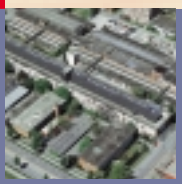
Annual Report 2002

Key areas
and
selected projects
of the year 2002



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Swiss Federal Laboratories for Materials Testing and Research EMPA A Research Institution of the ETH Domain

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Empa

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Generating and implementing relevant knowledge

Louis Schlapbach

What do the citizens of a small industrialized country with a high standard of living expect from public-sector education, research and technology institutions?

- Knowledge propagation to achieve and maintain excellence in the international environment,
- Innovation through knowledge transfer to solve known problems and develop new sustainable products,
- Provision of education and training to the emerging generation of leaders and decisionmakers,
- Knowledge with which to identify, reduce and combat the threats posed by nature, humans and inadequate material resources,
- Creation of the basis required to ensure sustainable mobility, communications, energy, health and food supplies,
- Provision of neutral expertise for conflict resolution.

Switzerland has a large number of small, medium-sized and large public-sector education, research and technology institutions. They are poorly networked and are distributed across several government departments. Empa is assuming the role of a national institution for sustainable materials science technology. We gather basic knowledge in the national and international environment and use it to develop new and innovative solutions. As a neutral institution, we wel-

come national and international challenges by virtue of our expertise, experienced specialists and modern equipment. Thus we are not just a partner to private, technology-centred companies: we also work with public offices with no laboratory facilities of their own and collaborate with universities of applied technology, other universities and the two Federal Institutes of Technology in Zurich and Lausanne.

Just as Empa benefits from its membership of the ETH domain, the ETH domain in turn benefits from Empa's expertise.

This Annual Report gives you an insight into some of our activities and results. It discusses our new orientation – 60% applied research and development, 30% high-level services and 10% teaching and knowledge management. We have more PhD candidates, more members of scientific staff, more peer-reviewed publications and more third-party funding than in the previous year. All this has been achieved with no increase in our budget. Our new direction is also producing impressive results in terms of our success stories, priority programmes such as nanotechnology or adaptive material systems and our awards. You will find descriptions of our projects, with full technical details and references, in our English-language publication «Empa Activities 2002». We hope you will enjoy reading our Annual Report.

On behalf of the General Management
Louis Schlapbach

Research programs

Nanotechnology
Adaptive Material Systems
Technosphere – Atmosphere
Sustainability in the Information Society
Protection, comfort and wellbeing of the human body
Ecoinvent

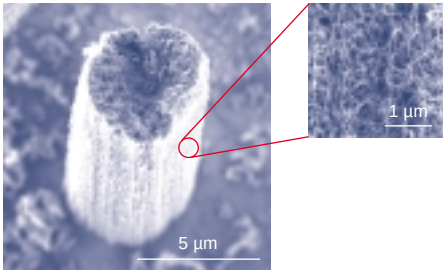
Nanotechnology

A peek into a lilliputian world

The Empa has pushed hard in 2002 toward achieving its high-priority goal of establishing a National Competence Center for Nanotechnology. A visible sign of the progress being made is the creation of a nanotechnology laboratory and the rapid expansion of the necessary infrastructure.

Behind the magic word «nanotechnology», which is often regarded as the technology of the 21st century, lies the ability to design and engineer objects on the nanometer scale. This capability, which demands a very high level of skill, will allow us in the future to produce and assemble tailor-made, complex structures out of nanocomponents (such as molecular and supermolecular aggregates) and so create new functional elements. Sustainable success in the research and development world is best measured by the extent of industrial involvement. Carbon nanotubes as a cold electron source seem to be especially attractive in this regard. The recognized ability of our researchers to exploit the electron emission properties of single nanotubes and nanotube films has already lead to co-operative projects – including amongst others, the development of new X-ray tubes, microwave amplifiers and flat display screens – with well-known Swiss and foreign firms.

A similar situation exists in the development of nanocomposites, which are materials consisting of special matrices with well-defined «Second-phase» particles embedded in them. These can be used, for example, to create innovative, functional surface coatings or basic materials with particular optical, thermal and mechanical properties using nanopowder techniques or through chemically or physically controlled nanocluster creation. Two newly commissioned pilot plants with kg/h capacity are now available for the manufacture of nanopowders. One of these plants uses flame synthesis technology (oxide powder), the other plasma synthesis technology (non-oxide powder).



REM image of a compact electrode bundle consisting of a large number of nanotubes.

Nano-laboratory at the Thun site

The new «nanotech@surfaces» laboratory at the Empa Thun will devote its outstanding research infrastructure primarily to work in two thematic areas:

- Molecular electronics (exploiting the self-organizing behavior of molecules to form supermolecular aggregates used as active electronic elements)
- Carbon-nanotube technology (used to create miniature «cold» electron emission sources)

Collaborative projects in this area with leading European research institutes such as the Max-Planck Institute for Polymer Research in Mainz, or the CSEM in Neuenburg, are already well established. A generally stronger emphasis on fundamental research with a long-term horizon will be achieved with the involvement of the Swiss National Centers of Competence in Research (NCCR).

Empa's second new laboratory, «Functional Polymers» will also engage in work on nanotechnology. The initial projects deal with the functionalisation of nanoparticles for integrating into polymer matrices or the targeted exploitation of nanoclusters for use in high-performance photographic paper.

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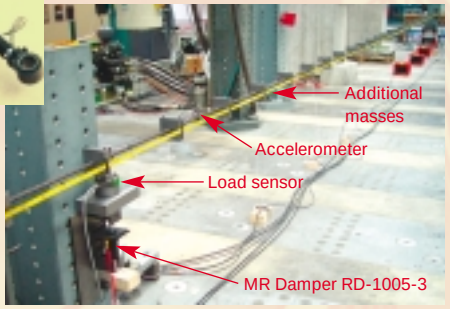
MR Damper RD-1005-3



Adaptive damping of cable oscillations with a so-called magnetorheological damper (MR damper) on the test bed at Empa.

Showing potential in many disciplines

Adaptive Material Systems are, like biological systems, able to react autonomously to changes in their surroundings by adapting their characteristics in an appropriate way when in use. The program encourages the transfer of the results of fundamental research to practical applications and collaborates with industry in applications-oriented research.

A typical example of a cable-stayed bridge: the Erasmus bridge in Rotterdam. The inset shows the passive viscous dampers, which were installed to reduce cable resonance.

Knowledge from the fields of sensors, actuators, signal transmission, control systems, and the use and characterization of multifunctional composite materials is necessary for the development of adaptive material systems. From the beginning of the program, the Empa has built up a comprehensive degree of expert knowledge, which enables it to conduct research in this subject area at an international level.

They move by themselves!

«Active Fiber Composites» (AFC) produced by the Empa – piezoelectric fibers in a polymer matrix, intended to be used as actuators – have been «moving by themselves» in precise response to the programmed commands of their developers since autumn 2002. The same is true of Electro-active Polymer Systems (EAP). Both techniques function, but have significantly different characteristics. AFCs exert large forces with small deformation while EAPs give large deformation and low force levels.

The aim for the year – «They have to move by themselves!» – has in both cases been achieved without major difficulty.

Sought after applications

Over the last year, the Empa has done pioneering work on the vibro-acoustic modeling and optimization of the sound-reducing characteristics of double glazed windows. It is now possible to model actively regulated systems by finite-element methods. The agreement between the model predictions and experimental data is impressive.

In addition, adaptive systems are finding applications in the fields of building physics (controlling the warmth and humidity budget of building façades), constructional dynamics (oscillating bridge cables) and materials (piezoelectric fibers, magneto-active polymer composites).

Research Triangle with the ETH Zurich

For several years there has been close collaboration with Prof. Manfred Morari of the Institute for Automation, ETH Zurich. In addition, cooperation with Prof. Paolo Ermanni of the Center for Structural Technology has been newly established. This triangle of institutes with complementary and self-strengthening expertise is concentrating on the subject of «Active Control via Shunted Embedded Piezoelectric Fibers», which shows great future potential for success.

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Identifying and remediating sources of pollution

The flow of polluting substances into the air as a result of human activity leads to the contamination of the lower layer of the atmosphere as well as increasing the levels of greenhouse gas activity. Many pollutants are transferred to the soil or natural waters, with the atmosphere acting as an agent of transport. The program aims to characterize and reduce the flow of pollutants at the boundary between the technosphere and atmosphere.

The Clean Engine Vehicle on the dynamometer

How do POPs get into fish fillets?

Persistent organic pollutants (POPs) are toxic compounds which are emitted by certain materials and industrial processes. Because they are broken down only very slowly under natural conditions, they are transported large distances in the atmosphere, and have even been identified in the Antarctic. As a result of their fat-solubility, these chemicals also enter the food chain. In an investigation into the accumulation of polybromated diphenylethers (which are used as flame-retardants) in white fish in Swiss lakes, Empa researchers were able to demonstrate that concentrations increased with larger lake surfaces and smaller lake volumes. This indicates that the contaminants enter the water via the atmosphere.

The Envisat satellite. (Image: ESA)

Methane-based fuels for «clean» exhaust gas

Replacing petrol and diesel by methane-based fuels, it would significantly reduce the amount of CO_2 released into the atmosphere by road traffic. In the «Clean Engine Vehicle» project, the Empa has, in cooperation with the ETH Zurich, developed a methane-fuelled automobile engine. Results show that, in contrast to petrol engines, methane-fuelled motors allow a higher compression ratio to be used simultaneously with an exhaust-driven turbocharger. When combined with an advanced motor control system and suitable catalytic converter, tail-pipe emissions in such an engine can be highly reduced. The necessary conditions for the change to using methane-fuelled engines have thus been identified.

Satellite-based pollutant measurements

Air pollution data derived from satellite-based instruments can, with the help of meteorological models, be combined with ground-level measurements to give a comprehensive picture of atmospheric emissions, transport and distribution. The European Space Agency ESA has developed applications, which make satellite data useful for pollution monitoring purposes. At the Empa, we have used tropospheric data derived from satellite measurements (from the University of Bremen) for our investigations. It could be shown that when the alpine and lower-alpine measurement stations record elevated levels of pollution, transnational long-distance transport can play as large a role as local sources.

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ICT in the service of the environment and society

The Research program «Sustainability in the Information Society» (SIS) deals with the opportunities and risks for sustainable development involved with digital Information and Communication Technology (ICT).

The Empa has realized the project «The Precautionary Principle in the Information Society – the Risks of Pervasive Computing for Health and the Environment» for the Center for the Evaluation of the Effects of Technology. As a result, measures have been formulated to minimize the potential risks involved when invisible computer technology pervades every day life.

In order to develop ICT applications in the field of renewable raw materials, the Empa has created a Laboratory for Geographical Information Systems (GIS) and Remote Sensing. This offers the computer hardware, software and above all expert staff for the purposes of evaluating satellite data and visualizing environmental data.

The Commission for Technology and Innovation (CTI) project «Information Technology Solutions for the Swiss Transport Industry» has played a significant role in the optimization of road transport logistics through the use of ICT. Optimal analysis of the available data leads to the avoidance of many trips by unloaded vehicles. The project was executed with the collaboration of the Swiss Universities of Applied Sciences at Solothurn, Lucerne and Basel, and Circon AG.

