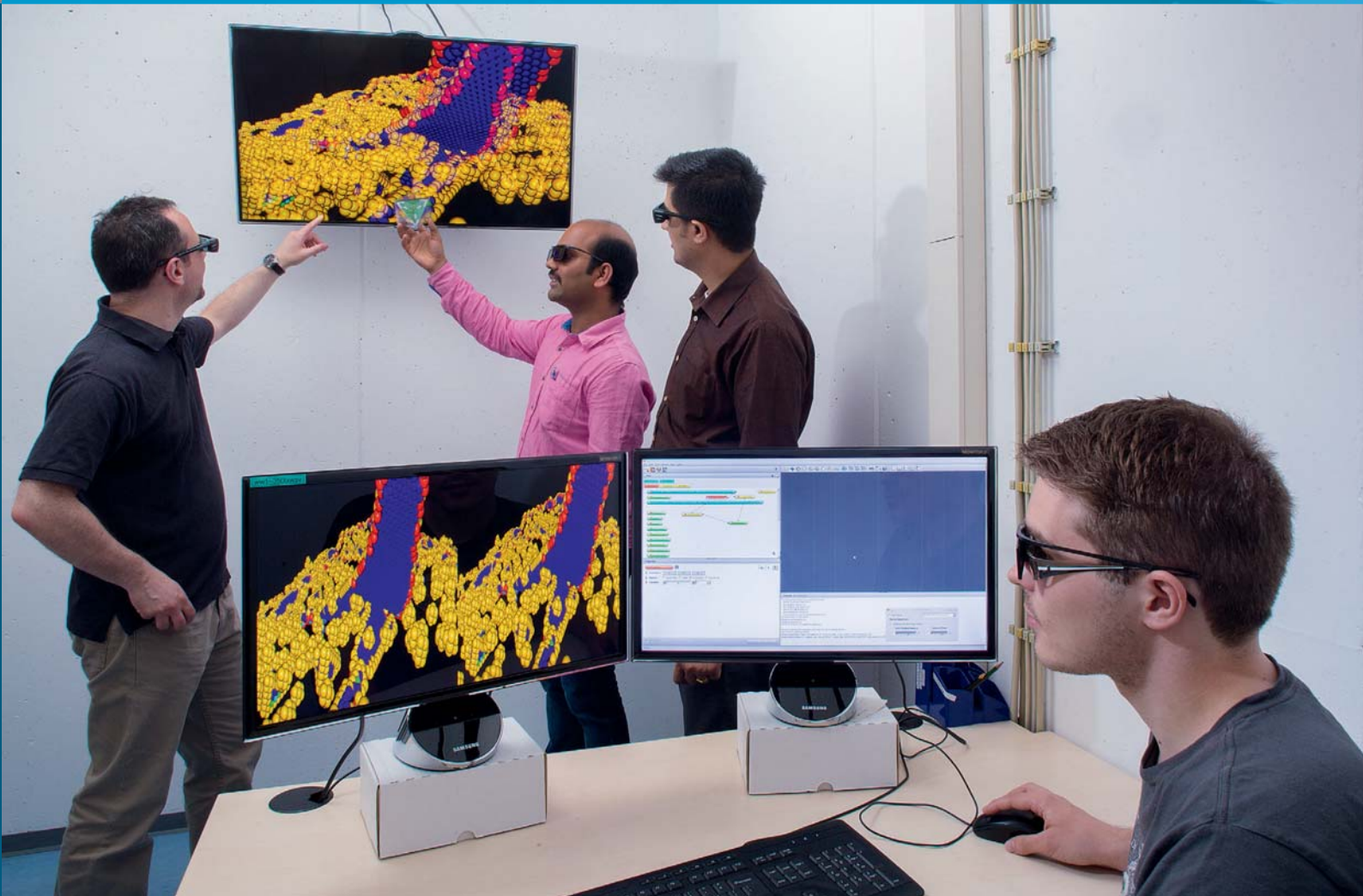
PROCESSING NANOMATERIALS BY ACCUMULATIVE ROLL BONDING

The rolling mill is based on a quarto roll stand from Carl Wezel which was modernized in 2012 by hpl Neugnadenfelder Maschinenfabrik GmbH. It is used to perform the Accumulative Roll Bonding of metallic sheets as broad as 250 mm. The rolling mill is currently intensively used for the production of tailored sheet materials with ultrafine-grained microstructure. Unprecedented mechanical properties are also obtained through particle reinforcement and the combination of different materials into a laminate structure.

HIGH PERFORMANCE COMPUTING AND VISUALIZATION

The simulation group at Institute I uses high performance workstations for the visualization and analysis of massively parallel molecular dynamic simulations, which typically involve hundreds of millions of atoms. The workstations are equipped with 128 GB RAM, 20 TB hard disk space and high-end graphics cards with 4 GB internal memory. One of the workstations in housed in the visualization room, which facilitates the visualization of atomistic simulations on high resolution monitors and a broad screen with 3D capability. A second machine is dedicated for remote visualization and analysis over the network.

The Institute I has also contributed to the high performance compute clusters “Lima” and “Emmy” at the regional computing center RRZE, which have a combined performance of about 300 TFlop/s. The Modelling and Simulation Group of Institute I is one of the top 10 users of these facilities.



HISTORY AND DEVELOPMENT

1965

HISTORICAL DEVELOPMENT

Historical Development of the Institute I and the Department of Materials Science & Engineering

1965 began the history of Materials Science in Erlangen in the Egerlandstraße 3 in a low-rise building with Prof. Dr. rer. nat. Bernhard Ilschner, who was appointed on 9th August 1965 as the first Chair for Materials Science & Engineering in Erlangen. Bernhard Ilschner, who studied metal physics at the prestigious Institute of Prof. Peter Haasen at the University of Göttingen, became the second professor of the new Technical Faculty in Erlangen, which officially was founded only in 1966. At that time the term "Werkstoffwissenschaften" was not commonly known or even used in Germany, but there have been some archetypes in the USA called Materials Science & Engineering. Thus, the Institute I can be regarded as one of the nuclei of Materials Science and Engineering in Germany. Institute I was the first of originally planned six Institutes within the Department of Materials Science & Engineering, MSE. In March 1966 the Institute of Metals and Technology has opened and Prof. U. Zwicker was appointed Head of the Institute. In February 1968 the Institute "Glas and Ceramics" (Head: Prof. H. Oel) followed. The Institute IV (Corrosion and Surface Science, Prof. H. Kaesche) was founded in September 1970, followed by the Institute "Polymeric Materials" (Prof. F. Schwarzl). The planned structure of the Department has been finalized in October 1974, when the Institute "Materials for Electrical Engineering" (Prof. H. Weiss) was established. On the occasion of the 10th anniversary of the Institute I Prof. Ilschner stated in 1975 that "the Institute I feels fit as a fiddle in the group of 6 chairs of the Department with which a so gratifying collegial, uncomplicated relationship has developed". Not only was the Department rapidly growing during that time, but also the Faculty with the departments Chemical Engineering, Electrical Engineering, Computer Science and later on starting in 1982 also with Mechanical Engieering.

Head of the Chair for General Materials Properties, Institute I
Prof. B. Ilschner (middle) 1965 – 1982
Prof. H, Mughrabi (left) 1984 – 2002
Prof. M. Göken (right) since 2002

Foundation stone of the new building Martensstraße 5

The early years of the Institute I in Egerlandstraße 3. It is noteworthy that there were students who drove up in a Porsche.

During the first years after its establishment, the Institute I resided in a low-rise building in Egerlandstraße 3. Together with the Institute of Technology of Metals, Prof. U. Zwicker, they were both able to make wide on 250 m² each. One of the first team-building measures was the clearance of rubble from the laboratories. The new subject was very attractive and first students changed their subject from physics or chemistry to materials science. Thus, in 1971 an apartment in the Liegnitzerstraße was rented in order to provide additional space for new experimental equipment. However, the electrical infrastructure of the apartment was not designed for running creep experiments at temperatures of 1000°C and above. Therefore, one eagerly awaited the completion of the new building.

With the establishment of the Technical Faculty (TF) in 1966 it was decided to build up a new campus in the south of Erlangen, called as "Südgelände", which was planned to be the home of all the new institutes of the TF. In this course, the foundation stone for the materials science building was laid in summer 1969.

Friedrich-Alexander-Universität
Erlangen – Nürnberg
Fachbereich Werkstoffwissenschaften
Institute I – VI
Erster Bauabschnitt Institute I – III
Institut I Allg. Stoffeigenschaften
Institut II Metalle
Institut III Keramik und Glas
Grundsteinlegung am 14. VIII 1969

Inscription of the foundation stone

F. Pschenitzka at the construction site of the new building of the Institute.

Prof. Bernhard Ilschner (1928 – 2006) in front of the new building

One of the first students of Prof. Ilschner was F. Pschenitzka, who studied physics in Erlangen and decided to choose Materials Science as his minor subject. After he has finished his Diploma thesis he was asked by Prof. Ilschner whether he would like to start to work at the Institute I. During these exciting initial years of settling of the Institute F. Pschenitzka took over many organizational and administrative tasks at the Institute.

1972 had come and after a fierce battle for the limited number of desks, the Institute was able on the October 20th to spread over 1,500 m².

In reminiscence to that event the second image shows the leading team of Institute I at the same place but 43 years later.

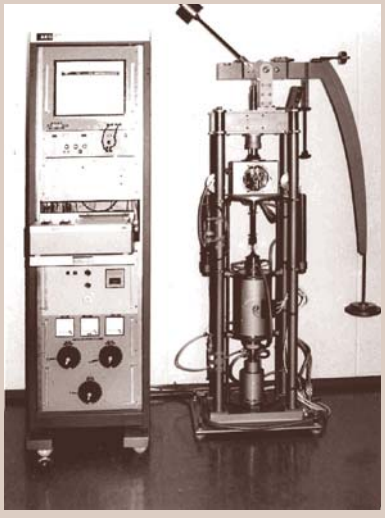
PROF. B. ILSCHNER
1965 – 1982
PROF. H. MUGHRABI
1984 – 2002
PROF. M. GÖKEN
SINCE 2002

Opening of the new building in Martensstr. 5 on October, 20th, 1972. From left to right: Fuchs, Knoch, Hübner, Hofmann, Ilschner, Hering, Schmidt-Whitley, Betz, Soschinska, Finkelnburg (hidden), Schuh, Schmidt, Forschauer, Reppich, Haußelt (hidden), Streb, Hüther, Schneider, Blum, Schneibel.

20.X.1972

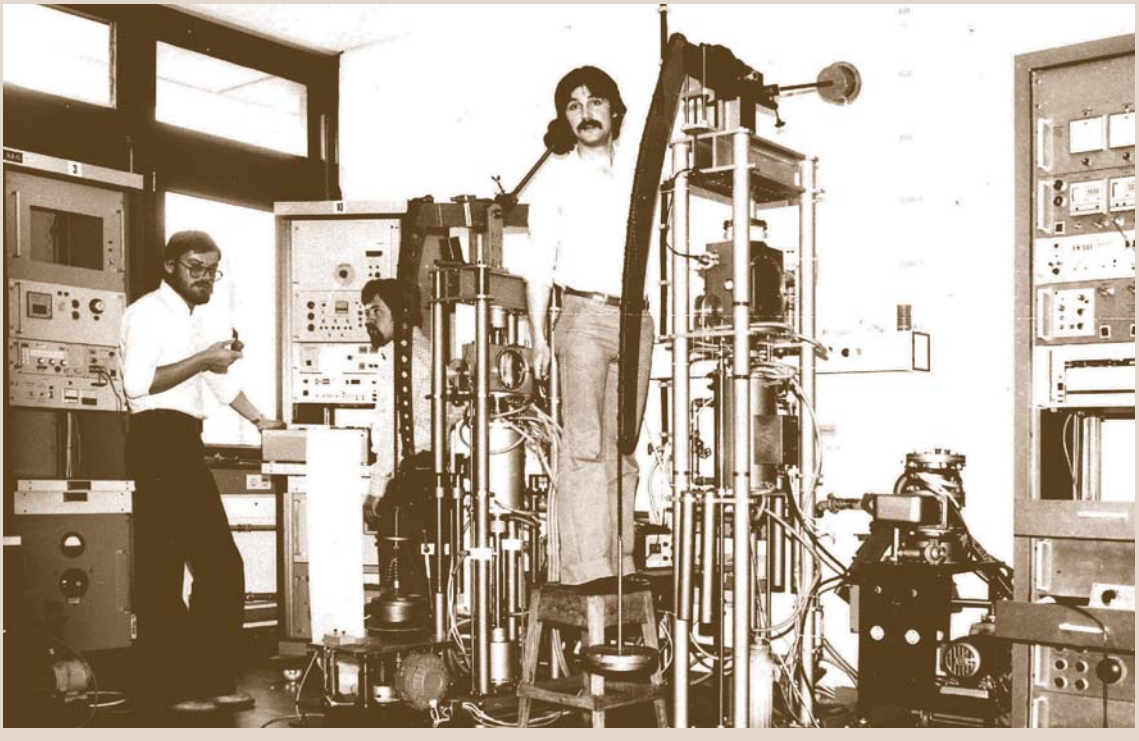
43 YEARS LATER

Institutional Board "Leitungskreis" of Institute I with Prof. Mughrabi in reminiscence to the opening picture of the New Building, October 1972 – October 2015. (From left to right: Neumeier, Mughrabi, Höppel, Amberger, Göken, Prakash, Felfer, Bitzek, Merle).



