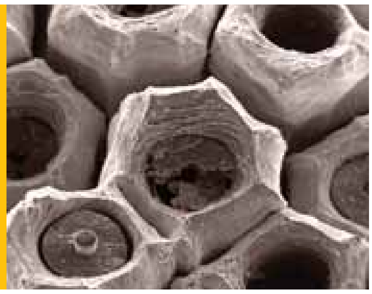
ExtreMat

New Materials for Extreme Environments



project | news

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The European Research Project ExtreMat – Heading towards Breakthroughs in Materials Research for Extreme Environments

Mission and Objectives

The ExtreMat Integrated Project, co-funded by the European Community under the Sixth Framework Programme for Research and Technological Development, targets on the creation of new multifunctional materials being beyond reach with conventional incremental materials development.

Based on an integrated approach, ExtreMat shall push forward the limits in materials technology and will provide and industrialize new knowledge-based materials and compounds for top-end and new applications in extreme environments.

At the beginning of the 21st century, the conventional production industry is undergoing a dramatic change towards an innovative, high-tech, knowledge-based industry. Increasing competition on the global market constantly demands for new and better products and services.

A key driver at the forefront of industrial innovation are new materials which allow to either strongly widen the operational windows of existing systems or even enabling breakthroughs which will lead to new products and systems.

Today in many cases the development of top-end products and systems has reached limits set by the capabilities of currently existing materials. Examples from different industrial sectors are

- electronic components: performance limits due to limited thermal management capabilities of heat sink materials
- re-entry space vehicles and hypersonic aircrafts: safety and life cycle limits due to limited performance of protection shields against aerodynamic loads

> Thermal management is one of the key concerns in diverse fields such as microelectronics and space technology. ExtreMat represents a joint approach to solve these problems.
>
> Dr. Heiko Wildner
> Plansee AG, Austria

- space engines and supersonic combustion engines: lifetime limits due to limited thermo-mechanical capabilities of thruster walls
- high power brake systems, e.g. for aircrafts, formula1 racing cars or emergency brakes for high-speed trains: safety and efficiency limits due to thermo-mechanical limits in brake disc and pad materials
- fusion reactors: limitations of wall materials in the irradiation stability at high operation temperatures which is required for an efficient fusion energy system
- very high temperature gas cooled fission reactors: corrosion of materials in the core; corrosion products which enter the coolant gas prevent the direct cycle energy conversion with the associated very high efficiency.

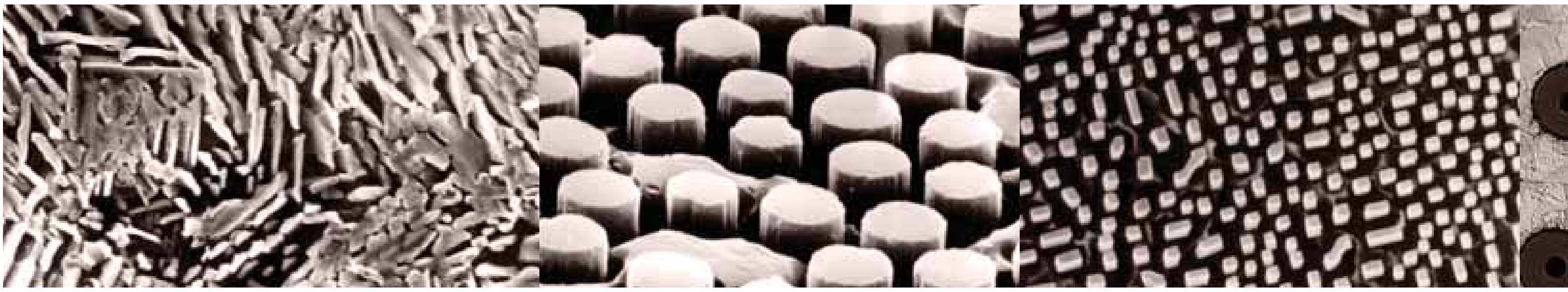
To the extent operational conditions become more and more demanding, existing limitations in materials technology more and more act as roadblocks for breakthrough industrial innovation.

New horizons of performance of products and systems are directly connected with an intense need for innovative materials and processing routes for those materials or complex compounds to perform multiple functions.

The combined research work of 37 renowned institutions throughout Europe joined in the ExtreMat project will contribute significantly to remove such roadblocks in important industrial fields (see "Application fields").