Further development of methods

The SIS program has developed a new way of tackling the problem of the determination of functional units in the Life Cycle Assessment (LCA) of ICT products. In a doctoral dissertation supervised jointly by the Empa and the Swiss Federal Institute of Technology, Lausanne, this method is used for the analysis of the ecological life cycle of an ICT-based service, taking mobile telephony as an example. The aim is to reduce the environmental burden caused by the use and disposal of future mobile telephones

ICT encourages globalization, creating both opportunities and risks in striving for the goal of sustainable development.

Creation of data foundations

SIS has initiated a «Network of Excellence» in the EU 6th Framework Program which is aimed at structuring and coordinating European research efforts in the field of Environmental Informatics.

In addition, SIS is involved in the preparation for the World Summit on Information Society (WSIS) through the ICT Working Group of the Swiss Academy of Engineering Sciences (SATW). The summit takes place in December in Geneva.

The subjects covered in SIS program have found their way into university syllabuses. Interdisciplinary courses in this area are being offered by the University of Basel (Man-Society-Environment) and Webster University in Geneva.

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The human being at the center of attention

The benefits of this research program are very clear to see: the projects help to protect humans, to maintain and improve their health and to increase the body's ability to work. These factors are gaining more and more importance as a result of the ever-increasing life expectancy in the industrialized countries.

How dangerous is clothing when on fire?

The «BREMA» project offers answers to this question, using «Henry», the anatomically correct dummy as an investigative tool. Henry is fitted out with 120 temperature sensors, which measure the heat transfer to the human skin when a clothing is burning, a parameter which is of critical importance in the determination of the severity of the resulting burn injuries. Various factors such as humidity, age and prior treatment of the clothing materials were also investigated. The results show that even thin materials made of fast-burning cellulose-derivatives can produce skin burns.

One way of reducing the flammability of textiles is by developing or changing the fibers of which they are made. Another is the plasma coating of fibers and threads. In collaboration with the Karlsruhe research centre, the Empa has constructed a suitable coating plant. This has already been used to manufacture fibers with high electrical conductivity and good mechanical resistance on a laboratory scale, for use in antibacterial and antistatic textiles.

Close to real-life measurement of the effects of a clothing fire, on «Henry» the dummy. In the photograph «Henry» is being subjected to a feared «surface flash».

New materials for healthcare

Bacteriologically manufactured polymers are suitable starting materials for products with medical applications because they are well-tolerated by the human body (see article on page 32). Additional research is in progress to investigate the behavior of living cells (e.g. division, reproduction, specialization, vitality) at the boundary surfaces of materials. The results obtained aid in the development of materials which encourage the regeneration of diseased or injured tissue.

Safety and comfort in our daily lives

In Switzerland more people die in accidents involving falls than on the roads. The Empa is therefore investigating the risk of falling on various different floor materials. To this end the influence on walking adhesion of the microscopic surface structure and the boundary layer between liquid and solid media is being studied. This is an active contribution to accident prevention by helping industry to optimize its products.

Spending a night in the open air or in a tent brings us nearer to nature. Sleeping bags, however, only insulate upwards and sideways but not downwards. In order to improve the thermal insulation between the bag and the ground the Empa, in cooperation with an industrial partner, has developed a special mat. Its constant air-down filling reduces the critical effects of thermal conduction and convection, offering protection even at very low temperatures and yet being very light. This patented development has received the «Outdoor Award 2002».

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Better life cycle assessments thanks to high-quality data

In the past few years, life cycle inventory databases have been compiled in Switzerland in a variety of areas, however, data was often collected and evaluated using different methodologies. With the goal of systematically and continuously providing standardized and up-to-date life cycle assessment data of high quality, several institutes in the ETH-domain have joined together with a number of federal offices and agencies to form the Swiss Center for Life Cycle Inventories.

In the «Ecoinvent» project under the leadership of Empa, life cycle inventory (LCI) databases in the areas of energy, transportation, waste disposal, construction, chemicals, detergents, papers and agriculture are currently being totally revised, standardized and supplemented where necessary. «Ecoivent» should be providing national and international users with access to a comprehensive and coherent life cycle database by the autumn of 2003.

In 1996, ETH-Zurich and the Paul-Scherrer-Institute (PSI) compiled an LCI database on energy supply systems. These so-called «Ökoinventare von Energiesystemen» also included data on waste disposal and transportation services as well as on the supply of materials. Empa itself performed numerous life cycle assessment (LCA) studies of construction materials, components and structures, as well as of consumer goods such as packaging, detergents, chemicals, paper and communications technology. The Swiss Federal Research Station for Agroecology and Agriculture (FAL) also conducted LCA studies in the agricultural sector.

In order to unify and standardize these databases, the project «Ecoinvent» was launched with the support of a number of federal offices and agencies. The general goal is to create a database which enables standardized compilation, management and calculation of LCA data.

«Ecoinvent» provides access to the kind of quality-assured life cycle data required for truly comprehensive assessments such as evaluation of investments, for example.

ecoinvent

Swiss Centre for Life Cycle Inventories

Quality-assured data warehouse

Consistent, coherent and thoroughly up-to-date data simplify LCA studies and increase their credibility and acceptance. The assured quality of the data in the «Ecoinvent» database and the user-friendly interface provide the prerequisites for establishing LCA as a reliable environmental analysis tool for use in support of an integrated product policy (IPP). «Ecoinvent» will be one of the largest publicly accessible environmental databases in which the quality of data has been assessed both internally and externally. It is not a coincidence that there is also considerable international interest in «Ecoinvent»: Not only Switzerland, but also the EU is increasing its efforts in the direction of an integrated product policy which aims to raise the gross national product while simultaneously decreasing demands on the environment. The basis for all such efforts is comprehensible and reliable supporting data of the type to be provided by the «Ecoinvent» database. With the aid of several sample data sets, the power of the database can already be seen today under www.ecoinvent.ch

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Succes
stories

Environmental acoustics
Top-level Sports and Engineering
High Performance Ceramics
Empa-Academy

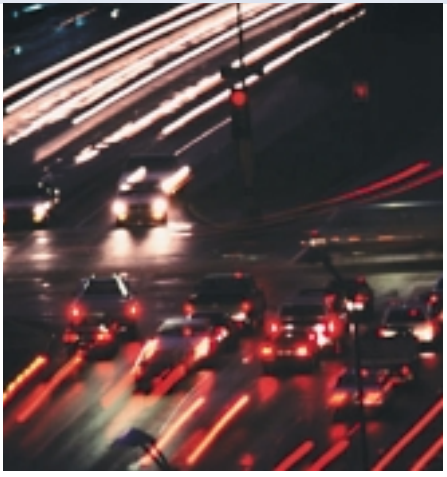
Environmental acoustics

Facts instead of Noise about Noise

Fundamentals and Technology for successful Noise Abatement

In our society, noise is overall. It detracts from living quality and can make people sick. Since tolerance (or intolerance) to noise depends on subjective factors, discussions about noise are often carried out without reference to the objective fundamentals. This is particularly the case when politics are involved. However, a real analysis and solution to noise problems is not possible without knowledge of these fundamentals. Empa strives to provide this basis and has proven its capability through the success of various environmental projects.

In selected areas of acoustics, Empa is in a leading position with regard to research, knowledge transfer and consulting. In addition, in the field of noise control it acts as technical advisor to the Swiss Agency for the Environment, Forests and Landscape (BUWAL) and Swiss Airforce Logistics Command (BABLW).



Contribution to a factual discussion concerning aircraft

According to estimates of the Environmental Protection Agency, approximately 550'000 persons in Switzerland are exposed to traffic noise levels lying above the noise limit. With respect to railway noise, the figure lies at about 265'000, respectively over 100'000 for aircraft noise (civil and military aircraft). Although only in third place, aircraft noise is repeatedly in the headlines. Due to the wide areas of coverage, it is not possible to measure aircraft noise exposure reliably. For this reason, the Noise Abatement Regulation calls for the assessment by means of calculations. Empa has developed a detailed and reliable computer program for calculating the geographic distribution of aircraft noise. The program is named «FLULA 2». In international scientific circles, the program is considered to be quite advanced. It is based upon controlled measurements, which Empa performed at the Zurich Airport (Kloten) on all the common aircraft types. This unique database allows realistic and accurate predictions of the noise exposure at any given location. Thanks to its solid and competent procedure, Empa has gained the confidence of the residents, thus contributing to a realistic discussion. The reliable investigations of the effects of aircraft noise exposure in the regions of Zurich, Geneva and Basle are also highly respected in other countries. This is likely the reason that Empa was asked to evaluate the actual noise monitoring system of the Frankfurt airport. Since various airports (including Zurich airport) impose landing fees which depend on the noise emissions, in the

long run, reliable noise measurements contribute considerably to the development and employment of quieter aircraft types.

Complex Propagation of Road and Railway Noise

Empa applied its know-how in a project toward determining the source strength of road traffic noise. Measurements pointed to a disturbing trend: Heavy vehicles with wide tires are being used increasingly, with the result that the noise generation is rising correspondingly. Study of this development is taking first priority. A second project involves the noise propagation paths. At large distances, sound propagation is influenced strongly by the temperature distribution and wind. In fact, under certain weather conditions sound can even pass over barriers. Empa has developed advanced methods to estimate propagation under various weather conditions. These methods are also suited to obtain a reliable calculation of railway noise exposure.

Successful Technology Transfer

Long-term noise abatement strategy concentrates on measures at the source. In the ideal case, the noise should not even be generated in the first place. In this context, Empa has been successful with regard to heat exchange pumps. Within the framework of a project conducted with the Swiss Association for Heat Pump Promotion (FWS) and Sulzer Innotec, industry was made aware of the existing problem. This resulted in the development of quieter models, which are now available on the market. Considering the goal of the program «Swiss Energy», namely that 120'000 heat exchange pumps are expected to be installed up to the year 2010, this represents notable progress.

Measuring the directional emission characteristics of an Alouette III helicopter at Turtmann airfield.

Fighting Noise with Noise

In the area of noise control, Empa is also engaged in research and development of actively controlled construction elements with the purpose of reducing sound and vibration. In 1999 an actively controlled window with improved sound insulation could be demonstrated. The principle was applied to a double-glazed window but may also be applied to other double-wall structures such as separating walls in buildings or walls of vehicles and aircraft. However further development efforts will be required in order to transfer these basic results into finished products. A future topic for EMPA research could focus on investigating noise generating effects on surfaces in the microscopic scale and to develop suitable material surfaces.

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Top-level Sports and Engineering

A high-tech link between disciplines

While they sailed against the competition from New Zealand, several crew members onboard the racing yacht Alinghi were regularly in touch - as previously in the Louis Vitton Cup - with technical specialists at Empa. Victory in this high prestige and high stakes duel would only be within reach of the team which pushed the limit in all respects. This was as true for the skipper and his crew as it was for the designers of the yacht and their suppliers.