One of the first (self constructed) machines for creep tests under constant stress at Institute I.

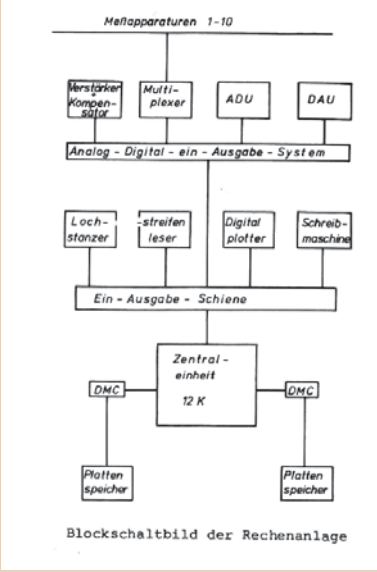
It was also clear that the new Institute with its direction towards materials science and engineering has to find a place in academia and also in economy. Ilschner stated in 1969 that one major goal of materials science in Erlangen is to bring together technology with physics and chemistry. This statement is still valid today, although materials have changed significantly. The inaugural lecture of Prof. Ilschner was titled "Werkstoffe der Technik als Aufgabe der Wissenschaft" (Technological materials: a challenge for science). From the beginning the main research activities of the Institute, then as now, were focused on the microstructure-property correlations of materials and material systems. Research activities at the Institute I were characterized in 1965 by two main directions: 1) The role of vacancies on the creep properties of NaCl-ioncristals and 2) The role of precipitates on the creep behavior of metals, including nucleation and ageing processes. In parallel, they started to build up their own creep machines, as well as techniques for microstructural analysis were established.



Engel, Freimann and Schepp working in the creep lab

Since 1968 the role of subgrains on the one hand and the role of complex vacancy and foreign atom clusters on the other hand turn more and more into focus. The groups of Prof. Blum and Prof. Reppich established during that time. It also became evident that research no longer only focused on academic model materials, like NaCl LiF, or pure iron, but then also addressed aspects for technologically more relevant material systems, like Al alloys, steels, etc. In parallel Prof. Heimendahl, who came from Clausthal introduced the very important new field of transmission electron microscopy in Erlangen. Consequently, the groups of Prof. Reppich and Prof. Blum rather quickly took advantage from the newly introduced method and applied the new technique to their particular scientific questions. Thus, understanding creep processes from a microstructural point of view (also in multiphase alloys) and particle/precipitation hardening mechanisms turned into focus. Besides the mechanical/microstructural topics thermodynamics became also of interest. In 1971 Prof. Sockel came from Clausthal to Erlangen in order to intensify the research activities in the field of thermodynamics and kinetics of phase transformations. The main activities in this field were put on disordering phenomena in crystalline silicates. In 1972 the group of Dr. Hübner has settled with a focus on fracture mechanics and fracture related phenomena under different loading conditions and at various temperatures. Besides the fundamental questions on academic materials also more application-related questions of alloy development and the impact of process parameters on the material component properties turned into focus in parallel with the growth of the Institute. In particular, the development of a mechanisms based understanding of material behavior in a wide variety of loading conditions and, derived therefrom, a targeted improvement of materials and material systems, built up expertise of the Institute over the years.

In 1972 Prof. Ilschner was appointed as “Rektor” (president) of the FAU. As a consequence he became rather occupied with other obligations and thus his daily attendance at the Institute was strongly reduced to normally two hours in the morning. To countervail these strong limitations and to keep the different groups within the Institute together it was decided to introduce a retreat symposium (“Konzentrationstage”). The intention of this Symposium, which was held for the first time at the Bernhardshöhe in 1972, was that all researchers of the Institute come together for three days to discuss intensively their newest results. The positive effect of this Symposium was very impressive and it was decided to keep this activity. Up to now, the spirit of this Symposium is still vital and we are very glad that we just organized the 42th Retreat Symposium, held again in the Bavarian Woods, now in Sattelbogen. In 1982 Prof. Ilschner received an attractive call to build up a new institute in Lausanne and finally decided to leave the FAU and to move to Lausanne.



Block diagram of the interaction between the creep machines and the first Honeywell H-316 computer

F. Pschenitzka and G. Freimann in front of the workstation

In 1984, Prof. Dr. rer. nat. Haël Mughrabi, who came from the Max Planck Institute of Metal Physics in Stuttgart, took over the Chair of the Institute. The research priorities in the field of strength of materials and their microstructures, including the underlying deformation mechanisms, were continued and new topics, such as crystal plasticity, composite model based prediction of the mechanical properties by the underlying dislocation arrangements, fatigue properties and cyclic deformation mechanisms were started. Thus, a research group on fatigue properties of metallic materials was established and two servohydraulic MTS- and one electro-mechanical Schenck-Trebel testing machines were installed. Besides the studies on simple model materials (Cu, Al, -brass) also technologically more important materials like various steels, aluminum alloys and Nickel-based superalloys turned into focus. With the beginning of the new millennium also ultra-fine grained materials have been fatigued. The focus of research still remained on the microstructure-properties correlation of crystalline materials, the qualitative and also quantitative analysis of the dislocations – microstructure interactions became even more prominent. Hence, new X-ray equipment was built up and new methods like the rocking curve analysis were established. On the other hand electron microscopy turns to become more and more to the workhorse in microstructure analysis. Thus, in 1991 a Jeol JSM 6400 Scanning electron microcops, SEM (later equipped with EDS (1997) and EBSD (1994) was established at the Institute. In parallel, the Philips EM 300 was replaced in 1997 by the CM200T and advanced TEM methods, like CBED, were introduced. During the second half of the 1990s digitalization developed to one of the key issues at the Institute. Thanks to the input of F. Pschenitzka supported by G. Freimann, the Institute already started in 1972 (!) with the first digitalization of experimental creep data, see the block diagram of the interaction between the creep machines and the first Honeywell H-316 computer.

During the 80's a UNIX-server was established and several workstations have been intensively used for computing various experimental data. However, it took almost until the mid of the 90s, when personal computers became more and more affordable and PC-networks reasonable in administration, that the digitalization area swept through the Institute. PCs were installed in almost every desktop, a Windows for workgroups network was settled and operated by some PhD-students and digital data acquisition systems were introduced. Over the time the network-infrastructure was expanded together with the RRZE and modernized forming nowadays the backbone of fast high-capacity networking, which is most relevant for the High Performance Computing (HPC) activities.

1985

In 2002 Prof. Mughrabi retired and Prof. Dr. rer. nat. Mathias Göken, was appointed professor. Prof. Göken previously worked for several years at the Max Planck Institute for Iron Research in Düsseldorf and at the University of Saarland. Prof. Göken kept the well-established topics, added the new field of nano mechanics and intensified the research in the field of nanocrystalline materials. Atomic Force Microscopy and nanoindentation have been introduced and the metallographic lab, the Instron tensile testing and MTS fatigue machines have been modernized. In 2006 a Zeiss dual-beam Focused Ion Beam (FIB) microscope was acquired, a technique which developed to a workhorse in the field of microstructural characterization due to its capability of targeted investigation of structures down to the nanometer scale. One year earlier, the worldwide unique Large Chamber-SEM (LC-SEM) with an integrated servohydraulic test-rig was built up at the ZMP, at Uferstadt, Fürth. However, as this microscope exhibits a couple of growing pains it took another 4 years and additional money from the DFG and also from the Institute to eliminate these difficulties. Nowadays, this microscope provides excellent possibilities for in-situ testing and investigation of large parts. In 2013 the Institute also acquired new space at Technikum 2, Uferstadt, Fürth. In addition to some office space, the X-ray equipment was established there and the new technological hall of InstituteI was filled up with two mills, which are used for producing nanocrystalline sheet materials (Nanometals) by using the accumulative roll bonding process. In 2015, the latest equipment was acquired, which again strengthens the possibilities of the Institute in the field of microstructural characterization. The Atom Probe Microscope Leap 4000 (APT) allows detecting and visualizing atomic arrangements of materials, opening new possibilities to understand basic mechanisms like nucleation processes or grain or phase boundary segregations in depth. All the new equipment and fields of activities combined with the well-established topics and experimental techniques led to a further thematic broadening the Institute, which enables the Institute nowadays to cover mechanical properties and microstructure related deformation mechanisms on different length scales.

Prof. Göken took over the key to the Institute I from Prof. Mughrabi at the Sattelbogen symposium in October 2002.

2002

Prof. Göken is explaining Dr. T. Jung, the mayor of Fürth, the accumulative roll bonding process during the official opening of the new facilities for Nanometals in Fürth on the 6th February 2014.

Also the structure of the permanent staff significantly changes during the years. Since the mid of the 90ties many technicians, like W. Teichmann, H. Steinbrecher, Schneiderhahn, G. Freimann, K. Eckert, have been retired without any replacement. Thus the remaining technicians have had to bury additional loads. In parallel the equipment proliferated which also leads to the consequence that the PhD-students have to take over further responsibility for the technological equipment. Besides, also many changes in the field of the academics took place. When Prof. Mughrabi took over the chair almost all permanent academic positions were fixed for many years. Only the position of the professorship in electron microscopy was open. In 1986 Prof. K. Urban was appointed as the successor to Prof. Heimendahl who retired in 1983. Unfortunately, Prof. Urban, who is today well-known as one of the fathers of aberration corrected TEM, left the Institute almost 1 year later and took up a position at the Helmholtz research center in Jülich. In 1999 H.W. Höppel was appointed to a permanent position as designated successor of F. Pschenitzka, who retired in 2004. In the year before Prof. B. Reppich and Prof. H.-G. Sockel retired. Prof. W. Blum followed in 2005. Only the position of Prof. Blum could be replaced. Prof. Göken used the chance to broaden the activities at the Institute with the field of molecular and discrete dislocation dynamics. Thus, Prof. A. Hartmaier was appointed in 2005. In 2009 he left the Institute and took over a Chair position at the ICAMS in Bochum. Prof. E. Bitzek followed him, now focusing more on atomistic simulations. In 2010 a new junior-professorship position was funded in the framework of the Cluster of Excellence of Advanced Materials (EAM) and was appointed to Sandra Korte, who came from Cambridge to Erlangen. Prof. Korte laid her focus on small-scale plasticity and related deformation mechanisms. In 2013 she was appointed as the successor to Prof. Gottstein at the Institute IMM at the RWTH Aachen. In parallel also Dr. Karsten Durst was offered a W3-professorship at the TU Darmstadt, which was of course a big loss for the Institute, but on the other hand clearly showing how successful the Institute was running. In July 2015 the microscopic facilities of the institute could be expanded with an Atom Probe Tomographe, APT, which allows chemical analysis with highest lateal resolution. With roughly 2.5 Mio € this instrument became the highest financial investment of the Chair and we are most thankful to the cluster of excellence and the DFG for funding. With the new APT instrument it appeared to be demanding to establish a new group which focuses on the methodology of APT analysis. Thus, Dr. Peter Felfer, who worked for many years in Sydney, Australia, was appointed as a new junior professor in 2015. As with Prof. Korte this position is funded from the Cluster of Excellence as a tenure-track professorship and we hope that Prof. Felfer will also find a good basis for excellent research in Erlangen.