> As a components manufacturer, we find in ExtreMat an exceptional opportunity for joint developments across the supply chain.
>
> Dr. Giuseppe Carlo Gualco
> Ansaldo Ricerche S.p.A., Italy

The project shall result in a generation of new commercial materials and multi-materials components and the corresponding crosscutting processing technologies. The availability of this new materials and compounds will give the European industry a decisive technological lead in the world market.



Extreme Environments

Extreme environments dealt with in this project can be characterised as situations where a complex combination of different loads act simultaneously on a single material or component. Typically, such complex loads can comprise four different basic factors:

Thermal loads e.g. temperatures of more than 2000 °C, heat fluxes up to 20 MW/m^2 requiring thermal conductivities up to 800 W/mK, up to 5 million temperature cycles during the lifetime

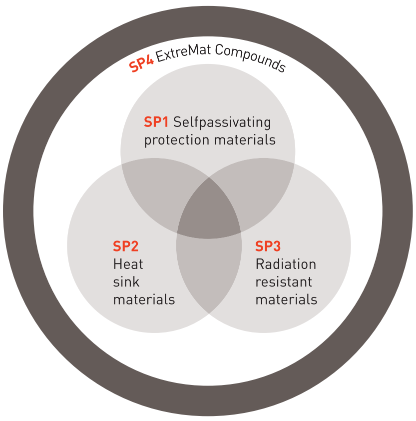
Physico-chemical attacks by aggressive media e.g. oxygen and hydrogen radicals causing internal oxidation, erosion or embrittlement

Complex mechanical loads e.g. from vibrations, aerodynamic forces, friction, thermally induced strain due to mismatch of thermal expansion in bonded compound systems or extremely steep thermal gradients in actively cooled compounds

Strong radiation e.g. highly energetic alpha, beta, gamma irradiation or neutron doses of up to 150 dpa, causing activation, defects and structural changes.

Materials Research

Materials research in ExtreMat focuses on four main aspects, each addressed by one specific sub-project:



For each sub-project, in a first step user requirement specifications (URS) were defined by analysing typical applications in various fields. Then corresponding materials requirement specifications (MRS) were deduced from these URS in a next step. These MRS serve as starting points for targeted materials development. The following materials have been identified as most promising candidates:

- Carbon and silicon carbide based composites with further passivating constituents
- Refractory alloys and nano-structured metallic materials
- Ceramic/metal-matrix composites
- Functional coatings and films (e.g. as interfaces and diffusion barriers)

Application Fields

The fundamental approach of ExtreMat opens a multitude of potential applications in various industrial sectors. Currently, the following fields are particularly addressed in ExtreMat:

- Electronics (power electronics, microelectronics, optoelectronics)
- Space Applications (thrusters, re-entry protection)
- Fusion Reactor Technology (first wall heat sinks, structural materials, hydrogen diffusion barriers)
- Advanced nuclear fission reactors (structure materials, control rods)
- Spin-off applications like advanced brake systems, gas turbines and combustion chambers, dry lubricants etc.

This list, however, is not exhaustive. Industrial users with interest in other potential application fields are welcome to join the ExtreMat Industrial User Group (IUG) to broaden and diversify the generation, use and exploitation of ExtreMat project results.

Contact can be made to the IUG by using the Industrial Entry Point, established on the project website www.extremat.org.

Present State and Further Work

The first two phases of the project have been concluded and the basis for the

Interview with the ExtreMa

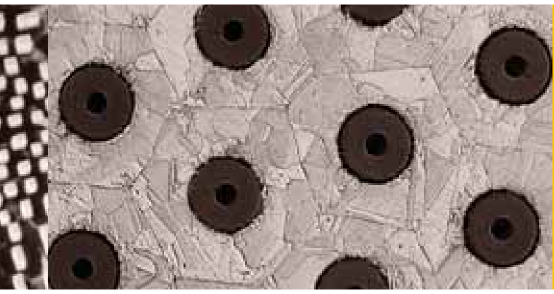
On December 2004 the ExtreMat research project was officially launched after nearly two years of preparation. What initiated this project?

Prof. Bolt: Often the lack of solutions in the materials field prohibits progress on large technical frontiers.

Prof. Dr. Dr. Harald Bolt, Head of Materials Research Division of the Max-Planck Institute for Plasma Physics in Garching/Germany and Coordinator of the FP6 Integrated Project 'ExtreMat'

In my case, the Max Planck Institute for Plasma Physics has the aim to develop fusion as an inexhaustible energy source. It became obvious that the lack of adequate materials is a roadblock to the development of fusion energy.