The rigging of modern racing yachts is much less the focus of public attention than the design of the hull or the keel. Optimization of the rigging's components, however, is at least as important in order to secure victory. This is particularly true for the stays. Stays are tensile elements stabilizing the mast of the sailing boat which must exhibit the highest possible tensile strength and resistance to failure with the smallest possible mass. In the case of Alinghi, the stays were up to 33 meters long and posed rigging specialists with particularly difficult structural strength problems. Confronted with these problems, the Alinghi team turned to Empa for help.

A technology predestined for transfer

Empa has been involved for some time in the field of strengthening load-bearing structural elements using pretensioned pin-loaded straps made of carbon fiber reinforced polymer (CFRP). Tensile forces are normally transferred into the straps over cylindrical bolts. Initially, the strap elements were made of CFRP layers bonded to each another to form solid laminates. Testing revealed, however, that this fabrication method by no means fully exploited the theoretical tensile strength of the material. Based on calculations and analyses, Empa developed and patented pin-loaded straps consisting of several very thin unbonded strap layers. Under load, the individual layers can slide past each other, thereby reducing stresses in the strap. Using this design, the tensile strength of the straps could be markedly increased to a level much closer to the intrinsic strength of the material.

The trimaran «TechnoMarine», which is equipped with CARBO-LINK stays.

Empa enters the international racing yacht scene

As is frequently the case with technology transfers, the impulse to apply this successful technology and the associated expertise to the construction of yacht rigging came about through personal contacts. The result was Empa entering into the field of stay development for racing yachts in the worldwide limelight of the Alinghi Project. Another task was the development of the stays for the trimaran TechnoMarine with which Swiss skipper Stève Ravussin competed in the 2002 Route du Rhum single handed regatta. The high-performance stays developed at Empa are basically long, thin and very light pin-loaded straps consisting of thin unbonded layers of CFRP.

Development at the limits of feasibility

The stays for Alinghi were designed along the same lines, however, CFRP was replaced by the high performance fibrous material PBO (polyphenylene benzobisoxazole) which exhibits outstanding tensile strength. The equipment on the yacht is constantly being perfected, even while racing is in progress, driven on in part by detailed observation of the competition. The specialists at Empa are in touch with the Alinghi team and also tirelessly push their development work forward. Among other issues, aerodynamic effects are currently being combated which cause the stays to oscillate at high wind speeds. Solutions such as streamlined fairings are being considered to solve this particular problem. The excitement associated with working at the leading edge of materials development, rapidly transforming new ideas into working solutions and testing them under real-world conditions motivates all those participating to give their very best.

High-tech link made of carbon fiber reinforced polymer (CFRP)

Spin-off for commercial utilization

Empa's involvement in top-level yachting spawned the formation of a spin-off company named Carbo-Link Tendon Systems GmbH (www.carbo-link.com) by a team of Empa technical specialists. The company will commence work in May 2003 and commercially apply the patented know-how and processing of fiber-reinforced tensile elements to problems in civil engineering, racing-yacht construction and other fields.

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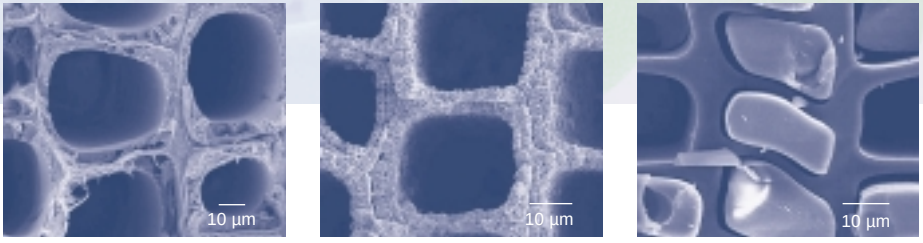
Ceramics: Materials with a past and a future

Successful development of ceramic materials and processing procedures

Ceramics are among the oldest known materials known to man, however their future in technical applications has only just begun. In many areas, modern high-performance ceramics are being used by researchers and engineers to solve the problems of our time, including the development of environmentally-friendly power sources, the minimization of damage to a material caused by wear and ensuring the supply of clean drinking water.



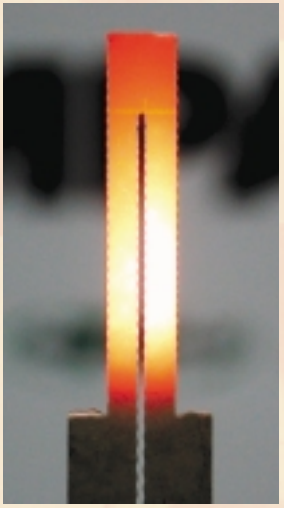
Materials made of ceramized wood have selectable porosity, and find applications such as filter elements, catalyst substrates and high-temperature insulation. (left: wood structure, middle: silicon carbide derived from wood, right: pyrolized wood.

The positive attributes of high performance ceramics are extreme hardness, resistance to wear and corrosion, low mass, good biocompatibility and a variety of special electrical properties. The technical applications of this class of materials has been under constant development since approximately 1970, and new materials and application areas continue to be discovered. Since being founded in 1982, the Laboratory for High Performance Ceramics at Empa, in cooperation with academia and industry, has made important contributions to the development of innovative materials, their processing and their applications.

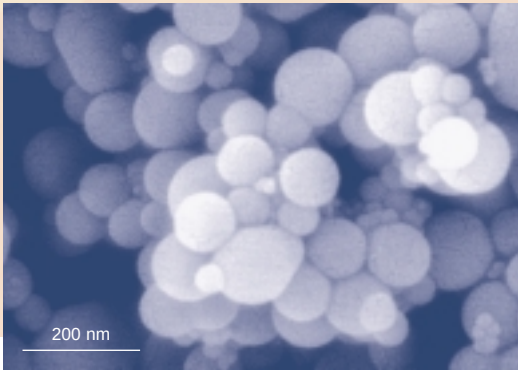
Economical fabrication of high-performance solid oxide fuel cells

Solid oxide fuel cells convert the chemical energy of a fuel directly into electrical and thermal energy without combustion. Supported by the Bundesamt für Energie (Federal Department of Energy), Empa is concentrating on the development of high-temperature solid oxide fuel cells with ceramic and metallic components. In domestic homes, for example, such cells fuelled by natural gas will be able to supply electricity and heat in an environmentally-friendly manner independently of the domestic electricity supply.

Using a novel cell design based on metallic and ceramic layers, a solid oxide fuel cell has been realized which exhibits an outstanding power density of 430 mW/cm^2 at an operating temperature of 800 °C. Parallel to the development of the materials involved, an innovative and cost-effective fabrication procedure has also been developed. This combines dry pressing with spray pyrolysis, a process in which heated ceramic powders are sprayed onto a substrate under vacuum. The project, performed in cooperation with ETH Zürich, ETH Lausanne and an industrial partner of Empa, has been successfully concluded and all the fundamental knowledge necessary to develop the various procedures further for use in practical applications is available.



Glow igniter for gas-heated systems.



Silicon dioxide nanoparticles coated with a 5 nm thick platinum sputter layer.

Strengths of steel and high performance ceramics combined

Wear- and corrosion-resistant materials are needed for use in tools, machines and industrial plants. While high-performance ceramics are wear resistant, they are very brittle compared to metals and thus liable to fracture. The ideal solution is provided by composites of the two material classes, so-called metal-matrix-composites (MMCs), which combine the advantageous properties of ceramics and metals. In this area, Empa is actively involved in the EUREKA-Project «Damage-Tolerant Metal-Ceramic Composite Materials" funded by the Kommission für Technologie und Innovation (KTI; Commission for Technology and Innovation), as well as in a number projects funded directly by industry.

The processing of composite materials based on silicon carbide in combination with metals and alloys having low melting points is well understood. For a variety of applications, however, the properties which could be provided by steel-ceramic composites would be more suitable. These properties include a particularly high fracture toughness and, of special relevance in the pharmaceutical and food sectors, chemical fastness with respect to foodstuffs. Because the well-established ceramics used in combination with low melting point metals degrade at the temperatures required to melt steel, innovative solutions had to be found to process these materials.

Selected oxides proved to be sufficiently chemically-resistant to be incorporated as the ceramic component into a steel matrix. Through exacting process design, parts with dimensions on the order of centimeters exhibiting homogeneous microstructures can be fabricated. At the end of 2002, the project reached an important milestone in the form of a patent application for these ceramic metal composites, their fabrication and the optimization of their microstructures.

Competitive advantage through the extrusion of ceramic filters

Through a KTI-funded project in cooperation with a Swiss company, Empa developed a new and economical process to manufacture ceramic filter elements used to remove bacteria from water. Previously, the tubular filter elements based on diatomaceous earth had been produced by a slip casting process. This process yielded a high-quality product at a high cost, and this latter fact was a serious disadvantage on the international market. Today, the filter elements are manufactured via the extrusion route at approximately half the cost, finishing after sintering is no longer required and the quality standard has been maintained at its previous high level.

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Empa-Academy

Knowledge Transfer Platform and Discussion Forum

The Empa-Academy in its third year of existence

Compared to the previous year, the Empa-Academy was able to increase the number of participants at meetings, courses and presentations by 30% to 6000. The Academy has thus made a good start as a platform for the transfer of know-how and as a discussion forum for socially-relevant topics.

Information technology bridges distances.

Next to courses, meetings and presentations, six Science Forums were held at the Empa-Academy, each of which was attended by an interested audience of, on average, 100 people.

Fuels and Vehicles for the 2000-Watt Society

Traffic, and its associated rapid increase in consumption of energy resources, is partially responsible for the climate changes threatening our planet. To counter this problem, commercially-viable propulsion concepts are being sought which would significantly and sustainably reduce our dependence on oil and the emission of green-house gases and other airborne pollutants.

While a representative from the Swiss Association for Transport and Environment (ATE) promoted intelligent mobility management combining cycling, car-sharing and the use of public transportation and private cars, a speaker from BMW presented the vision of a hydrogen-fuelled internal combustion engine. A specialist from Empa reported on advances in the area of efficient super-low-emission vehicles powered by natural gas.

Nanotechnology – Small particles, big effect

Because nanoscale materials harbor interesting possible solutions to problems in many areas, new technologies and processes are being developed at a rapid rate. For example, carbon nanotubes acting as electron sources open new possibilities, and Empa is actively working on this subject. The company Bühler AG has developed a new comminution and deagglomeration process which enables, for instance, the economical production of nano-pigment-based paints. Empa has demonstrated new combinations of materials which, by virtue of their special nanostructure, make tools more wear resistant.

Adaptive materials systems – (r)evolution in technology?

How can the sound-insulating properties of windows be further improved? The application of adaptive materials systems provides one possible solution. These systems respond usefully to changes in their environment by autonomously altering their properties. As a speaker from Empa reported, first successful developments have been achieved in noise and vibration suppression. Detrimental acoustic and vibration waves are cancelled out by counter-waves superimposed by an active system. The Center of Competence at Empa concerned with this research is supporting the transfer of results into practical applications. The challenges facing the development of materials and technology were illustrated by the speaker from the Fraunhofer Institute for Silicate Research with the example of integrated piezoelectric sensor/actuator materials.

No sweat, no prize – New developments in sports and outdoor clothing

In today's world, sports and outdoor clothing must increasingly exhibit «functionality». There is a demand for articles of clothing which exhibit humidity- and heat-exchange properties which are adapted to their respective areas of use.