Parallel with the growth of the Institute I also the whole Department of Materials Science showed a strong development and today the Department consists of 9 different Chairs. The first development period was finished in 1974. However already in 1989 a new Chair for Microcharacterization was founded and Prof. Horst Strunk († 2015) came from Stuttgart to Erlangen. After his retirement in 2009, this chair has been reoriented to Biomaterials research by Prof. Aldo Boccacini, to complement the already existing teaching subject of Materials for Medicine. During the growth period due to the shortening of the highschool education by one year a new Chair for Materials Simulation could be established (Prof. M. Zaiser) and this Chair is situated in the Technikum II in Fürth and with this Fürth eventually became a University town. In 2014 the group for electron microscopy (Prof. Erdmann Spiecker) which so far still belonged to the Chair 7 became an independent Chair again, so that the Department now has 9 Chairs and 17 professors. The department covers more or less all aspects of materials science and engineering and became one of the major places for materials in Germany.

Inauguration of the new Technikum II building in Fürth

The strong increase in the number of students by the new programs of nanotechnology, MAP etc. and the shortening of the highschool education by one year in Bavaria made it necessary to restructure some rooms and build a bigger lecture hall in the department. In 2010 the former library has been integrated into the library of the Technical Faculty and in this rooms a new lecture hall has been built, which in honor of the founder of our department has been named Bernhard Ilschner lecture hall.

The Professors of the Department Materials Science and Engineering from 2001 (from left to right: Blum, Sockel, Roosen, Reppich, Strunk, Mughrabi, Greil, Müller, Singer, Münstedt, Schmuki, Weissmann, Winnacker)

Another important milestone of the department was the establishment of a new campus on the former Grundig areal in the "Uferstadt" Fürth, where today the Neue Materialien Fürth GmbH, NMF, the Zentralinstitut für neue Materialien und Prozesstechnik, ZMP and also several working groups of the Department are situated. Only here the needed room for the strong expansion of the Department could be satisfied. In 2010 the Energiecampus has been founded close to the Uferstadt on the former AEG area and in 2014 the Helmholtz-Institut Erlangen-Nürnberg, HI ERN which focuses on materials for renewable energy technology has been initiated with strong contributions from the MSE department. For HI ERN institute a new building is planned in direct neighboorhood to the MSE buildings on the southcampus Erlangen. Also the Bavarian Center for Applied Energy Research (ZAE Bayern), headed now by Prof. C. Brabec (Chair 6), became a new building in 2012 close to MSE on the Haberstrasse.

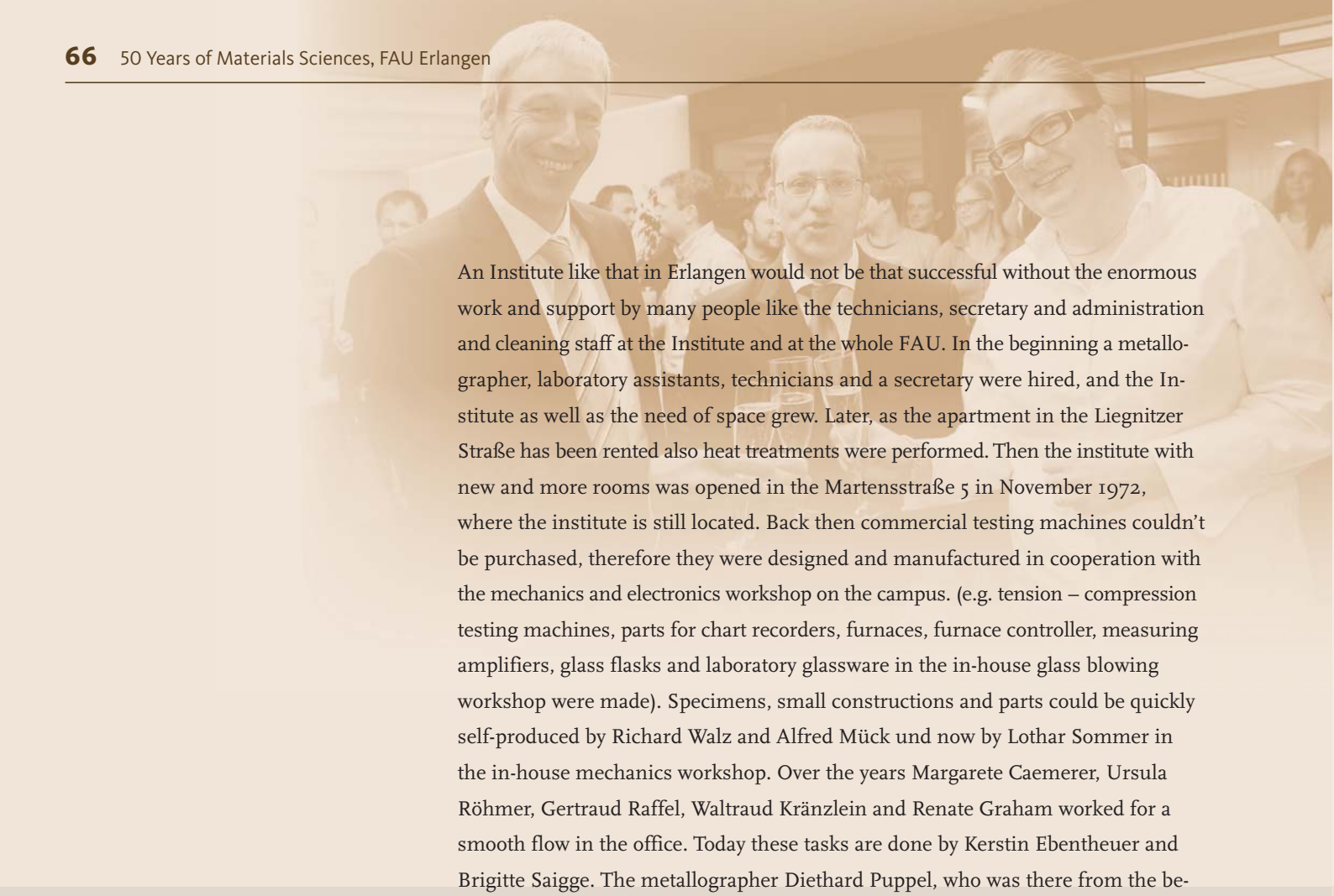
Furthermore very important for the Institute I was the establishment of a new central organization for microstructural characterization of materials, the Center for Nanoanalysis and Electron Microscopy, CENEM. This has been founded in 2010 in the framework of the cluster of excellence by Prof. Göken and now several professors are involved in the CENEM.

PROFESSORS, STAFF AND TECHNICIANS AT THE INSTITUTE I

Up to now 12 professors have been working at the institute over the fifty years. They have been supported by several staff scientists. Furthermore two honorary professors (Prof. Tenckhoff, Prof. Weidinger) have supported the teaching duties.

In 2014 Dr. Peter Weidinger, who is employed at Brose, Coburg was awarded the title of a honorary professor from the Technical Faculty by the dean Prof. Marion Merklein. Prof. Weidinger supports the teaching and research activities at the Chair already since 2003 by his well received lectures from the industrial perspective.

Name	Function	Period
Prof. Bernhard Ilschner	Chair Professor	1965 – 1982
Prof. Bernd Reppich	Professor	1966 – 2002
Prof. Manfred von Heimendahl	Professor	1967 – 1982
Prof. Wolfgang Blum	Professor	1969 – 2005
Prof. Hans-Georg Sockel	Professor (APL, Oberingenieur)	1973 – 2003
Prof. Haël Mughrabi	Chair Professor	1984 – 2002
Prof. Knut Urban	Professor	1986 – 1987
Prof. Mathias Göken	Chair Professor	since 2002
Prof. Alexander Hartmaier	Professor	2005 – 2008
Prof. Sandra Korte-Kerzel	Junior Professor	2011 – 2013
Prof. Erik Bitzek	Junior Professor	since 2009
Prof. Peter Felfer	Junior Professor	since 2015



An Institute like that in Erlangen would not be that successful without the enormous work and support by many people like the technicians, secretary and administration and cleaning staff at the Institute and at the whole FAU. In the beginning a metallographer, laboratory assistants, technicians and a secretary were hired, and the Institute as well as the need of space grew. Later, as the apartment in the Liegnitzer Straße has been rented also heat treatments were performed. Then the institute with new and more rooms was opened in the Martensstraße 5 in November 1972, where the institute is still located. Back then commercial testing machines couldn't be purchased, therefore they were designed and manufactured in cooperation with the mechanics and electronics workshop on the campus. (e.g. tension – compression testing machines, parts for chart recorders, furnaces, furnace controller, measuring amplifiers, glass flasks and laboratory glassware in the in-house glass blowing workshop were made). Specimens, small constructions and parts could be quickly self-produced by Richard Walz and Alfred Mück und now by Lothar Sommer in the in-house mechanics workshop. Over the years Margarete Caemerer, Ursula Röhmer, Gertraud Raffel, Waltraud Kränzlein and Renate Graham worked for a smooth flow in the office. Today these tasks are done by Kerstin Ebentheuer and Brigitte Saigge. The metallographer Diethard Puppel, who was there from the beginning, later supervised our first transmission electron microscope. The metallography was reinforced by Waltraut Teichmann who also made all photo prints. A great support of the institute was Horst Steinbrecher. Later he headed the internships. The two Instron – tension and compression – testing machines were built up and overseen by Bernhard Kummer. Now it´s the task of Wolfgang Maier. Karl Eckert was in charge of the MTS testing machines and was able to adapt with many detail improvements the devices to the users' needs. Now Jonas Harrer is taking over the responsibility for the MTs machines. Friedrich Pschenitzka and Günther Freimann established the electronic data processing, initially with punch cards, at the department in the 80s. G. Freimann and later BerndHässler operated the ultrasonic testing machines for measureing Young's modulus up to very high temperatures, which is still an important task. Ingrit Lutz handled over the years the X-ray equipment. Our scanning electron microscope was operated by Christa Koch and Anneliese Weiß. Now the metallography is directed by Richard Kosmala and Christina Hasenest.

In general the very good working atmosphere at the institute during the periods of all three heads of the institute created an ideal environment for work and research.

Dr. Peter Weidinger awarded the title of a honorary professor. (From left to right: M. Göken, P. Weidinger, M. Merklein)

Retiremnet of R. Graham and A. Weiß

PERMANENT STAFF WORKING AT THE INSTITUTE

Axel Fuchs
Research Assistant

Heinz Hübner
Research Assistant

Dirk Uelze
Research Assistant

Bernd Reppich
Research Assistant

Wolfgang Blum
Research Assistant

Wolfgang Betz
Research Assistant

Hans-Georg Sockel
Research Assistant

Friederich Pschenitzka
Research Assistant (1972 – 2004)

Horst Biermann
Research Assistant

Florian Pyczak
Research Assistant

Rebecca Janisch
Research Assistant

Hans-Jürgen Christ
Research Assistant

Stefan Straub
Research Assistant

Hans-Jürgen Maier
Research Assistant

Martin Riemer
Research Assistant

Martin Heilmaier
Research Assistant

Gerald Hoffmann
Research Assistant

Philip Eisenlohr
Research Assistant

Dr. Karsten Durst
Research Assistant

Pavel Leiva-Ronda
Research Assistant

Margarete Caemerer
Secretary (1966 – 1981)

Diethard Puppel
Metallography (1966 – 2003)

Waltraud Teichmann
Metallography (1969 – 2001)

Horst Steinbrecher
Technician (1969 – 2002)

Ursula Röhmer
Secretary

Richard Walz
Technician (1971 – 1990)

Bernhard Kummer
Technician (1972 – 2008)

Ingrit Lutz
Technician (1972 – 2009)

Alexander Wagner
Technician (1973 – 1987)

Alfred Mück
Technician (1974 – 1996)

Günther Freimann
Technician (1974 – 2013)

Marianne Seeberger
Technician

Christel Schneiderhan
Technician (1977 – 1994)

Gertraud Raffel
Secretary (1977 – 1996)

Karin Schuhmann
Technician (1979 – 1990)

Karl Eckert
Technician (1980 – 2009)

Waltraud Kränzlein
Secretary (1981 – 2008)

Anneliese Weiß
Technician (1985 – 2011)

Christa Koch
Technician (1994 – 2008)

Franz Wissenz
Technician (1996 – 1998)

Renate Graham
Secretary (1996 – 2011)

Tobias Sommer
Apprentice (2005 – 2009)

Mathias Heil
Apprentice (2008 – 2012)

Julius Leisgang
Apprentice (2009 – 2013)

Bernd Hässler
Technician (2009 – 2014)

Tobias Hofmann
Apprentice (2010 – 2015)