The Institute of Hygiene and Applied Physiology at ETH Zürich demonstrated that clothing and sweating are significant factors in determining the comfort level and energy balance of an individual. The development of new materials with adaptable properties at Empa will help to improve the performance and user-comfort of clothing and minimize the feared loss of body heat experienced after participating in sporting activities.

Information technology – The key to sustainability?

Does the path to an information-oriented society automatically lead us closer to the goal of sustainable development? Despite rapid technological developments, the power requirements to support our ever-growing information and communications infrastructure will increase significantly in the future, as shown by a speaker from the ETH. In a heated discussion, two Empa representatives debated the pros and cons of information technology. The problems facing sustainable development were introduced using the example of obsolete electronic goods.

Almost 6000 visitors participated in activities held in the EMPA Academy.

The bridge of the future

The world-renowned bridge builder from Switzerland, Prof. Dr. Dr. h.c. Christian Menn, has determined that, in contrast to the fields of automobile and aircraft engineering, physics and chemistry, technological innovation has not occurred in bridge engineering for a longer period of time. More research and development is needed, for example to realize tougher coatings for steel reinforcements in concrete and to improve the sealing of concrete surfaces. Empa presented a wealth of suggestions for the future, including the development of intelligent and adaptive bridge systems.

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What is a Science Forum?

With its regularly-scheduled Science Forums, the Empa-Academy broaches technical and socially-relevant questions. At each event, three to four speakers from the worlds of research, politics and economics present results and opinions in presentations treating the topic at hand. Over refreshments following the presentations, everybody, including those not familiar with the subject of the day, can discuss matters further with the speakers.

Selected projects

Only the best material for tunnel construction
Nanomechanics – tools for the nanoworld
JunFunori – a technically improved natural product
Biopolymers – bacteria as plastic suppliers
How pollutants reach the Jungfraujoch
Doping tests at trace concentrations
Ecological disposal of used electronics

Only the best material for tunnel contruction

Situation

Searching for the best sealing and drainage systems (SDS)

The Gotthard base tunnel covered by mountains rising up to 2‘500 m will, upon completion, be the longest railway tunnel in the world. Not only there, but also for the Lötschberg tunnel, pioneering developments

Sealing and drainage system: waterproofing membrane with lap joint with test channel and drainage material.

in sealing technology for future tunnel constructions have been achieved. For both tunnels, the huge rock layers create unfavorable conditions. Compressive loads and rock temperatures up to 45° C combined with mountain water can cause considerable damage to both, tunnel construction and railway installations. Thus, tunnel engineers are challenged in seeking new methods for pressure-less drainage of the intruding water. The goal is to find the best suited sealing and drainage systems (SDS) made from polymers, enabling a double-shell construction with a shotcrete outer layer above the inner concrete shell.

Project

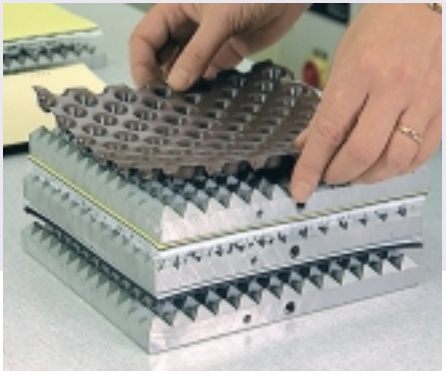
Simulation of the installation conditions

There is a service-life requirement of 100 years for the materials to be used. However, definitive long-term experience with presently available materials that allows reliable predictions does not exist. First, before the materials evaluation, requirements had to be formulated. The AlpTransit construction consortia therefore assigned Empa the task of evaluating the suitability of the various SDS submitted by industry. In order to simulate the conditions in the Alpine railway tunnels, the sealing systems were tested in a series of exposures in a two year resistance evaluation procedure.

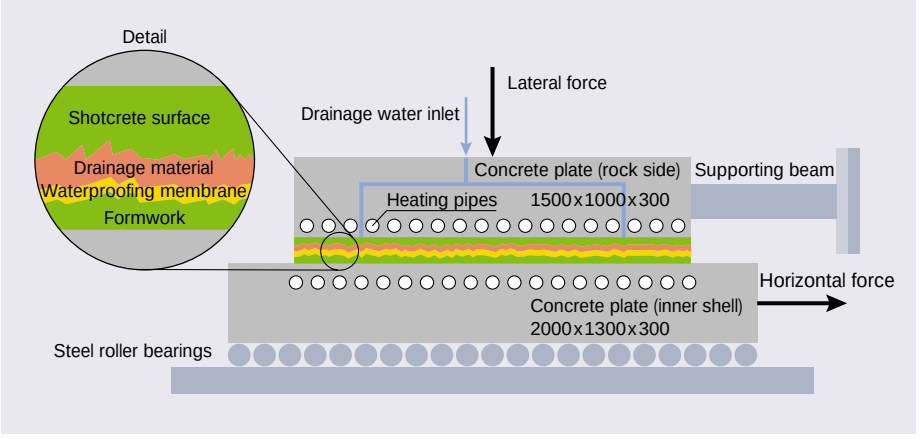
Realization/Results

Materials technology under water and compression loads

During 24 months, SDS-material specimens were stored in alkaline, acidic and oxygen-enriched water at temperatures up to 70° C and exposed to an environment of aerobic as well as anaerobic micro-organisms. In com-



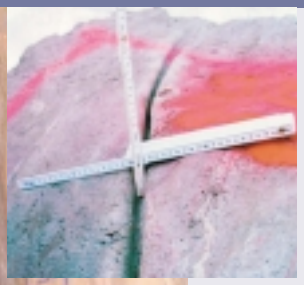
Sealing and drainage system between smooth and rippled pressure plates.



Schematic cross-section of the compression/shear set-up for the determination of the drainage capacity.

Removal of the concrete support shell for the inspection of the waterproofing membrane.

pression tests, the sealing and drainage systems were stored in alkaline water, each clamped between a smooth and rippled pressure plate. Already after six months, some materials showed first signs of deterioration. Therefore, a second series of evaluation tests with optimized SDS proved necessary from which suitable material combinations could be determined. A test series in which large size samples of SDS in a sophisticated test set-up producing vertical and horizontal mechanical loading were subject to combined lateral load and horizontal shear still went one step further. In order to be able to simulate both, the high temperatures present underneath the mountain cover, and the effects of water exposure, and thus to determine the drainage capacity, the test set-up



Deep groove in the concrete support shell caused by folds in the waterproofing membrane.

was equipped with heating pipes and a sophisticated water circulation system.
For assessing the suitability of the materials for installation and during the concreting of the inner shell, sealing and drainage systems were installed in a test gallery under conditions equivalent to those on the construction site, covered with conrete, and then re-exposed. It turned out that that due to the waviness and surface roughness of the shotcrete surface and to the number of fixation points folds had formed in the waterproofing membranes. Due to the high strains in the folds, cracks could later have developed in these locations.

Inspection of the welded joints before concreting.

Sparking innovations in tunnel design and construction

During the project, partners form industry repeatedly used knowledge and research results generated at Empa in order to formulate and produce new, more robust material systems that were temperature and oxidation resistant and yielded higher compression stiffness and improved aging resistance. A variety of material specific and technological innovations were thus developed in the course of the project. Progress was achieved, not only with respect to welding technology but also a new fastening technique for the waterproofing membranes was introduced, utilizing a flexible Velcro fastener instead of the fixation points. Likewise, the problem of fold formation was solved: the stringent requirements on the surface geometry of the shotcrete layer led to a new, three-dimensional measurement method which is being applied everywhere inside the Lötschberg tunnel.
Together with professor Hans Böhni (emeritus) of the Swiss Federal Institute of Technology, and the AlpTransit construction and the engineering consortia, new standards for the durability of these constructions of the century were set and pioneering work was performed. In this way, the engineers are well prepared for future large tunnel constructions, both domestic and abroad.
A video «The NEAT Licence» describing the project is available.

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Nanomechanics – tools for the nanoworld

Initial situation

Machining of materials at small scales with nanotools

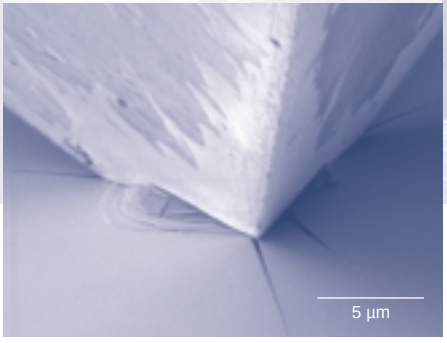
Classical measurement methods for macroscopic materials properties may not be transferred easily to the micro- and nanoworld as physical phenomena change with scale. For instance, as a result of forces on very small areas, extremely high local pressure may be generated that limit lifetime of a device through friction and wear. When working with micro electromechanical systems (MEMS), composite materials, and thin films, exact knowledge of the mechanical materials properties is required. Conventional tensile and bending tests may not be used as traditional standard tools and analysis methods are not suitable for these small dimensions. It is even difficult to grip and load a sample, let alone investigate or adequately machine it. Those who wish to assess the micro- and nanoworld need new and reliable tools.

Idea

Analysis in the nanolaboratory - with the help of scanning electron microscope

Alternative methods to perform tasks in the nanofactory have existed for some time. They do not allow, however, to obtain information about fundamental materials properties like fracture toughness or stress strain curves. Therefore, measurement methods like nanoindentation are employed. During nanoindentation a diamond pyramid penetrates (indents) a surface while continuously recording load and tip displacement. In this way the elastic modulus may be determined, even if the indent is too small to be observed under an optical microscope. To assess the plasticity of specimens, the indentation is analyzed by computer-aided, numerical methods (finite element calculations). In this way intrinsic material properties like load-displacement curves may be determined.

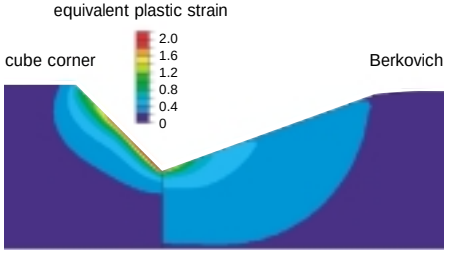
Through visual inspection during the measurement additional knowledge on materials properties may be gained. Therefore, a controllable and miniaturized nanoindenter is being integrated into a scanning electron microscope. The midterm aim is the integration of a complete mechanical analysis laboratory inside a scanning electron microscope. The handling of small specimens inside the vacuum chamber of the microscope will be performed by the nanofactory tools that will transport and selectively load the samples.



Diamond pyramids leave traces during nanoindentation.

Useful tools for the nanofactury and algorithms

In cooperation with two international tool manufacturers particular setups were built for use inside the scanning electron microscope that allow to analyze the behavior of materials under compressive and tensile loading as well as under bending. Partners from France, Germany and Switzerland constructed within the European project ROBOSEM micro-robots that allow to handle miniaturized specimens on a platform inside a scanning electron microscope. Furthermore, algorithms were developed together with Ecole des Mines de Paris and ETH in Lausanne that allow to convert nanoindentation load-displacement data into stress-strain curves. In this way results from nanoscale measurements may be better compared with results from tensile tests at macroscopic scales.



Computer simulation of the deformation field around a nanohardness impression.

Perfect nanotools for new application domains

The huge potential of nanomechanical tools in combination with a scanning electron microscope and numerical simulation has been demonstrated in a variety of projects. The application of indenter tips with different shapes allowed successful determination of the stress-strain curves of MEMS-parts and thin films. Similarly the deformation behavior of aluminum fiber composite transmission lines could be investigated precisely. Current projects are dedicated to the investigation of different shapes of pyramidal indenters.
Other ideas are related to the use of nanoscratch tools. It has been shown that an atomic force microscope can be used to engrave mechanically a pattern into a surface that can be activated for selective electrodeposition of materials within the pattern. Another project within the national nanotechnology initiative «Top Nano 21» is related to the investigation of the fundamental modes of crack propagation in semiconductor crystals using the nanofactory tools integrated into the scanning electron microscope.

«Empa» – engraved by nanotools onto a cross-section of human hair.

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JunFunori – a technically improved natural product

Situation

Japanese red algae saves chalking matte paint

Matte paint is found in all eras and cultures – from prehistoric cave paintings to the chalk drawings of Joseph Beuys. Due to environmental influences, use and material composition of the work of art, the paint layer can become chalky and flaking. The consolidation of matte paint is a great challenge to conservators.

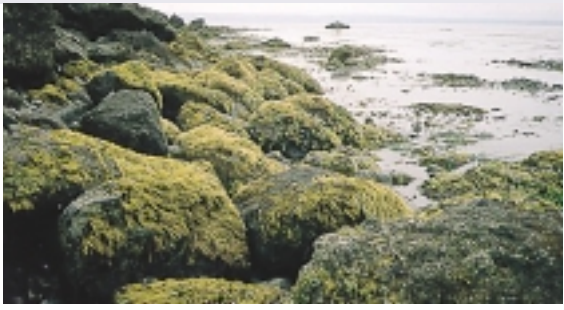
In the last few years conservators have taken interest in a Japanese adhesive from red algae called Funori (Fu = sea, No = moss, Ri = fragrance). However, in order to evaluate the possible risk by the application of Funori, the material had to be investigated. Accelerated aging tests were made to determine the chemical and physical stability. Susceptibility to micro-organisms such as fungus had to be studied.

Board from Wall Painting by Hans Erni (National Exhibition, 1939), Swiss National Museum, consolidated with JunFunori.

Project

Coping with quality variations in Funori

In an interdisciplinary project the consolidant extracted from the red alga species Gloiopeltis was investigated. In the project, Empa cooperated with the Institute of Monument Conservation of the Swiss Technical University and the Center of Conservation of the Swiss National Museum. The good properties of this consolidant could be confirmed. Funori is a natural product and therefore of variable quality depending on the growing area and the processing. To counter the disadvantages of the traditional natural product Funori a cleaning process was developed in a follow-up project at Empa and a new consolidant extracted from red algae was produced.



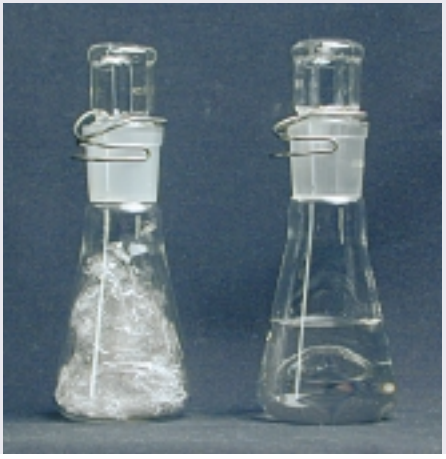
Gloiopeltis furcata grows on rocks in the splash zone.

New JunFunori investigated under laboratory and museum conditions

The new, colorless product JunFunori (Jun = pure) has the same good properties as Funori but the adhesive strength is higher and it is considerably easier to apply. To investigate its long-term stability films of Funori and JunFunori were artificially aged by means of increased exposure to ultra-violet light and simultaneously to fluctuations of temperature and humidity. Results: Neither of the two products showed changes, the chemical and physical properties remained flawless.

Fortunately, the films also have excellent optical properties: They were transparent and neither milky nor yellowed or faded. They remained mat and did not become glossy; they still were elastic, not brittle and did not tear or split off. The surface of the consolidated paint layers did not show any marks like fogging, tide marks or darkening. The excellent optical properties make it an important alternative to common consolidants.

Since model tests are merely approximations to reality, the new product was investigated on several objects of the Swiss National Museum and the Ethnographic Museum of the University of Zurich. Further conservators received small samples of JunFunori including the recipe so that they could test the new Empa product in their work. The feedback is very positive. In fact, several students at different colleges included their experience with Funori and JunFunori in their diploma thesis.



Consolidation solution from the cleaned algae product

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Further fields of application for JunFunori

Their success motivated the researchers to enter the market with JunFunori. Further projects are proposed to promote a better understanding of Funori. The new findings will be important for the further development of JunFunori. In order to satisfy the increased demands for the product, large-scale production is to be undertaken in cooperation with industrial partners. It is also conceivable that the new product may be employed in other fields aside from conservation, for example in medicine, pharmacy or in the cosmetic industry.

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Biopolymers – bacteria as plastic suppliers

Situation/Concept

«Bioplastic» with tailored properties

When microorganisms are supplied with nutrients and appropriate carbon substrates, some of the bacteria produce «bioplastic». This polymer substance has significant advantages over common, petrol-based plastic: it can be produced from sustainable resources and is completely decomposed by fungi or bacteria.

Whether the biopolymer is brittle, elastic or sticky depends on the type of microorganism, the carbon substrates, and the growth conditions in the bioreactor. In research projects at Empa and in collaborations with ETHZ and Eawag the proper biotechnical process conditions are being evaluated and optimized, with the goal of producing «tailor-made» biopolymers.

Project

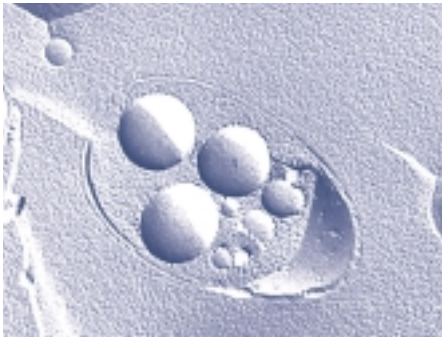
The right diet for the bacteria does the trick

The continuous cultivation in a chemostat allows the control of the carbon flux of the bioplastic producing microorganism. The Empa team investigates the effect of new recipes and various growth conditions on the polymer production and material properties.

To date, more than 90 microorganisms are known to accumulate the bioplastic polyhydroxyalkanoate (PHA) as a carbon and energy storage material. PHA is stored as intracellular granules but can be extracted from the dried cells with organic solvents and purified by precipitation using methanol or ethanol.

Generally, PHA is produced when the growth of bacteria is limited by one nutrient, e.g. nitrogen, but the carbon substrate, e.g. a fatty acid, is in excess. The chemostat cultivation allows the control of the molecular composition and thus the physical and macroscopic properties of PHA.

Controlled growth conditions in the chemostat allow the constant, reproducible production of biopolymers.



The bacterium Pseudomonas oleovorans accumulates polyhydroxyalkanoate («bioplastic») as intracellular granules.

Biological and chemical findings

Crude extract of polyhydroxyalkanoate (PHA) before (left) and after purification (middle and right).

Biopolymers produced with our own recipes are evaluated, not only from the physical but also from the biological and chemical viewpoints. PHA's with short side chains (sclPHA) are thermoplastic substances and can be used for medical applications and throw-away articles (e.g., laboratory material, body care). PHA's of medium chain length (mclPHA) are more flexible than the brittle and stiff sclPHA's. They are likewise well-suited for medical applications.

Biopolymer implants with medical fillings

Thanks to their good decomposition and high degree of biological compatibility, natural polymer substances are materials with many applications in industry, chemistry, pharmacy and, equally important, in medicine. Conceivable products from biopolymers are wound stitches, skin replacement, implants, artificial arteries, veins, and heart valves.

PHA's offer further advantages as well. For example, PHA's may be used as a carrier material for other substances. Thus, in the future medicine may be embedded in PHA implants: As the body decomposes PHA, drugs will be set free at defined rates. Empa is now developing the techniques for this special application.

Also in industry, PHA applications are assessed. For example, «zosteric acid» (ZA) a non-toxic antifoulant from seaweed may be bound to the biopolymers. PHA with ZA can then be applied as a surface impregnation in the fight against destructive biofilm. This is likewise being studied at Empa.

Crosslinking of unsaturated PHA allows the production of a biodegradable rubber.

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How pollutants reach the Jungfraujoch

Current situation

Halogenated greenhouse gases: regulated and forbidden, but still present

The Kyoto and Montreal Protocols regulate the use of a number of halogenated hydrocarbons, which due to their infra-red absorption contribute to the greenhouse effect. The question arises as to how closely these regulations are being followed in Europe. Chemical analyses and meteorological models are required to gain an understanding of the emissions of these substances into the atmosphere. In addition, information is necessary regarding the type and quantity of halogenated compounds used as alternatives to substances forbidden in the Montreal protocol. At the moment, the concentrations of these alternatives are rising rapidly. Of interest are not only the actual concentration levels, but also which regions and countries of Europe are the sources of the emissions.

Project

Measurements on «Top of Europe» for Europe

The concentrations of 23 halogenated greenhouse gases have been continuously measured on the Jungfraujoch (3580m above sea level), using a gas chromatograph mass spectrometer (GCMS) since January 2000. In addition to the Empa GCMS, there are a further three of these instruments (out of a worldwide total of five) in operation as part of the SOGE (System for Observation of Halogenated Greenhouse Gases in Europe) Project. These three systems are located in Italy (Monte Cimone), Norway (Spitzbergen) and Ireland (Mace Head). The common aim is to model the emissions of halogenated greenhouse gases in Western Europe. Thanks to its unique location on the Jungfraujoch, the Swiss station offers the best combination of measurement conditions. The high alpine altitude means that the measured concentrations are practically uninfluenced by local effects. In addition, location in the heart of Europe means that it is nearer to potential emission sources than either Ireland or Norway.

Foreign project partners

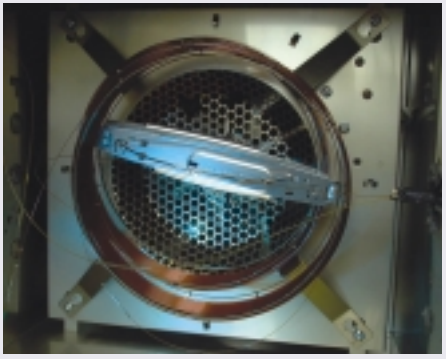
- Norwegian Institute for Air Research (Norway)
- University of Bristol (UK)
- University of Urbino (Italy)
- University of Liège (Belgium)
- Alfred-Wegener-Institut, AWI (Germany)
- University of Oslo, Geophysics Department (Norway)

The High Alpine Research Station, Jungfraujoch, 3580 m asl.