Ingrid Schwarm
Apprentice

Doris Schönfeld
Apprentice

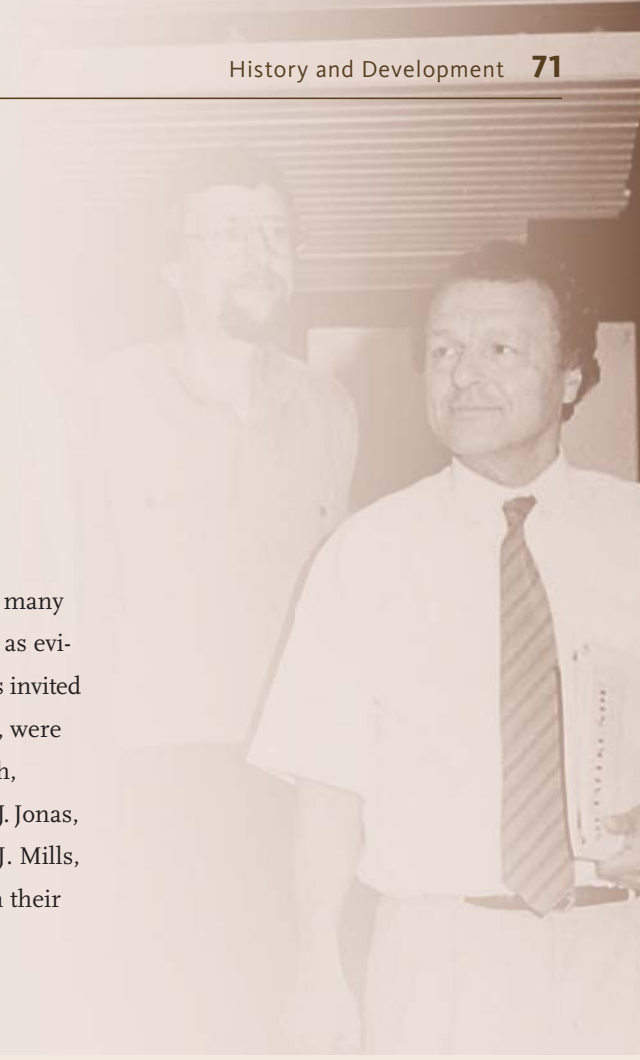
REMINISCENCES
HAËL MUGHRABI 1984 – 2002

THE BEGINNING

In 1982, Haël Mughrabi was offered the successorship to succeed Professor Bernhard Ilschner as Chair and Head of Institute I and as a member of the Board of Directors of the Institute of Materials Science. When he took office in 1984, he found a well-equipped laboratory, with international reputation in high-temperature mechanical properties, reflecting the pioneering research by Bernhard Ilschner himself and his group leaders, Professors Bernd Reppich and Wolfgang Blum. In addition, there was the group of Professor Hans-Georg Sockel whose research focused on topics in solid state thermodynamics and surface analysis. Fritz Pschenitzka, as "Akademischer Direktor", acted as a General Manager and took care of the administrative problems and was responsible for our HP 1000 computer.

RESEARCH

With the active support of Hans-Jürgen Christ who was just finishing his doctoral work and Karl Eckert, as a very capable technician, new equipment, mainly in the form of servohydraulic testing machines, was bought and installed, and very soon the first Diplom and Doctoral Theses were started. The main fields of research in the new research group centered around crystal plasticity and microstructure, and on the "new" subject of cyclic deformation and fatigue of metals and alloys. In addition, other studies were initiated, mainly in the area of high-temperature fatigue and creep of monocrystalline nickel-base superalloys. As more research proposals were granted, and after the equipment had been expanded by acquisition of new transmission and scanning electron microscopes and X-ray diffraction equipment, more demanding new studies became possible.



INTERNATIONAL CONTACTS

Research in Institute I was strongly influenced by fruitful interaction with many internationally well-known colleagues from Germany and other countries, as evidenced in the guestbook of Institute I. The lab hosted esteemed colleagues as invited speakers in their seminars and colloquia, among them, to name just a few, were K. A. Padmanabhan, A. K. Mukherjee, P. Haasen, K. Lücke, E. Macherauch, A. S. Argon, R. W. Balluffi, F. R. N. Nabarro, L. P. Kubin, H.J. McQueen, J. J. Jonas, J. Gil Sevillano, J.-L. Martin, A. Plumtree, C. Laird, E.W. Hart, T. Kahn, M. J. Mills, T. M. Pollock, T. Ungár, Z. G. Wang and many others as invited speakers in their seminars and colloquia.

THE RETREAT SYMPOSIA

These informal annual Symposia had traditionally been taking place for many years in the Sattelbogener Hof, hosted by the Mitterbiller family, in the Bavarian Woods, in a very pleasant rural environment. Most talks were given by the Diploma and Doctoral students – who also chaired most of the sessions – and by the professors (and usually a few invited colleagues). These impressive meetings were enriched by inspiring discussions and one longer hike with a beer after more than 10 km. Until 1996, German had been the language of these Symposia. In 1997, after a longer discussion, the Retreat Symposium was held test wise for the first time in English language. Only after everybody had witnessed the impressive performance of the young researchers, did English become the language of the Symposia. Since that time, the Retreat Symposia have the character of an international conference of high standard.

REMINISCENCES

H. Mughrabi, HW. Höppel, L. Schultz, H. Biermann, HG. Sockel

ACADEMIC HIGHLIGHTS

Habilitations

Hans-Jürgen Christ, 1990, Horst Biermann, 1999.

Professorships

Hans-Jürgen Christ, Horst Biermann and Hans-Jürgen Maier are now University Professors and Heads of Institutes. Berthold von Großmann, Joachim Hammer, Christof Sommer, Ulrich Tetzlaff and Simon Reichstein are now Professors at different Universities of Applied Science.

Awards

Hans-Jürgen Christ was the recipient of the Masing-Gedächtnis-Preis of the Deutsche Gesellschaft für Materialkunde (DGM), the German Society of Materials, in 1991. Hans-Georg Sockel was honored with the Tammann- Gedenkmünze of DGM in 1998. Haël Mughrabi received the Heyn-Denkmünze of DGM in 2000 and was named Honorary Member of DGM in 2008. In the same year the TMS Haël Mughrabi Honorary Symposium was held in New Orleans.

RESEARCH GRANT PROGRAMME "NEUE WERKSTOFFE IN BAYERN"

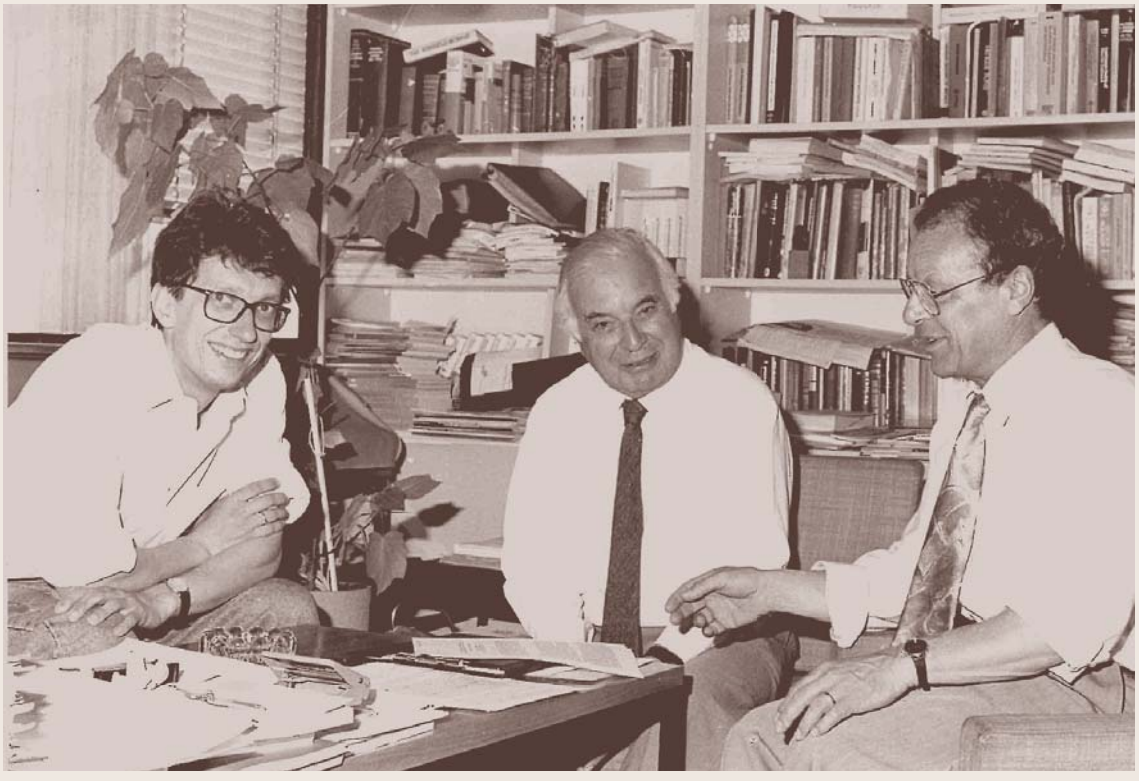
This big Bavarian Sponsorhip program of "New materials in Bavaria" was launched by the Ministry of Education in the nineties in close collaboration with Haël Mughrabi who chaired the local committee at Erlangen.

Deanship

Haël Mughrabi was Dean of the School of Engineering at University of Erlangen-Nürnberg from 1999 – 2001.

PLANNING FOR THE FUTURE, RETIREMENT IN 2002

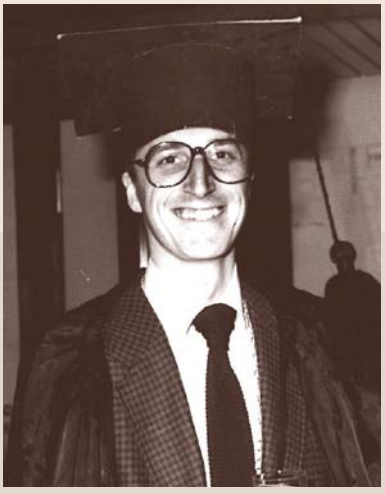
In the nineties, the laboratory had to be adjusted to upcoming new developments in computerization and digitalizing of equipment. In this situation, Heinz Werner Höppel, who was planning to leave for a responsible position in industry, played an outstanding role. His departure would have left a big gap. This prompted Haël Mughrabi, shortly before his retirement in 2002, to come to an agreement with the President of the University to offer Höppel a permanent position. In retrospect, Haël Mughrabi is proud of this achievement from which his successor Mathias Göken and Institute I have benefitted until today. Since his retirement in 2002, Haël Mughrabi still keeps an office, enjoys coming to the lab regularly and is grateful to Mathias Göken for his hospitality.



F. R. N. Nabarro (middle) visiting the Institute in 1995, H. Biermann (left) and H. Mughrabi (right)

DISSERTATIONS

Dissertation
of Wolfgang Blum



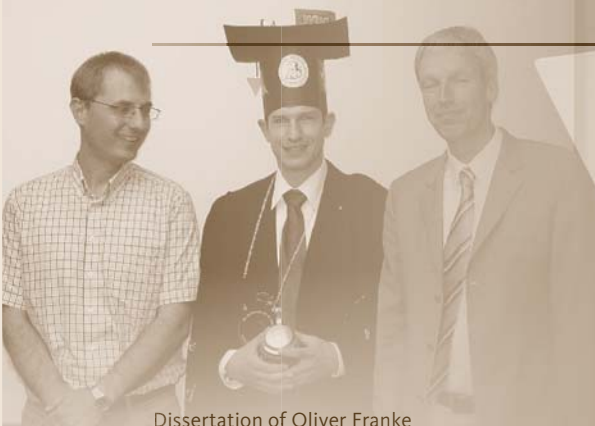
Dissertation of Robert Singer

Dissertation of Sigrid Schwub

Finishing a Dissertation is the most important milestone in the academic education and therefore celebrating this events has a long tradition at our Chair. Since 1965 in total 146 PhD students have finished their Dissertations with the oral exam. The first dissertation at the Chair in 1968 (only three years after founding of the institute) by Dierk Uelze was also the first dissertation of the newly established Faculty of Engineering. It took quite a while until women were also attracted for dissertation projects and the first female candidate Adelheid Jessen successfully finished her dissertation in 1981. Since then the percentage of women at the chair has increased constantly and nowadays around 20% of all PhD students are female.