Problematic alternatives replace forbidden substances

The results of investigations over the last three years have shown that the atmospheric concentrations of various chemicals forbidden in the Montreal Protocol have stabilized. However, a significant increase in the concentrations of alternative substances has also been measured. For example the fluorinated hydrocarbon HFC-134a has replaced the forbidden CFC-12 as a cooling medium in car air-conditioning units and household refrigerators. The concentration of HFC-134a is currently rising at an annual rate of 20 per cent.

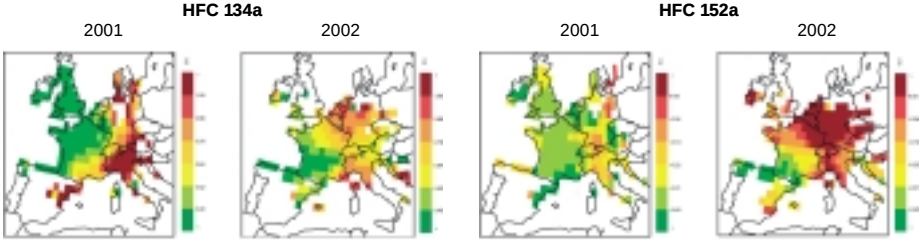
To trace the sources of the emissions, data from Jungfraujoch is compared with data from the other European collaborators and then combined with meteorological information. Trajectory calculations plot the path taken by the greenhouse gas plume. Analysis of the weather and air mass movements over the period of time in question shows the geographical area from where the emissions emanated, the original source of pollution. In the case of HFC-134a, the Po valley, with its high level of industry, has been identified as one important European source.



Gas chromatograph used to analyze halogenated greenhouse gases.

European sources of greenhouse gas emissions under permanent observation

The more data available from measurements, the finer the net for monitoring halogenated greenhouse gases in Europe and the more accurate the conclusions regarding adherence to the regulations over a given period of time. The Empa, together with its European partners, is scaling the models in such a way as to be able to make a comprehensive, quantitative, precise identification of the emissions of halogenated greenhouse gases, and the source of the emissions in Europe. This will provide the authorities with the information necessary to take decisive action against proven environmental polluters.



Modelled potential emission regions for HFC 134a and 152a in Europe, and their development between 2000 and 2002.

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Doping tests at trace concentrations

Background

A guilty verdict must be supported by evidence

In 2002, two players of the Dutch national football team were accused of doping with Nandrolon and subsequently banned from playing. Both players insisted that they had been wrongly accused and questioned the validity of the doping analysis. Following these events, the Institute for Metrology and Technology (NMi) in the Netherlands compiled an independent expert opinion on the data. While this report confirmed that the results were above the threshold concentration of 2 ng/mL, the data were not considered to be sufficiently reliable for a definite conviction. A second expert opinion by Empa reached the same conclusion, and representatives from NMi and Empa were summoned to appear before a FIFA committee to explain their reports. Shortly after this, the sentences in both cases were reduced and since then, both men have returned to professional sports action.

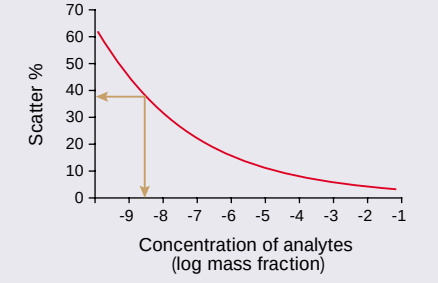
Problem

How reliable are chemical analyses?

Verdicts in doping cases are always based on the results of chemical analyses. Such measurements, however, are naturally never perfect. Multiple analyses of the same sample always yield a scatter of values which differ from each other by varying amounts. This fact is taken into consideration by stating the uncertainty of the measurement. Especially in cases dealing with the adherence to thresholds, it is insufficient to state the result of only a single measurement in relation to a given threshold value. When a verdict is to be passed, it is absolutely necessary to consider the experimental uncertainty, and the greater the consequences of a guilty verdict are for the accused, the less doubt there must be in the analytical results. This approach is applied in many practical situations: In traffic speed traps, for example, a tolerance is always subtracted from the measured speed.

Chemical trace analysis is not a trivial matter

The difficulties encountered with chemical analyses are frequently underestimated, particularly in so-called trace analyses where measurements are performed at very low concentrations. The material to be identified must first be extracted from the sample matrix. In the case of Nandrolone, this is done using solid phase extraction. To then detect the substance, it must first be converted into a suitable derivative, performed by an enzymatic splitting reaction followed by a chemical derivatization (silylization). Only now can the sample be evaluated using coupled GC-MS (gas chromatography – mass spectrometry). With Nandrolon, this all occurs at concentrations of a few nanograms (millionths of a milligram). Double-digit variability in the measured percentage is normal at such low concentrations, even when the greatest care is taken during the analysis.

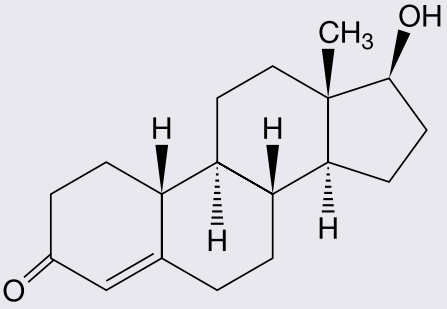


Horwitz' approximation states that the lower the analyte concentration, the greater the scatter in the chemical analysis data. In the ng/mL region (-9 on the scale) double-digit uncertainty is normal.

Nandrolon is everywhere

At first glance, the sentencing of the player with the higher Nandrolon concentrations seems justified. Both the A- and B-samples with concentrations of 2.6 and 2.3 ng/mL, respectively, exceeded the threshold value of 2.0 ng/mL. The clear difference between the two values is indicative of a large experimental uncertainty in the measurements. The fact that the expert analyses by both metrological institutes exhibited large measurement uncertainties indicates the presence of other sources of uncertainty. All in all, this meant that a violation of the threshold value could not be proven unambiguously.

Several aspects must be kept in mind when considering the topic of Nandrolon doping. Nadrolon can enter the human body by a variety of ways without being noticed. In the USA, the drug is present in numerous nutritional supplements which are legally available. Frequently, however, the stated concentration on the container labeling does not reflect the actual concentration in the supplement. A study showed that the consumption of supplements declared as »dopant-free» could result in Nadrolon levels in excess of 600 ng/mL being measured in urine samples. Nandrolon is also used in cattle farming and consequently the consumption of spaghetti bolognaise can lead to significant amounts of the drug being absorbed. Furthermore, the body itself produces Nandrolon at a concentration up to 0.6 ng/mL, and this level can be



Nandrolon

multiplied several times when extreme physical demands are placed on the body.

Deliberate doping with Nandrolon often leads to concentrations of several thousand ng/mL in urine and such high concentrations can be very reliably determined in the laboratory. However, as in the case discussed above where a sportsperson is convicted on the basis of concentrations below 10 ng/mL, the probability is high that the guilty verdict is unjustified. Considering these findings, it is likely that the IOC threshold value of 2 ng/mL Nandrolon in urine has been set too low.

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Ecological disposal of used electronics

Present situation

Mountains of electronic waste with millions of faultless components ...

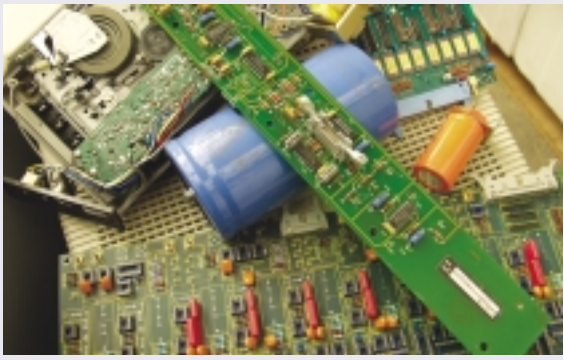
The expected lifetime of electronic consumer goods is usually much longer than their time of use. Television sets are replaced, on the average, every six years, although they are usable for fifteen years or more. When an electronic device no longer functions properly, it is replaced even if failure is caused by a single component only. Thus, electronic waste is piling high with millions of faultless components. In order to avoid the destruction of valuable raw materials, the new Swiss and European laws require manufacturers to take back old electronic devices for proper disposal.

This kind of waste disposal, where only the materials are recycled, is hopefully a thing of the past.

Project

Re-use, repair, recycle or upgrade electronics?

Among the various environmentally acceptable methods, materials recycling is presently favored. However, this is neither from the ecological nor the economical standpoint always an optimal solution. It is often better to consider a combination of repair and upgrading of devices, re-use of components, and recycling of materials. Only by combining different methods it will be possible to achieve a sustaining management of used electronics.
In order to assure that manufacturers are ready to re-use components, validated data as to their functionablility and lifetime expectancy must be made available. For this reason, Empa initiated the project «Care Electronics Materials and Ageing» in cooperation with the Fraunhofer Institute for Reliability and Microintegration (IZM) in Berlin, the University of Natural Resources and Applied Life Sciences (BOKU) in Vienna and 14 industrial partners. The partners from research and practice developed methods to determine the availability of devices, suggested repair strategies and defined criteria for estimating the lifetime expectancy of components. Methods developed for assessing remaining lifetime range from simple visual inspection to procedures in which the temperature in power electronics or the leakage current in logic circuits is measured.



Many circuit boards contain industry-standard ICs (e.g. memory chips) which are suitable for reuse in low-cost consumer applications.

Award

Lillehammer award for ecologically suitable solutions

The tools developed to support the semiconductor industry in recycling and re-use of electronic components convinced the jury of the Research Initiative EUREKA. As a result, in June 2002, at the ministerial conference in Thessaloniki (Greece) the team was presented with the Lillehammer Award. According to the jury, the project allows economically attractive and ecologically suitable solutions to be reached. With 31 participating countries the Research Initiative EUREKA is a permanent tool of the European and Swiss research and technology politics.

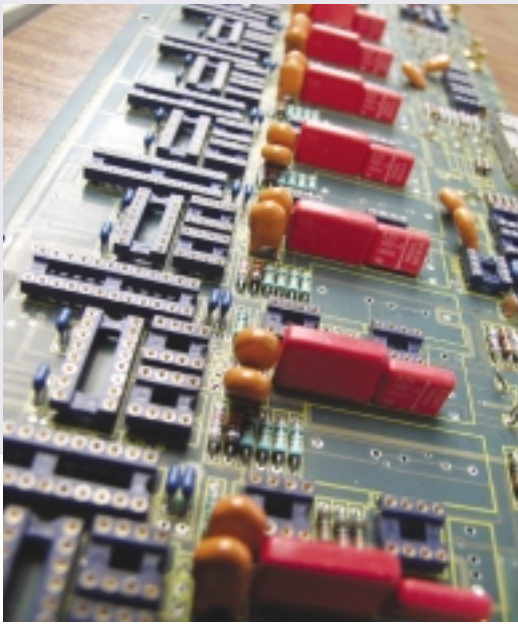
Outlook

Practical indicators, ecological materials and eco-design

Winning the Lillehammer prize encouraged Empa to continue its research in this field. Soon there will be practical indicators for parts and components, which reduce the costs for technical requalification. These indicators will show how much a device had been stressed and whether components of it can be re-used.