In the beginning celebration of a new Doctor happened in a quite similar way as it had been the tradition in Göttingen, where Bernhard Ilschner came from. The new Doctors were carried to the Schloßplatz where they had to devote a gift to the University founders Friedrich and Alexander. But very soon a new tradition was established in Erlangen, the so called Burgers circuit, where the candidate had to surround the inner laboratory circle on our 3rd level with different vehicles. From this it is obvious that dislocations and their Burgers vector always had played a very important role in analysing material defects. The time needed for completing the Burgers circuit is always documented quite meticulously and has become the only official list of completed dissertations at the Institute. Since different vehicles such as flippers, bobby cars or even a motorbike are used for the Burgers circuit, the time for completing the circuit is obviously not a direct quality index for the dissertation. However, the entire *after-exam* event has been established as a nice tradition, where some light is shed on the more social or leisure activities and the personality of the new Doctor.

The new Doctors of course are always decorated with a nice doctoral cap and a traditional gown, where all Doctors embroider their name on. The first gown was used from the beginning until 2006 and is now displayed in the lobby of the Institute.



Dissertation of Oliver Franke

In the early years of the institute a Dissertation thesis could be really short, although the scientific value was quite good. The length of the thesis has, however, increased from a median of 35 pages to a maximum of 259 pages. This has of course to do with the introduction of word-processing systems and computers, which makes writing of a long thesis significantly easier. However since the maximum in the early 90s the length of the thesis decreased again slightly, which makes reading and focusing of a dissertation on the really new insights significantly better and easier.

Historical list of the famous Burgers circuit of the new Doctors at the Institute I

Dissertation of Ralf Webler

Dissertation of Irena Topic

Dissertation of Furqan Ahmed

Traditional doctor gown

DISSERTATIONS

1968

Dirk Uelze
Der Einfluß einer überlagerten Verformung auf die Ausscheidung von epsilon-Phase in einer Eisen-Molybdän-Legierung
24. 05. 1968, Ilschner

Fuchs, Axel
Das Kriechverhalten von Eisen-Molybdän-Mischkristallen im Temperaturbereich von 500°C bis 1000°C
19. 07. 1968, Ilschner

1969

Scheucher, Erwin
Rekristallisations-Kinetik von Kupfer im Bereich sehr kurzer Zeiten
12. 02. 1969, Ilschner

Blum, Wolfgang
Stationäre Verformung von polykristallinem Natriumchlorid
14. 02. 1969, Ilschner

1970

Hering, Wolfgang
Über die Diffusion im Dreistoffsystem $MgO\text{-}Fe_2O_3\text{-}Cr_2O_3$
28. 05. 1970, Ilschner

Reichel, Rudolf
Untersuchung des Einflusses der Übergangselemente Cr, Mn und Zr auf die Spannungsrißkorrosion von AlZnMgI-Legierungen
21. 12. 1970, Heimendahl

Schmidt, Horst Dieter
Der Einfluß von Legierungselementen auf die Raumtemperaturfestigkeit des polykristallinen Aluminiumoxids
16. 12. 1970, Ilschner

1971

Hübner, Heinz
Partikelwachstum und Kriechverhalten von feindispersen UO2/Mo-Cermets im Temperaturbereich von 1450°C bis 2000°C
13. 07. 1971, Ilschner

Betz, Wolfgang
Untersuchungen zur Warmverformung heterogener Eisen-Molybdän-Legierungen mit unterschiedlicher Ausscheidungsverteilung
20. 09. 1971, Ilschner

1972

Schneider, Klaus
Untersuchung des Ausscheidungsverhaltens einer technischen Al-Cu-Li-Legierung (Typ 2020)
25. 07. 1972, Heimendahl

Willig, Wolf-Rüdiger
Entwicklung und Untersuchung von Einkristallen aus stark absorbierenden Halbleiterwerkstoffen für die Gamma-Spektroskopie (PbO, PbJ2, HgJ2)
28. 07. 1972, Ilschner

Schmidt-Whitley, Robin
Einfluß von Form und Größe der Phasen auf das Kriechverhalten des $Al\text{-}CuAl_3$-Eutektikums
28. 07. 1972, Ilschner

Froschauer, Leonhard
Mechanische Eigenschaften eines zweiphasigen Systems Glas – Keramik bei höheren Temperaturen
28. 12. 1972, Ilschner

1973

Schuh, Frieder
Die Ausbildung der Versetzungsstruktur und deren Beziehungen zum Verformungsverhalten in Aluminium
11. 07. 1973, Heimendahl/Ilschner

1975

Haußelt, Jürgen
Erholungsverhalten der Versetzungsstruktur nach stationärer Verformung am Beispiel der Legierung Al-11 Gew. % Zn
22. 07. 1975, Ilschner

Knoch, Heiner
Das Kriechverhalten von ein- und zweiphasigem Magnesiumoxid mit hohen Eisengehalten
21. 08. 1975, Ilschner

Hüther, Werner
Ordnungshärtung und Orowanprozess im einkristallinen System MgO-Fe_2O_3
18. 12. 1975, Reppich

1978

Strobl, Walter
Modelluntersuchungen zur Faserverstärkung keramischer Werkstoffe
25. 04. 1978, Ilschner

Streb, Günther
Das Kriechverhalten von polykristallinem Fe_2SiO_4 bei hohen Temperaturen
25.04.1978, Sockel

Singer, Robert
Hochtemperatur-Kriechen einer ausscheidungsgehärteten Aluminium-Legierung
18. 07. 1978, Ilschner

Gerhäußer, Wilfried
Beitrag zur Lebensdauervorhersage warmfester Stähle bei wechselnder Beanspruchung
19. 07. 1978, Ilschner

Hendawy, Hanafy
Beurteilung der Zeitstandschädigung des warmfesten Stahles 13 CrMo 44 durch Kombination mehrerer Meßverfahren
20. 07. 1978, Ilschner

König, Gerhard
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2015

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08. 09. 2015, Göken

HABILITATIONS

A Habilitation is a further academic degree, which qualifies for teaching and research at a University. Typically the candidates work at least six years after their doctoral degree before applying for a Habilitation and submitting again a thesis. After a successful Habilitation the candidates obtain the right to use the title of a Privatdozent or PD and become faculty members. Later on after several further years of teaching and research they also can be promoted to get the title of an apl. Professorship. Over the fifty years 9 scientists from the Institute I successfully finished their Habilitation.

HABIL.

Bernd Reppich
Ausscheidungs- und Mischkristallhärtung in Fe-dotierten MgO
1973, Prof. Ilschner

Erich Tenckhoff
Verformungsmechanismen,Textur und Anisotropie in Zirkonium und Zircaloy
1977, Prof. Ilschner

Wolfgang Blum
Gleitung und Erholung während plastischer Verformung kristalliner Stoffe bei hoher Temperatur
1978, Prof. Ilschner

Hans-Georg Sockel
Punktfehlstellen in nichtstöchiometrischen Oxiden
1980, Prof. Ilschner

Hans-Jürgen Christ
Wechselverformung von Metallen
1990, Prof. Mughrabi

Horst Biermann
Ursachen und Auswirkungen der gerichteten Vergröberung ("Floßbildung") in einkristallinen Nickelbasis-Superlegierungen
1999, Prof. Mughrabi

Karsten Durst
Indentation size effect in crystalline materials
2010, Prof. Göken

Heinz Werner Höppel
Monotonic and Cyclic Deformation Behaviour of Very Fine Grained Metals: Microstructural Mechanisms and Mechanical Properties
2015, Prof. Göken

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TiAl- and Nickel-Base Alloys: Structures on the Nano- and Microscale determine the Properties of Multiphase Materials
2015, Prof. Göken

Habilitation of Heinz-Werner Höppel

Habilitation of Bernd Reppich

Habilitation of Karsten Durst

CONGRATULATIONS

ALUMNI, GUESTS AND VISITORS

Fifty years of research at Institute I has helped a large number of researchers gain their Doctorate, Diploma, Master's and/or Bachelor's degrees. Most of them have gone on to successful careers, both in academia as well as in Industry. A look at the maps shows some places where alumni of the Institute I can be found. Not surprisingly, most of them land up jobs in the Nürnberg/Fürth/Erlangen area, which offers excellent opportunities with companies like Siemens, Schaeffler Technologies, Federal Mogul etc. Nonetheless, former members of our Institute can be found not just in Germany, especially in industrial hubs like Munich, Stuttgart etc., but also around the world.

Quite a large number of former students from the institute also continued their career in academia and many also succeeded to become a professor at another University.

B. Eckert, K. Durst, George Pharr, B. Nix, M. Göken at the ECI conference on Nanomechanics in Crete

Wordcloud reflecting Companies and Instituions former members of Institute I have left to.

ALUMNI OF INSTITUTE I

Map of the world showing alumni of Institute I outside of Germany.

J. Müller, Ruslan Valiev, M. Göken, A. Naveed. Playing table tennis was at some time performed quite regularly and Prof. Ruslan Valiev from UFA, Russia could demonstrate his good skills in this sport.

GUESTS AND VISITORS

Marc Legros from Toulouse during a visit at the Institute I.

EMERGED PROFESSORS OF OUR INSTITUTE

Prof. Dr. G. Eggeler
Prof. Dr. A. Hartmaier
RU Bochum

Prof. Dr. S. Korte
RWTH Aachen

Prof. Dr. M. Schütze
DECHEMA, Frankfurt

Prof. Dr. K. Durst
TU Darmstadt

Prof. Dr. H. Hübner
TUHH Hamburg

Prof. Dr. F. Vollertsen
Uni Bremen

Prof. Dr. M. Heilmaier
Prof. Dr. J. H. Haußelt
KIT Karlsruhe

Prof. Dr. R. F. Singer
Prof. Dr. U. Engel
Prof. Dr. M. Merklein
FAU Erlangen-Nürnberg

Prof. Dr. H. J. Christ
Uni Siegen

Prof. Dr. H. J. Maier
LU Hannover

Prof. Dr. H. Biermann
TU Freiberg

Prof. Dr. S. Reichstein
Prof. Dr. B. v. Großmann
TH Nürnberg

Prof. Dr. F. Pycak
HZG Geesthacht
BTu Cottbus

Prof. Dr. P. D. Portella
BAM Berlin

Prof. Dr. J. Hammer
OTH Regensburg

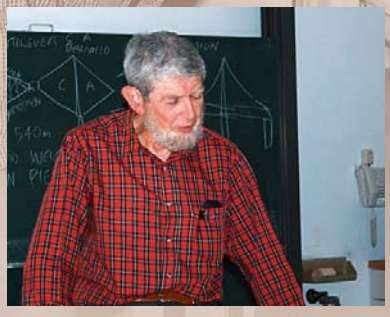
Prof. Dr. B. Eckert
HS Augsburg

Prof. Dr. O. Franke
USC Californien, USA

Prof. Dr. P. Eisenlohr
Michigan State University, USA

Prof. Dr. J. Eckert
ESI Leoben

ERLANGEN



Prof. Hugh Mc Queen from the Concordia University, Canada was a very faithful visitor and enthusiastic cyclist in Erlangen during the summer breaks.

Prof. M. Pohl (RUB) visiting the Institute, H. G. Sockel, H. W. Höppel, H. Mughrabi, V. Pugsley, H. Biermann

Prof. Dr. rer. nat. Dr. e.h. Peter Neumann, the former director of the MPI for Iron Research in Düsseldorf and PhD advisor of Prof. Göken, as he received the honorary doctoral degree of the FAU by the dean of the Technical Faculty Prof. A. Winnacker together with the Chair of the Department Prof. P. Greil and Prof. H. Mughrabi in 2005.

ALUMNI OF INSTITUTE I

Map of Germany showing alumni of Institute I. For clarity, major cities in Germany are also shown

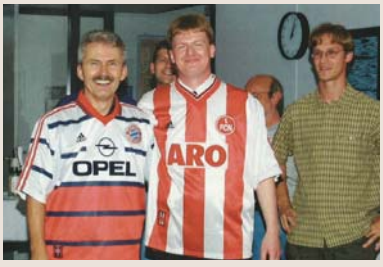
Ilschner opening a beer barrel

MISCELLANEOUS AND CURIOSITIES FROM 50 YEARS

CURIOSITIES

Enjoying the ride after a long hike at the excursion in 1977

The Institute I football team "the Fatigued Creepers" after winning the department's championship in 2008



Karl Eckert and Gerd Eisenmeier

SPORTS AND FOOTBALL AT INSTITUTE I

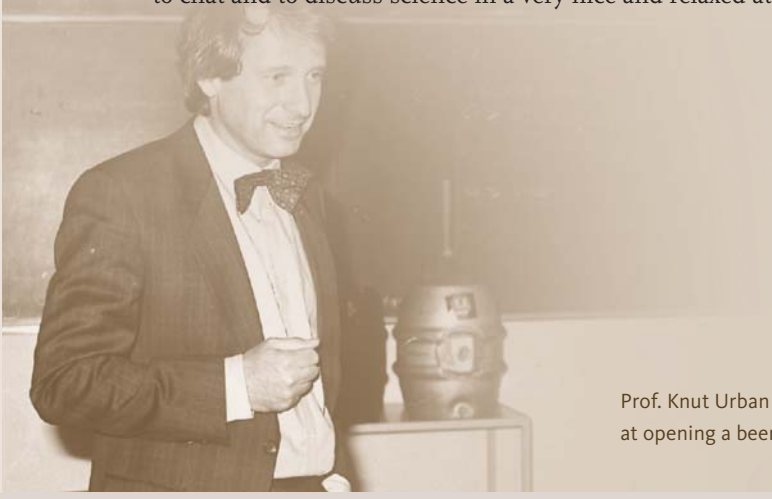
The people at Institute I like to play sports. In the 60s there were regular boomerang and chess tournaments where Institute I played against the group of the University of Göttingen. The games were hotly contested, but the Institute I team dominated in both disciplines. Later, the staff enjoyed playing table tennis at the Institute's attic and they also became more interested in playing football. The technician Karl Eckert and a PhD student Gerd Eisenmeier succeeded in keeping the ball in the air for more than 300 times without touching the ground. It's no wonder that Institute I established a football team called "the Fatigued Creepers" which became also very successful at the annual football tournament of the Department of Material Science & Engineering after the summer semester at the end of July. The weekly training before the tournament payed off quite often and the Institute I football team, cheered by many staff members and students of the institute, won the Championships in 2001, 2008, 2009, 2011 and 2012. In recent years, several PhD students of Institute I also took part at the Erlangen Winterwaldlauf.

Football team of 2011

Boomerang tournament

BEER FESTIVAL "BERGKIRCHWEIH"

Each year on the Tuesday after Pentecost the members of Institute I visit the well-known "Erlanger Bergkirchweih", Franconia's largest and very beautiful twelve-day festival, which has been celebrated at the Erlanger "Burgberg" for the last 260 years. This is an ideal opportunity for students, staff, professors and researchers to chat and to discuss science in a very nice and relaxed atmosphere.



Prof. Knut Urban in 1986
at opening a beer barrel

Heinz Werner Höppel, Mathias Göken, Steffen Neumeier, Werner Langner (left), Peter Weidinger, Fritz Pschenitzka, Karlhans Beigott and Ingrid Lutz at the Bergkirchweih in 2012.

SKIING AT ADELBODEN

Many researchers from Insitute I have participated at the yearly Materials Science Seminar organized by Prof. O. Vöhringer and Prof. A. Wanner of the Karlsruhe Institute of Technology, KIT. Since many years Prof. Göken and Prof. Mughrabi and their families are frequent guests at the Seminar at the Hotel Alpina in Adelboden, Switzerland. In the daytime the attendees go skiing in the wide-ranging slopes of this very beautiful ski resort in the Swiss Alps and in the evening they come together to listen to lectures and scientific talks on various topics of materials science and related fields. Over the years Prof. Göken invited also PhD students of his group to join him to Adelboden. Thus many PhD students of Institute I got the opportunity to combine leisure with work and to present their work during the evening seminar.

Prof. M. Göken and his wife G. Göken together with Prof. H. Mughrabi and his wife S. Mughrabi at the Hotel in Adelboden in 2004

MOVIE NIGHTS

The movie "Die Feuerzangenbowle" about a famous writer going undercover as a pupil at a small town high school after his friends have told him that he missed out on the best part of growing up by being educated at home has gained cult status at German universities. It is not surprising that the graduates at Institute I enjoy also preparing mulled wine with a rum-soaked sugarloaf above on several occasions during the winter over the past 50 years. The warming drink was made at Dr. Hüther's farewell party in 1976, for example, as well as at the movie nights in the meeting room of the institute, when movies like "Die Feuerzangenbowle", of course, were watched after work. Besides the movie nights also gaming nights were arranged at Institute I. All this shows that the people at Institute I like their workplace so much that they spend also some free time together at the institute.

Mulled wine in 1976 and 2010

WEDDINGS

In the past 50 years, many people of Institute I got married. Several of them had very strong links to the Institute I so that many of their colleagues were invited to their weddings. Florian Pyczak, the former group leader of the "High Temperature Materials group", now Prof. at the HZG in Geesthacht and the University of Cottbus celebrated his weeding in 2003. Later, the PhD student Elmar Schweitzer invited the people of Institute I to his wedding in 2006 and Björn Eckert, née Backes, married a Diploma student of Institute I, Anne Eckert. Two PhD students, Johannes May and Lilia Saitova also married in October 2008 and invited most of the staff from Institue I to their wedding. Just last year we could celebrate Lisa Benker's and this year Doris Amberger's wedding.

Prof. Florian Pyczak's wedding with his wife Akiko in 2003

Wedding of Björn Backes and Anne Eckert with guests from Institute I

CARNIVAL

From the 70's up to the end of the 80's big carnival parties were celebrated for all institutes of the two buildings of the department of Materials Science. Somehow carnival parties are not that popoular anymore, however, the wish to celebrate and masquerade is still quite present at the institute as can been seen from the pictures below.

Carnival at the department Materials Science & Engineering in 1979.

Masquerading in 2012

THE INTERNATIONAL MOUSTACHE DAY

International Moustache Day at the Institute I in 2014.

On the International Moustache Day, normally held on a Friday in October, a lot of the members of Insitute I wear a moustache. Most of the participants start to grow a beard in September, so that they can show off with a nice bushy moustache on Moustache Day. A highlight of the Moustache Day is the traditional lunch at the Mensa, were not only members of the institute, but the whole technical faculty can admire the different shapes and sizes of the moustache grown for this special day.

BBQ in Prof. Ilschner's garden

BARBECUE AT INSTITUTE I

Each year in the summer the new PhD students organize a barbecue to make their debut at Institute I. All members of the institute gather at the back of the department's building to have a suckling pig roast, steak, salads, vegetarian food and deserts. Apparently, this is not a new tradition. Prof. Ilschner, the first head of the institute, also invited people from Institute I to a BBQ at his garden.

The institute's BBQ in 2009 at the back of the building of the department Materials Science and Engineering.

EXCURSIONS OF THE INSTITUTE

The staff of Institute I have visited a variety of different locations and companies in the nice surroundings of Erlangen during the past 50 years. In the beginning, the researchers just went for a walk through the forest close to the department to the small village of Kalchreuth or they inspected the water wheels in Möhrendorf which have watered the farmlands in the valley of the river Regnitz for hundreds of years. Later they organized excursions to Regensburg, Augsburg, Herzogenaurach, etc to get a guided tour through the cities and to visit important companies in northern Bavaria where many of our Alumni are employed. These bonds to the former members of our institute as well as to our nice Franconian environment and the desire for maintaining traditions at our institute are nicely mirrored in the figure where people from Institute I visited the water wheels in Möhrendorf 40 years after their first visit in 1966.

Visit of the water wheels in Möhrendorf, a small village in the vicinity of Erlangen, in 1966 and 2006.

SATTELBOGEN SEMINARS

SATTELBOGEN SEMINARS

Sattelbogen group of 2015 again at the Bernhardshöhe

Bernhardshöhe 1972

From left to right:
Hübner, Schneider, Schuh, Sockel, Streb, Knoch, Wahi, Schoschinska, Haußelt, Pschenitzka, unknown, Ilschner, Blum, Reppich, v. Heimendahl, Finkelnburg

As mentioned earlier, it was decided to introduce a retreat symposium ("Konzentrationstage") in order to keep the different groups within the Institute together. The intention of this Symposium, which was held the first time in 1972, was that all researchers of the Institute come together for three days to discuss intensively their newest results. The following objectives for the seminar were called:

1. To present the current state of the research so that it can be discussed by all employees,

2. To give the individual researcher the opportunity to determine at what point of the entire program his/her work is, where cross-connections exist and where such have to be strengthened,

3. To enable the interaction and discussion particularly with regard to methodological difficulties,

4. To discuss objectives of the research work for the period ahead,

5. To know each other better and to strengthen also non-technical discussions.

Retirement of F. Pschenitzka

Impressions of our retreat symposia

The first seminar was held at Bernhardshöhe in the Bavarian Forest and lasted from Thursday to Sunday. Since then, the event has developed to a solid tradition for the Institute. Only in the years 1976 and 1983 the retreat symposium failed. To date (2015) the Retreat Symposium has taken place 42 times and the Institute has enjoyed for the 30th time the exemplary hospitality of the Sattelbogener Hof. During the first years of the Institute, around 15 – 20 participants attended this meeting. Today, with the growth of the Institute, more than 50 researchers contribute to this symposium nowadays. What was initially an event for internal scientific exchange developed over the time into a small symposium with national and international guests. Thus, it became rather critical not to overload the program (with up to 40 contributions) and on the other hand to keep a vital scientific discussion on current research activities at the Institute alive. It is also a good tradition, that there is time for an afternoon's hike in the surrounding area of the hotel. Typically that the complete group or some parts of it strayed around and managed at the end to return to the hotel much later than originally planned. Often also a non-specialized topic has been addressed in by separately invited speakers as an evening event. Last but not least a new tradition came in with Prof. Göken who introduced a "Happy Hour", which turned out to be an excellent practice to initiate long conversations or a cozy sheep's-head game.

Sattelbogen 2002 with many external guests

SATTEL BOGEN

Institute I Retreat Symposia "Konzentrationstage"

Year	Place	Participants
1972	Bernhardshöhe	17
1973	Bernhardshöhe	18
1974	Bernhardshöhe	25
1975	Kritzental	37
1977	Sattelbogen	33
1978	Erlangen	38
1979	Sattelbogen	27
1980	Sattelbogen	30
1981	Sattelbogen	31
1982	Sattelbogen	36
1984	Sattelbogen	31
1985	Sattelbogen	30
1986	Regensberg	35
1987	Sattelbogen	35
1988	Veldensteiner Forst	36
1989	Veldensteiner Forst	36
1990	Osternohe	35
1991	Sattelbogen	40
1992	Sattelbogen	43
1993	Sattelbogen	44
1994	Sattelbogen	43
1995	Sattelbogen	51
1996	Sattelbogen	35
1997	Sattelbogen	38
1998	Sattelbogen	30
1999	Sattelbogen	33
2000	Sattelbogen	33
2001	Sattelbogen	25
2002	Sattelbogen	32
2003	Sattelbogen	30
2004	Sattelbogen	31
2005	Sattelbogen	34
2006	Sattelbogen	39
2007	Sattelbogen	41
2008	Sattelbogen	42
2009	Sattelbogen	37
2010	Sattelbogen	41
2011	Sattelbogen	44
2012	Sattelbogen	65
2013	Sattelbogen	53
2014	Sattelbogen	52
2015	Sattelbogen	47

Traditional hiking event during
Sattelbogen symposium

Hiking around Sattelbogen

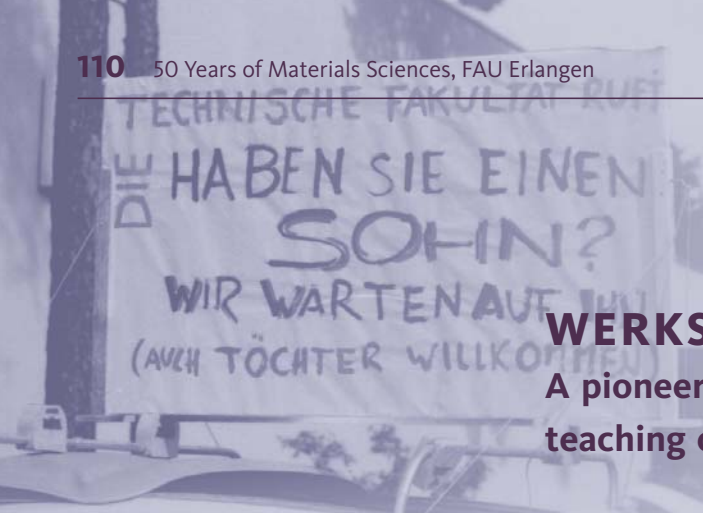
Sattelbogen in 2012

EDUCATION AND TEACHING

WERKSTOFFWISSENSCHAFTEN

NANOTECHNOLOGY

ADVANCED MATERIALS AND PROCESSES, MAP



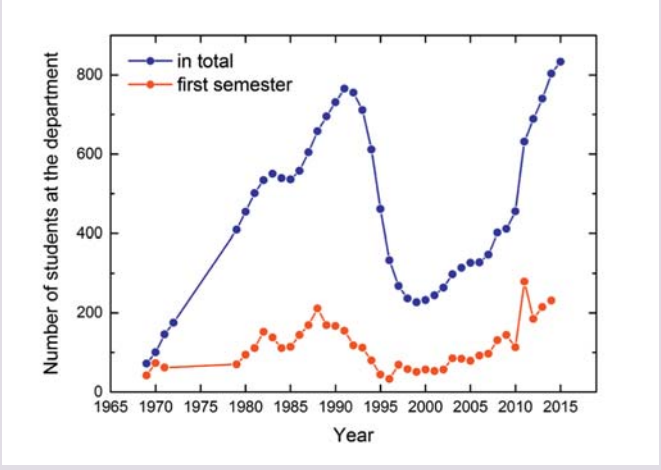
Advertisement of the new education possibilities in Erlangen was done sometimes in special ways as shown above on the picture from 1966.