Empa is also promoting the use of ecologically compatible materials. It is leading a European project with partners such as the Fraunhofer Institute for Silicium Technology (ISIT) in Itzehoe with the topic of lead-free soldering. Zinc-based lead-free solders are being investigated to develop reliable process parameters for new soldering procedures of electronics.

In the future, electronics manufacturers increasingly will have to deal with ecological design concepts. Therefore design guidelines must be developed which simplify the re-use of individual components and parts as well as the refurbishment (enhancing existing devices with new components).



Socketed ICs can be removed without the need for unsoldering. Hazardous components are then removed and the remainder of the board is sent for material recycling.

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Empa inside

Knowledge Management
Equal Opportunity
Mentoring
Emergency Medical Service/Fire Service
On the Death of Theodor H. Erismann

Knowledge Exchange via Network

The «Knowledge Management» project was established in 1999 with the aim of increasing the net value of the expertise on hand at the Empa by making it more widely available. At the heart of the project lies the vision of a knowledge-oriented research institute whose scientific staff interact with each other to create an active and enthusiastic information exchange network.

Niklaus Kläntschi, President of the SKMF

Knowledge Management at the Empa

Knowledge Management demonstrates how information and knowledge linked to an individual can be secured, further developed and exploited. The quality of research, services and teaching can be enhanced by networked, interdisciplinary collaboration, thus also increasing the competitiveness of the Empa.

In practical applications of this principle, such as the «Yellow Pages», «Communities of Practice» and various different kinds of seminars and meetings, Empa staff are encouraged to exchange knowledge. For example the Empa Academy organizes Scientific Apèros on a current research topic every three months in which external participants and Empa staff meet and network. The first «Research Marketplace», held in 2002, made a significant contribution to interdisciplinary networking between Empa researchers and will in future become an annual event. In the same year the Mentoring pilot-project was initiated and the new internet/intranet website www.empa.ch was created. Fundamental principles of knowledge management flow into Performance Agreements and personnel Annual Reviews. An interdisciplinary working group aims to apply requirement-oriented measures to inculcate a climate of knowledge management awareness within the Empa organization in a rapid and uncomplicated way. It is working towards fostering a suitable cultural atmosphere to this end, and is assisting the Personnel Section in the restructuring of induction activities for new employees. In other smaller projects the group is considering how to deal with knowledge, and is working on a new version of the «Yellow Pages» on the internet/intranet website.

Thanks to the Yellow Pages, researchers can find colleagues with the appropriate expertise more rapidly.

Swiss Knowledge Management Forum founded

The exchange of experiences with other companies and organizations contributes to the development of a practically oriented knowledge management system. The Empa believes this point of view to be important and encourages augmenting the level of such exchanges. For this reason Empa is one of the founder members (and also an active member of the steering committee) of the Swiss Knowledge Management Forum (SKMF). This is a vibrant network of companies, organizations, SMUs, research institutes, universities of technology and applied sciences, and individual persons, based on the Knowledge Management theme.

Swiss Knowledge Management Forum

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«Crystal» – Commitment to Equal Opportunity

For ten years now, women and men have been working together in the «Crystal» project, to foster wider support for an attitude encouraging equal opportunities for all Empa employees.

«Crystal» is committed to raising the proportion of women employees in general, and those in management positions in particular. The project strives to find solutions the problems mothers and fathers face in coping simultaneously with family and professional responsibilities.

Children's crèches are needed to help reconcile the requirements of family and work.

Prix Egalité 2002

The Empa just missed winning the Prix Egalité 2002, awarded annually by the KV Schweiz, the Swiss Association of Commercial Employees, to organizations which show a particular commitment to equal opportunities. The Empa was among the 16 finalists of an original field of 138 contestants. The jury had a difficult decision to make, and was impressed by Empa's many years of support for the principles of equal opportunities for both sexes, in particular by the concrete efforts demonstrated by the mentoring program, work on women's networking, and by the participation in activities oriented toward helping women returning to work after a career break. That the Empa should be recognized by an independent body as having demonstrated a high level of commitment to the principles and practice of equal opportunities is reason enough to be happy and proud, but this should also be an encouragement to continue the good work in the future.

Still a lot left to do

A further occasion for satisfaction is the fact that in 2002 the Empa could boast of having five female section heads (one interim) and a female director of the Empa Academy. However, on other fronts there still remains much to be done, for which reason several multifaceted projects to encourage equal opportunities were launched. For example the «Crystal» project group organized workshops on sexual harassment, and established guidelines for the prevention of such behavior. A survey of the opinions of Empa employees on the reconciling of family and professional responsibilities helped the Personnel Section in the creation of alternative models of flexible working hours. In the Mentoring project a one-year pilot scheme was conducted to encourage young persons – both women and men – to participate in Empa affairs.
More details can be found at
www.empa.ch/kristall

Information dossier on «Sexual Harassment, Bullying and Discrimination in the Workplace» (available in German only).

The «Crystal» group.

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Mentoring – Career Planning for the Next Generation

In these challenging times for research institutions, the Empa has decided to place more emphasis on the encouragement of career development for younger scientists and women, and for a trial period of one year has conducted a pilot-project on Mentoring.

Mentoring contributes to the professional and personal development of younger employees – the next generation of scientists – with the aim of motivating them to take on suitably challenging tasks and/or positions of leadership. It also serves to draw out and develop the potential of young staff, supporting those in management and personnel positions. Mentoring is also intended to contribute to the transfer of personal and operational expertise beyond the three Empa sites in Dübendorf, St.Gallen and Thun, thus also simultaneously supporting the aims of the Knowledge Management system.

Equal Opportunities

The project was supported by the ETH-Council in the framework of the Federal program for Equal Opportunities in the University Environment. The original idea was to specificly foster women. The Empa decided that, in keeping with the idea of true «equal opportunities», the program should also be accessible to men. However, the aim was to have at least 50 percent female participants. Young staff members were offered the chance to be mentored by experienced colleagues over a defined period of time.

Twelve mentors worked together with their mentees on a one-to-one basis toward predefined goals. In confidential discussions the mentors offered their mentees help in helping themselves, and assisted them in finding their individual ways forward. The mentors helped in problem solving and making difficult decisions (coaching), served as «door-openers», established contacts within and without the organization and showed their mentees how to take advantage of these contacts (networking). Finally the mentors were also able to offer concrete help to their young colleagues, for example in the form of introductions to professionally important persons or by invitations to lectures or business discussions.

Instrument for Personnel Development

All involved in the project felt that it had been a great success. The time and organizational energy devoted to it had been well rewarded, and the achievements in terms of reaching personal goals were regarded as very good. The mentees valued not only the confidential discussions which they had had, but also the breathing room which the project gave them – a chance to take a step back from the hustle and bustle of the daily routine. Based on this success, the Board of Directors has decided to introduce mentoring as a regular instrument for Personnel Development.

Young staff members welcome mentoring as an opportunity to further career planning.

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Well cared for – at work too

Larger organizations such as the Empa are legally bound to care for the physical and mental safety of their employees by the provision of emergency services. The Empa takes this duty seriously. With the Empa/Eawag Paramedical Service and the Works Fire Service, staff are offered a level of protection which is well in excess of the legal minimum.

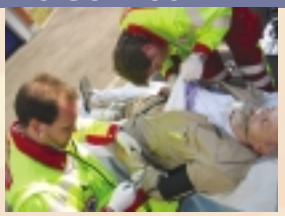
While the participants at a symposium in the Empa Academy are collecting their handouts in the foyer, the main speaker is receiving medical attention for injuries to his foot which he has suffered while setting up his lecturing equipment on stage. The first aid he receives from the paramedics of the Empa/Eawag emergency team enables him give his talk despite his injuries. The occasion is saved by the rapid availability of first aid. Later, the lecturer is driven to a local doctor in the Paramedical Service ambulance, for a check-up and further treatment if necessary.

A few days later the Works Fire Service receives an emergency call and rushes to the incident scene in their own fire-truck, blue lights flashing and siren wailing. Wearing breathing apparatus the fire officers enter a cellar room where thick smoke has reduced the visibility to zero. Insulating material has been set on fire accidentally during building work. The builders are brought out to safety and treated by the paramedics, while the firefighters rapidly extinguish the fire.

High level of training

Fortunately, incidents like these don't happen every day. Most are much less serious and serve as training occasions for the emergency services. The nine paramedics (including one woman) and their chief work in different sections of the Empa and Eawag. They meet every Monday mid-day, and one evening a month, to learn more about accidents involving dangerous substances, about ophthalmic emergencies, human anatomy, emergency medication, reanimation, care of injuries and so on, and to practice and deepen their knowledge of what they have already learned

The twenty fire officers meet monthly on a Monday evening. Here the training program includes learning about materials, locations and buildings, the use of extinguishing agents, evacuation, alarm procedures and much more. Both emergency services practice together often. In a real emergency incident they must be able to work together efficiently, rapidly and in harmony.



Paramedics and the work's fire service in action

An ever increasing range of duties

The emergency services no longer serve merely as first-aid points in cases of accident and illness. In tune with Empa strategy, the accumulated expertise is passed on through training courses to staff and external participants. The «Works Paramedic – Close Up!» seminar was held for the 7th time in 2002, with about 40 works paramedics from across Switzerland attending. In addition basic life support (BLS) and automatic external defibrillation (AED) courses are on offer.

But it is not only in Dübendorf that the staff can feel safe. In Thun, the military medical services take responsibility since the two Empa laboratories located there are sited on military premises. In St. Gallen a small group of paramedics provides first aid to the around 200 employees.

Emergency medical service
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Fire Service
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E-mail: heinz.kuehne@empa.ch

On the Death of Theodor H. Erismann

In the service of safety

On the 8th August 2002, the former Director of the Empa from1969 to1988, Theodor H. Erismann, passed away. As a tenured oder full professor at the ETH Zurich, he was a founding member of the Materials Department.

Erismann's primary research area was in instrumentation for modern material studies. His extraordinary range of interests – from mathematics, via railway engineering, the construction of testing machines, fracture mechanics, material fatigue, and the geotribology of landslides, to the boundaries between technology and psychology – is documented in the more than sixty publications he authored. He vehemently championed the cause of safety for humans and their environment, and achieved a great deal.

Empa
in figures

Personnel
Finances
Investment
Scientific output
Public Relations

Facts and Figures

Personnel

At the end of 2002, Empa had 809 staff, 38 more than the previous year. This increase was due to growth in the number of research personnel, in particular a virtual doubling the number of doctoral students (from 16 to 30). This has had practically no effect on personnel costs, which rose only slightly, primarily as a result of inflation. The proportion of women increased from 24.4% in 2001 to 25.1% in 2002, with four management positions now occupied by women. The number of foreign staff rose to 183, up 6.2% to 23.5%

During the reporting year, 70 individuals (49 the previous year) completed apprenticeships at Empa. In addition, 19 (17) diploma students from the ETH, universities and technical colleges were supervised by the institute. With 29 positions, the number of trainees was down slightly from last year (31).

The emphasis in personnel matters was on dealing with the consequences for staff brought about by the strategic reorientation of Empa, bringing the new employee bill of rights into effect, preparing for the transition from the federal pension fund to the privately-owned «Publica» pension fund and introducing a new salary system.