WERKSTOFFWISSENSCHAFTEN

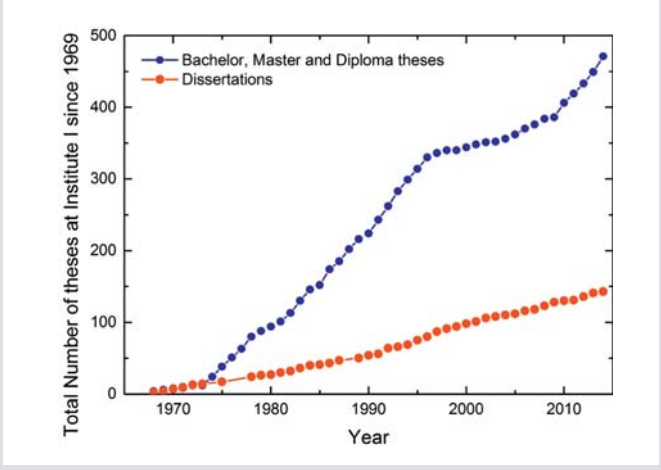
A pioneering approach of interdisciplinary teaching on materials

Dislocations in the "Real World" as for example on a cactus

Also in teaching, the Institute I has a long tradition to look back. In the winter semester 1965/66 the first lecture in the field of materials science was offered with "Fundamentals in Materials Science I" by Prof. Ilschner, which was rounded off by the second part in the following summer semester. From the beginning, the new program was to stand out from other places with established lectures in the field of metal physics and thus it was filled with different lectures mediating the close interaction of technology and science and integrating over the different classes of materials. The audience in the first year consisted of students of physics and mineralogy. In 1968 the lecture "Introduction to Materials Science" was introduced by Prof. Ilschner, in order to provide a compact survey of the field of material science for beginners. Already in WS 1969/1970 42 beginners were attracted to the new program with a total 72 students being registered. Later Prof. Heimendahl introduced the two-semester course on "Experimental Methods in Material Science", which addressed not only metallographic aspects and measurement techniques but also applied techniques in microscopy including OM, SEM and TEM.



Number of students at our Department until 2015



Total number of theses written at our Institute since 1969

Last lecture of Prof. Reppich

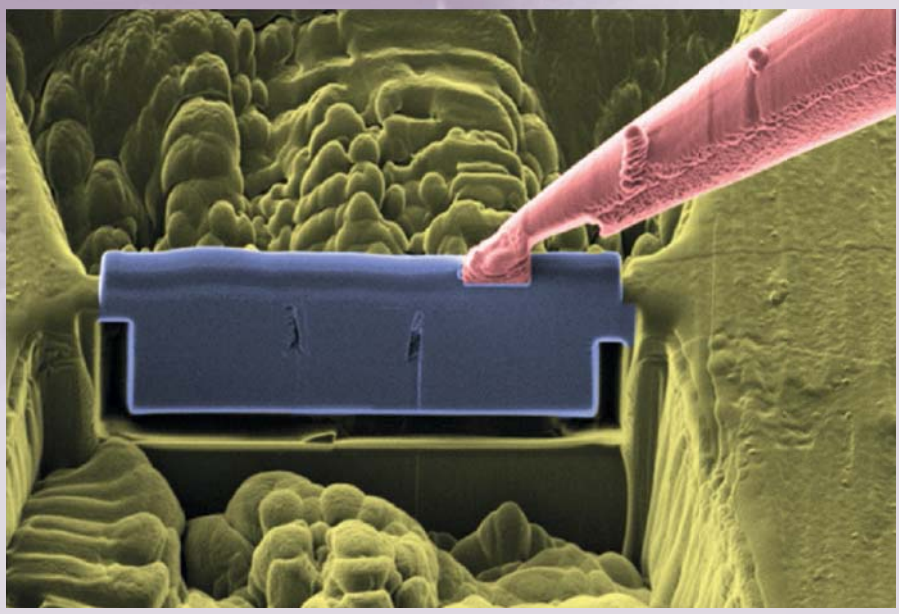
In 1975 the new two-term lecture “Ringvorlesung Werkstoffkunde” was established by the 6 Institutes in order to provide for the students in materials science a broad overview on the different classes of materials. It was regarded that it is essential for a material scientist coming from Erlangen that he/she is well educated in all classes of materials, a benefit which still holds today. From this seed of lectures, different lectures (more general ones and highly specialized ones) evolved over the time. For beginners, the Institute I provides nowadays the lecture “Materials and their Structure” and “Mechanical Properties”, which both convey the material scientific basis in its present form to the students in the 1st and 2nd semester. For the master program the lecture “Fundamentals in Materials Science” has been evolved to “Applied Fundamentals of Materials Science”, denoting the bridging between material physics and engineering. The curriculum was also diversified and progressively broadened over time and a lot of special lectures were created, such as “High Temperature Materials”, “Fatigue behavior of metallic materials”, “Intermetallic Alloys”, “Nanoindentation”, “Tribology and Surface technology”, “Finite Element Methods in Materials Science”, etc. In WS 2008/09 the additional program of “Nanotechnology” was started and the Institute also contributes to the programs “Power engineering” and “Advanced Materials and Processes MAP”. Additionally, the institute also took part in the study programs from the Departments of Mechanical Engineering and Chemical Engineering. Through the “Technical Application Field” Computational Materials Science the Institute I is also contributing to the International Masters Program Computational Engineering.

INSTITUTE I

NANOTECHNOLOGY

The newest consecutive Bachelor and Master program of the MSE Department, Nanotechnology, has been introduced in 2008. Prof. Göken coordinated this new program which started with around 45 students. In the last years the number of freshmen increased to close to 100, so that Nanotechnology and the MSE program have now comparable student numbers. The general idea behind this program is to intensify the education related to the aspects of nanotechnology and nanomaterials and to offer an attractive program that is closely related to physics and chemistry. Engineering subjects more relevant to MSE like mechanical engineering, on the other hand, have been dropped. The program started very successfully and the drop-out rate so far is significantly lower than in other programs. The students enjoy the intensive contacts with professors and teaching in quite small groups. The attractiveness of this program becomes also visible from the fact that students are recruited from significantly larger parts of Germany and even some students from northern Germany are coming to Erlangen to study Nanotechnology. On the other hand, however, it also became obvious that the rate of female students is lower than in MSE, which probably reflects the low number of female students in physics.

NANO



TEM foil prepared by Focused Ion Beam milling from an amorphous diamond coating

ADVANCED MATERIALS AND PROCESSES, MAP

map advanced materials and processes

Elitenetzwerk Bayern

The international masters program MAP offers an interdisciplinary education by combining the fields of chemical and biological engineering with materials science and engineering with the goal to train the next generation of engineers with the skills necessary to produce innovative materials in the most efficient and sustainable way. The English-taught program is supported and certified by the Elite network of Bavaria (ENB) and awards the degree of a Master of Science with Honors – M.Sc. (Hons). The program is built around four so-called focal topics: Biomaterials and Bioprocessing, Computational Materials Science and Process Simulation, Nanomaterials and Nanotechnology and Advanced Processes. These key technologies are particularly characterized by the synergies between materials science and engineering and chemical and biological engineering, and their study provides students with broad career opportunities in industry as well as in academia. MAP is furthermore defined by its strong research focus with students being exposed early on to current research in their two miniprojects, innovative teaching methods including literature reviews, lecturing training and poster presentations. MAP is a highly selective program with an intensive two-step selection process involving personal interviews: only about 20% of the more than 200 applicants are admitted. The high quality of MAP graduates is additionally assured by failure rules, which are stricter than in other Masters Degree Programs. The success of MAP is reflected by the large number of merit-based scholarships and prices obtained by its students, the careers of its graduates (over 70% continue their studies with a PhD at world-renowned universities) and the many papers published by its students even before their graduation, including some of their 2nd semester literature reviews. Since the foundation of MAP in 2005, the Institute I has been closely involved in its organization. In addition to the many miniprojects and master thesis done at

MAP

the institute, Professor Göken is acting as the head for the focal topic Nanomaterials and Nanotechnology, and many of our Professors like A. Hartmaier, S. Korte and E. Bitzek have served as chairs of the MAP Program. By bringing together the two Departments of Materials Science and Engineering and Chemical and Biological Engineering, MAP served also as nucleus for the creation 2007 of the Cluster of Excellence Engineering of Advanced Materials (EAM). MAP students are also junior members of the graduate school of EAM, thus providing a constant source of highly motivated and well-trained PhD students for the Cluster of Excellence. Through its truly international nature with students from 29 countries, MAP has helped to increase the international visibility of the FAU. With its partner universities in Bayreuth and Würzburg, MAP has furthermore created strong local connections, building on existing collaborations of Institute I.

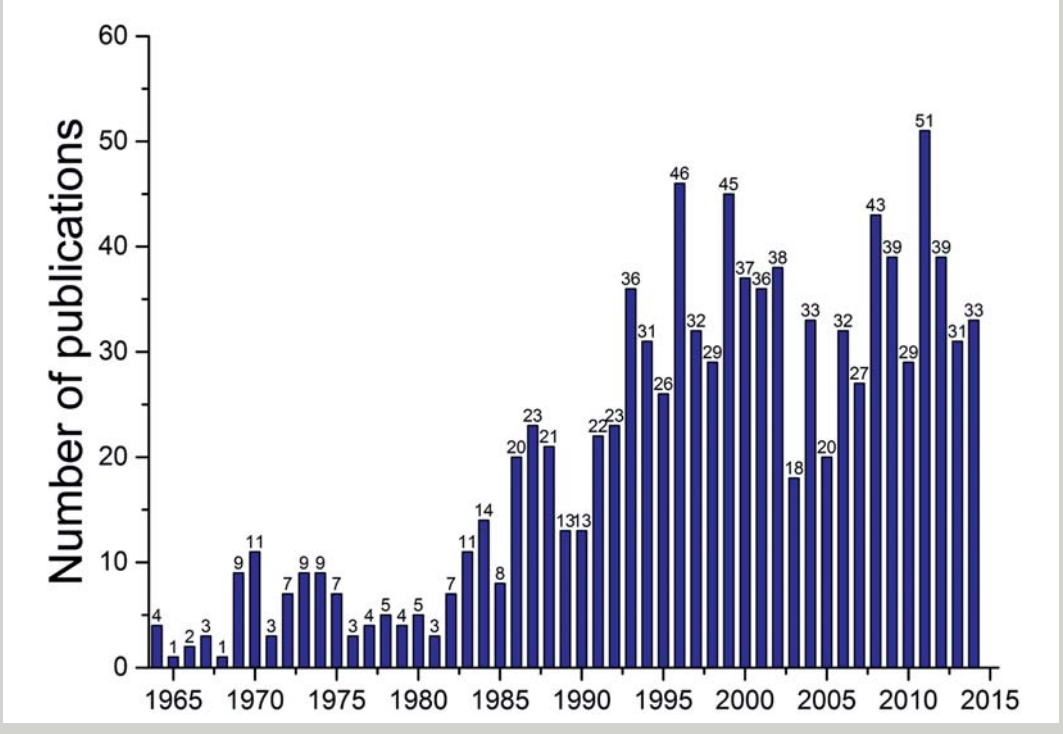
Graduates of the MAP Program including students of our Institue

OUTPUT

SELECTED PUBLICATIONS
SCIENTIFIC AWARDS
ORGANIZED CONFERENCES

PUBLICATIONS

PUBLICATIONS



Numbers of publications per year

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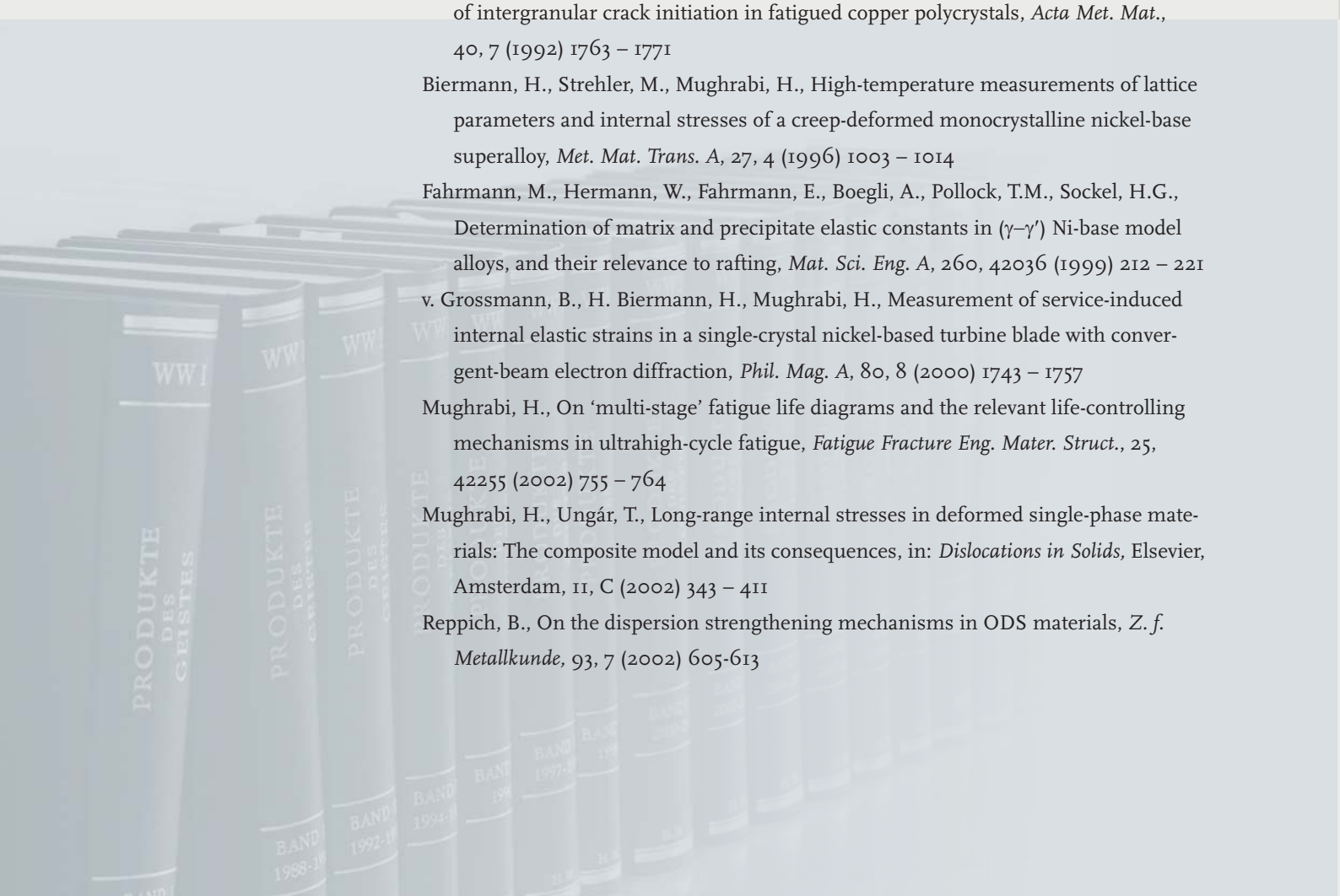

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SCIENTIFIC AWARDS

Awardees of the 'Masing-Gedächtnis- Preis'

Scientific awards play an important role in the research community, since with such awards new research findings are highlighted. More importantly, the strong commitment for science and the intensive work over many years is granted by such awards, which is often a very good motivation especially for younger scientists. Over the years many awards have been granted to scientists working at the Institute I and here only some examples can be mentioned. Especially important for us are always the awards of the DGM, which built a long tradition. For example the picture shows five awardees of the Masing-Gedächtnis Preis working at the institute in 2009. Karsten Durst received this award in 2009 from Prof. Wolfgang Kayser (HZ Geesthacht) and Prof. Martin Heilmeier (now at KIT Karlsruhe).

Haël Mughrabi received the Hsun Lee Lecture Award

The DGM-Nachwuchspreis (given since 1994) has been awarded already seven times to young scientists from Erlangen, here shown is Benoit Merle together with the former Chairman of the DGM on the right Prof. Hans Christ, who gained his PhD at the Institute I. The Tamman prize of the DGM has been received by Prof. Hans Georg Sockel in 1988 and the highest DGM award the Heyn-Denkmünze has been received by Haël Mughrabi in the year 2000 and Bernhard Ilschner in 1995.

Prof. Ilschner, the founder of the Institute, who also served as Rektor of the FAU, received the highest honours from the State of Bavaria, namely the "Bayerischer Verdienstorden" and the "Bayerische Maximiliansorden". He also was awarded with a honorary Doktorate of our Technische Fakultät.

Haël Mughrabi received numerous appreciations of his lifetime achievements in science as the Hsun Lee Lecture Award from the Institute of Metal Research in Shenyang in 2006 and the Cook Albett Award of the IOM[3] in 2010, where the award ceremony is held in a quite traditional and special atmosphere as visible from the picture. Prof. Mughrabi also received an honorary doctoral degree from the Ruhr University Bochum in 2009.

Quite regularly younger members of the Institute are awarded with a poster award at international conferences. The overall very high quality of the posters and also oral presentations is of course a result of intense discussions of how to present the research results in a conclusive and clear manner, which is always trained at the Institute. The picture shows Johannes Ast and Carolin Puscholt, who both received a poster award at the Nanomechanics ECI conference in Portugal 2013 together with Prof. Korte (now at RWTH Aachen), Prof. Durst (now at TU Darmstadt) and Prof. Göken.

DGM-Nachwuchspreis for Benoit Merle

Some further important prizes received by members of the institute are the Nachwuchspreis-Werkstoffe from Bayern Innovativ (D. Bösch, 2012), the Acta student award 2006 (J. May) the Heinz Maier Leibnitz award of the DFG in 1992 by Orlaw Massler and in 2015 the Light Metals Subject Award – Aluminum Alloys of the TMS by D. Bösch, H.W. Höppel and coworkers in addition to many PhD and Diploma or Master thesis awards.

Johannes Ast and Carolin Puscholt, who both received a poster award at the Nanomechanics ECI conference in Portugal 2013 together with Prof. Korte (now at RWTH Aachen), Prof. Durst (now at TU Darmstadt) and Prof. Göken.

ORGANIZED CONFERENCES

ICSMA 2009 in Dresden

International conference on the strength of materials

Participation at international conferences is of course always very important to interact and combine the newest research results on an international level. All PhD students are at least participating on one really international conference. The picture below shows the Erlangen group at the ICSMA-15 in Dresden in 2009. The topics of the ICSMA (International conference on the strength of materials) conference series always fit quite well to our research topics. Prof. Mughrabi has attended most of the conferences and is always in favour of going there and has acted as president of organizing team for many years.

ECI conference on nanomechanical testing

In 2009 Prof. Göken, well supported by Karsten Durst, organized the second ECI conference on nanomechanical testing in Barga, Tuscany, which from them has now developed as a very successful conference series taking place always at nice resorts around the Mediterranean Sea.

DPG spring meetings

For planning of the parallel sessions of the meeting traditionally wooden boards are used, where the talks can be arranged and moved around accordingly. Interestingly as Mathias Göken took over the responsebility for Materials Science in the German Physical Society, DPG in 2011 and had to organize the spring meetings of the AGMM (Arbeitsgemeinschaft Metallund Materialphysik) these boards came back to Erlangen, where they were originally built in 1985 by Knut Urban, who also was a former AGMM meeting chair at his time in Erlangen.

ICSMA 2009 in Dresden

DPG spring meeting

ECI conference in 2009 in Barga

W. Skrotzki, Stanzl-Tschegg, Mughrabi, during the fatigue colloquia

Colloquia on (Fundamental) Fatigue Mechanisms

This series of colloquia has its roots back to 1972 where scientist from Eastern Germany and the Czech Republic met each other to discuss their findings in the field of fundamental mechanisms during cyclic loading. After the iron curtain has fallen scientists from the western parts of Europe were also invited to join the colloquia. Within this series the colloquium took place in Erlangen in 1992,1997, 2004, 2009 and 2014. In 2014 we celebrated the 25th Colloquium within this series in Erlangen. This series of colloquia has developed to one of the high-lights among the course of the conferences during a year, as they are rather focused and the scientific discussion is excellent.

NanoSPD4 August 2008 Goslar, L. Saitova, M. Korn, HW. Höppel, M. Göken, A. Böhner, T. Hausöl, A. Vevecka – Priftaj

K. J. Hsia, National Science Foundation, USA, M. Göken, Neville R. Moody, Sandia National Laboratories, Tresa Pollock, University of Michigan – Ann Arbor, Pedro Dolabella Portella, BAM Berlin (from left to right)

Further involvements

The Institute has further contributed to the organization of several conferences:

- TMS Hael Mughrabi Honorary symposium
- International Conference on Plasticity
- Failure and Fatigue in Structural Materials
- Metallographie Tagung
- Low Cycle Fatigue Conference (LCF)
- International workshop on Advanced Cobalt-Base Superalloys

Sandra Korte and Erik Bitzek successfully initiated the symposium “Fundamentals of Fracture” at the Spring meeting of the German Physical Society.

The week-long short course “Materials Modelling” with Ron Miller and Ellad Tadmor, organized by Prof. Bitzek, repeatedly managed to draw numerous participants from all over the world to Erlangen, including from South America and Australia.

The “Lange Nacht der Wissenschaften” is always a nice event, where the public can see what is ongoing at the University. The Institute contributes to this event interesting things related to high temperature materials or the mechanical properties.

Colloquium on (Fundamental) Fatigue Mechanisms in Erlangen, 2014

"Lange Nacht der Wissenschaften" a regular event in Erlangen, Nürnberg and Fürth

1. International workshop on Advanced Cobalt-Base Superalloys in Pommersfelden in 2013

IMPRESSUM

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1965

1966
14th August – Foundation stone for the new building in Martensstraße 5 was set. Installation of first creep and tensile testing machines

1972
May – Inauguration of the first transmission electron microscope TEM EM300. 20th October – Opening ceremony of the new building. October – first retreat symposium of the institute held at Bernhardshöhe and settlement of five research groups finalized

1982
Prof. Ilschner accepted a call to the EPFL in Lausanne

1983
Prof. M. v. Heimendahl retired

1984
Prof. H. Mughrabi took over Head of the Institute

1985
Installation of first servohydraulic testing machines and establishment of the fatigue group

1986
Prof. K. Urban became successor of Prof. Heimendahl (Prof. Urban left for Jülich in 1987)

1991
Installation of the first scanning electron microscope

1997
Acquisition of a new TEM, CM 200T

2015

2002
Prof. M. Göken took over Head of Institute from Prof. Mughrabi. Retirement of Prof. B. Reppich

2003
Retirement of Prof. H. G. Sockel

2004
Retirement of F. Pschenitzka

2005
Large chamber SEM installed in Fürth (> member of ZMP). Retirement of Prof. W. Blum

2006
Prof. Ilschner died in Lausanne (4.1.2006). First Focused Ion Beam, ZEISS 1450 ESB installed. Appointment of Prof. A. Hartmeier as successor to Prof. Blum

2009
Appointment of Prof. E. Bitzek as a successor to Prof. Hartmeier. Appointment of Prof. S. Korte on a new junior-professorship from the Cluster of Excellence

2013
PD Dr. Karsten Durst and Prof. Sandra Korte took up positions as full professors at the TU Darmstadt and RWTH Aachen

2014
Opening of the Technikum 2 at Uferstadt Fürth with the new Nanometals processing Hall

2015
July – Installation of the Atom Probe Microscope, LEAP 4000X HR. September – Appointment of Jun. Prof. Peter Felfer

50 YEARS INSTITUTE I