Staff, 31. Dezember 2002

Category	Number of individuals 2002	2001
Professors	5	4
Research personnel	328	293
Admin. and technical personnel (inc. trainees)	476	474
Total (incl. part time staff)	**809**	**771**

Selected personnel categories

Category	Number of persons 2002	2001
Doctoral candidates	30	16
Diploma students	19	17
Apprentices	70	49
Trainees	29	31

Finances

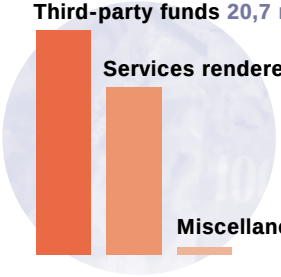
Total revenues in 2002 amounted to 118.3 million Swiss Francs, consisting of CHF 81.5 million in federal funding (CHF 89.3 million in 2001) and CHF 36.8 million in third-party funding and revenues from services rendered. Earnings from the latter, plus miscellaneous revenues, amounted to CHF 16.1 million, or about CHF 0.5 million higher than in the previous year (CHF 15.6 million). This is a good result considering the current economic climate and the fact that Empa is tending to reduce the number of services it is offering. Compared to last year, third-party funds were up by around CHF 0.8 million to CHF 20.7 million. About CHF 8.9 million of these third-

Income: 36,8 million

Third-party funds 20,7 million

Services rendered 15,4 million

Miscellaneous 0,7 million



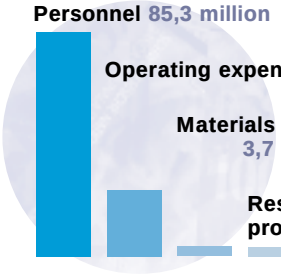
Expenditures: 117,7 million

Personnel 85,3 million

Operating expenses 25,1 million

Materials 3,7 million

Reserves for current projects 3,6 million

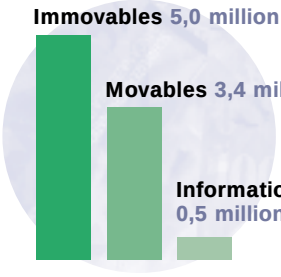


Investments: 8,9 million

Immovables 5,0 million

Movables 3,4 million

Information technology 0,5 million



Income Statement

(in millions of Swiss Francs)	2002	2001
Revenue		
Federal funding	81,5	89,3
Third-party funds	20,7	19,9
Services rendered	15,4	14,9
Miscellaneous	0,7	0,7
Total revenue	**118,3**	**124,8**
Expenditures		
Personnel	85,3	84,5
Materials	3,7	3,7
Operating expenses	25,1	28,1
Reserves for current projects	3,6	3,9
Total expenditure for current activities	**117,7**	**120,3**
Balance	**0,6**	**4,5**
Investments		
Immovables	5,0	5,3
Movables	3,4	8,7
Information technology	0,5	0,9
Total investment	**8,9**	**14,9**

Facts and Figures

party funds came about through industry-oriented research. The remainder was obtained as follows: CHF 6.8 million from departmental service research, CHF 2.8 million from research promotion institutes such as the Commission for Technology and Innovation (CTI) and the Swiss National Science Foundation (SNSF) and CHF 2.2 million from European research programs. The third-party funding of CHF 36.8 million in total covered approximately 31% of total expenditures.

Total expenditures reached CHF 117.7 million (CHF 120.3 in 2001), with the single largest item being personnel expenditure. This increased by CHF 0.8 million to CHF 85.3 million due to inflation and the small increase in the number of staff. Furthermore, CHF 25.1 million were spent to cover operating expenses, CHF 3.6 million were held in reserve for running projects and CHF 3.7 million were used to purchase materials.

Investment in buildings and equipment amounted to CHF 8.9 million in 2002 (CHF 14.9 million in 2001), with construction accounting for CHF 5.0 million (CHF 5.3 million). Investment in movables was reduced to CHF 3.4 million (CHF 8.7 million), and this new trend of sinking investment in equipment and machinery due to a tighter budget gives cause for concern. Investments in information technology amounted to CHF 0.5 million (CHF 0.9 million).

The final balance: For the first time the income statement includes all expenditures and revenues, including funds from third-parties and the federal government, and the values from the previous year have been adjusted for comparison. Since January 1, 2000, movables and information technology goods are Empa property and are being written off accordingly. This caused the final balance to be reduced by CHF 3.9 million from CHF 4.5 million to CHF 0.6 million.

Construction

Since no larger building projects were undertaken during the reporting year, expenditures for construction (investments and maintenance) remained average at CHF 6.5 million. A review detailing the refurbishment requirements for the Laboratory Building and the Administration Building was compiled. Both were built in the 1960's and their shells are now in need of renovation. This work will also permit a number of operational optimizations to be implemented. Empa also participated in defining the requirements for a new Eawag building and in preparing the project details for this enterprise. Shared use of this building is foreseen (entrance hall with exhibition areas, library) and Empa will also have room at its disposal for research and demonstration facilities, particularly in proximity to the building facade, for work in the domain «Energy and Sustainability in Buildings».

With regard to these building projects, Empa and Eawag in cooperation with the administration of the ETH Council have developed a common strategy for the institute grounds and compiled a common portfolio of immovables. Middle and longer-range strategies will reflect future utilization and refurbishment needs.

Finally, together with other involved parties, Empa has participated in the development of the «Giessen Master Plan». This covers the consequences of the future metropolitan railway on the utilization and development of Empa and Eawag and the property south of the Überlandstrasse which is being held in reserve by the federal government.

Scientific Output

At the end of the year, the number of publications had risen 14% in relation to the previous year (from 370 to 423). The number of publications recorded in the Science Citation Index Expanded (SCIE) increased from 67 to 90. Of these, 67 were Science Citation Index (SCI) papers. The latter figure also represents an increase over previous years where annually approx. 40 publications qualified for the SCI.

For the third year running, large growth occurred in the activities of the «Empa-Academy». The number of events organized increased from 71 to 106 and the number of participants rose from 4600 to 6000 in parallel. In contrast, the number of patent applications, license agreements and spin-offs decreased. Here it must be considered, however, that Empa has only limited influence on these particular annual statistics. Relatively large annual variations are judged to be normal and statistically significant interpretation of these particular trends can only be made after longer periods of record keeping.

Scientific output

	2002	2001
Publications		
• SCIE (of which 67 SCI)	90	67
• others	333	303
Total	**423**	**370**
Patent applications	10	14
License agreements	2	6
Spin-offs / Start-ups	1	4
Empa-Academy		
• Events	106	71
• Participants	6000	4600

Facts and Figures

Public Relations

The emphasis in public relations was placed on topics in research and development. As central themes, Empa selected specific activities in the five research departments and prepared these to be presented to a wide audience with interests in research. The population in all three linguistic regions of Switzerland should know what is already well known in expert circles: On the one hand, Empa is a recognized testing institute of high international standing, but on the other it is also an integral part the Swiss research environment. Empa has been continuously developing its contacts in the scientific community and in economic and political circles. The institute participated in a variety of fairs, including Materialica in Munich, the Hannover Messe Industrie (HMI; common booth for the entire ETH domain) and Intertech in Dornbirn. Empa also presented itself in numerous radio and television programs. The media were very interested in the topics of noise measurement/ noise abatement, the natural-gas-powered vehicle, and the focused-ion-beam (FIB; a scanning electron microscope which, in addition to its microscopy role, can be used as a «repair workshop» for microchips with fabrication defects). The Lillehammer-Award bestowed on Empa for its proposals on the subject of recycling defective electronic equipment also received much recognition. Over 1000 individuals took the opportunity to participate in tours of the institute's facilities to gain an in-depth view of the work being conducted. Finally, the new Empa website was also positively received.

Roland Knechtle

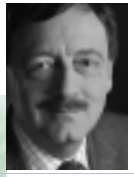
Empa
organization

Management and departments
Organs

Management and departments

Prof. Dr Louis Schlapbach
CEO

Prof. Urs Meier
Deputy



Walter Muster

Advanced Materials and Surfaces

Dr Peter Richner

Materials and Systems
for Civil Engineering

Markus Rüedi

Materials and Systems for
Protection and Wellbeing
of the Human Body

Dr Xaver Edelmann

Information, Reliability
and Simulation Technology

Dr Peter Hofer

Mobility and Environment

Roland Knechtle

Logistics, Controlling and Marketing

Organs of Empa

ETH council

The ETH council has overall responsibility for the management of the ETH domain, which incorporates the two Federal Institutes of Technology (ETHZ, EPFL) and the four federal research institutes (PSI, WSL, Eawag and Empa).

Chairman: *Francis Waldvogel, Prof. Dr med., Genf*

Delegate and Vice-Chairman: *Stephan Bieri, Dr oec. publ., Zürich*

Members:

Adriano Aguzzi, Prof. D. med., Zürich
Monica Duca Widmer, Dr, dipl. Ing. ETH, Manno
Beth Krasna, Dipl. Ing. ETH, Lausanne
Jacques Rognon, Dr sc. nat., Corcelles
Heinrich Rohrer, Dr sc. nat., Wollerau
Alois Sonnenmoser, Dipl. Ing. HTL, Baden

Advisory commission

A body of leading personalities which advises the Empa management on fundamental concerns.

Chairman: *Peter Loew, Dr, Basel*

Members:

Peter Edelmann, Wetzikon
Thomas Hinderling, Dr, Neuchâtel
Markus Oldani, Dr, Baden
Max Oppliger, Dr, Zürich
Fiorenzo Scaroni, Dr, Manno
Walter Steinmann, Dr, Bern
Thomas von Waldkirch, Dr, Zürich

Industry commission

A body of 20 members drawn from industry, trade, the services sector, consumer groups, technological institutions and governmental authorities, both national and international.

Chairman: *Bernhard Bischoff, St. Gallen*

Research Commission

The Research Commission advises Empa's Board of directors on general questions of research, on the choice of R&D spectrum and is involved with the evaluation of internal R&D projects, amongst its other activities. In addition to selected Empa senior staff, it consists of the following researchers and heads of Swiss and foreign institutes:

Robert W. Cahn, Prof. Dr, University of Cambridge, Great Britain
Herbert H. Einstein, Prof. Dr, MIT, Cambridge, USA
Paolo Ermanni, Prof. Dr, ETH, Zürich
Walter Giger, Prof. Dr, Eawag, Dübendorf
Teruo Kishi, Prof. Dr, President National Institute for Materials Science, Ibaraki, Japan
Karl Knop, Dr, Vice-President CSEM, Zürich
Erkki Leppävuori, Prof., Director VTT, Finnland
Jan-Anders Manson, Prof. Dr, EPF, Lausanne
Klaus Müllen, Prof. Dr, Director Max-Planck-Institut für Polymerforschung, Mainz, Germany
Jan G. M. Van Mier, Prof. Dr, ETH, Zürich

The technical-scientific report «EMPA Activities 2002»,
previous Annual Reports and further documentation
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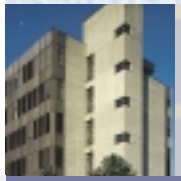

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