It also became clear that analogous situations occur in other fields where materials have to provide functions in extreme environments. Thus the consequence was to try to pool the expertises from different application fields and to launch a joint development of new materials in order to overcome these roadblocks.



main R&D phase has been set.

During the first phase the industrial users defined their needs and requirements to the materials to be developed within the project. On this basis a range of new materials which the project could possibly develop has been defined.

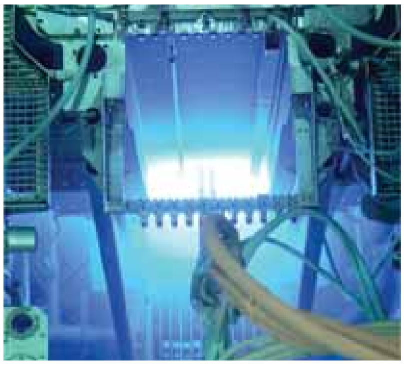
In the second phase of the project this range of materials has been screened by experiments and by theoretical studies. Having identified the most promising materials the full scale R&D activities are now being launched.

Main definitions that have been set for the next R&D activities are:

Self-passivating Protection Materials: passivating dopants and processing routes for carbon-based materials; passivating SiC-based multilayers and composites; alloy compositions for self-passivating refractory metals; parameters of environmental exposure and testing of these materials.

Heat Sink Materials: groups of copper-based composites and possible reinforcement architectures; constitution silver-based composites; programme to develop and optimize the interfacial bonding between composite constituents; reference characterization and testing methods.

Radiation Resistant Materials: consistent modelling activity to identify key processes leading to radiation induced embrittlement and failure; set of new



oxide dispersion strengthened steel alloys for high temperature applications in strong radiation fields; mechanical deformation of refractory metals for improved radiation resistance; set of ceramic materials for specific high temperature applications; irradiation programme in the HFR test reactor.

Compound Technologies: constitution and processing routes for thin film hydrogen barriers; interfacial films for bonding applications of materials to be developed in ExtreMat; bonding and interface development for compounds related to electronic, fusion and space applications; testing of compounds under realistic environmental conditions.

The interactions between the partners with different specialization have been defined for a consistent R&D phase which will have a duration of 26 months.

Based upon the evaluation of the results from this R&D phase the key items related to the industrialization of the most successful materials and compound technologies will be pursued during the remaining project duration in the industrialization phase.

reMat Coordinator Professor Harald Bolt

Cooperative research spanning different application fields is a key principle of ExtreMat. What is the reason for this strategy?

Prof. Bolt: During the first contacts institutions from different fields (space, electronics, fusion, fission, materials research, ...) came together and we found that often common loading conditions and common underlying materials issues exist which could not be successfully solved by singular and isolated approaches.

We can now bring our experiences, methods and tools together into a single project and use these capabilities to jointly resolve the underlying materials issues and to develop new materials.

ExtreMat is co-funded by the European Community as an FP6 Integrated Project. What does this mean for the project?

Prof. Bolt: The cofunding by the European Community provides a stable frame for the project activities.

It enables partners to dive into a new initiative for materials research and development which involves the investigation of the basic underlying questions of materials behaviour under extreme loading conditions up to the industrial upscaling of processes for compound production.

Innovations are essential for the competitiveness of the European industry. Which contribution can be expected from ExtreMat?

Prof. Bolt: One important ingredient to innovation is to bring together scientists and industrial partners which come from different application fields.
Thus new collaborations can form in which innovative ideas can be realized. On this basis we expect to provide to the industry and to the market technologies for new protection materials, heat sink materials and radiation resistant materials.

Within the project a large number of bi- and multilateral collaborations have started which range across application fields. Partners are injecting their knowledge and capabilities also into application fields which are new to them.

Personally, I am most thrilled about the new results which our partners have reported at our latest regular project and coordination workshops.

Regarding the actual scientific/technical development, the spirit is excellent in the project.

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Project Partnership

New horizons of the performance of materials for extreme environments are only accessible by merging the specific expertise so far mostly dispersed in different applications fields and sectors, e.g. materials industry, space industry, electronic device industry, power generation research, and radiation facilities.

Close co-operation of institutions with proven specific strengths is required to successfully resolve the fundamental materials issues, as a basis for subsequent developments of new or enhanced products.

The ExtreMat Integrated Project assembles the necessary critical mass of experts from different materials-related industries, research centres, universities and science institutes throughout Europe in a multi-sectorial and cross-cutting approach.

> ExtreMat keeps us in touch with advanced applications for materials. It allows us to explore and evaluate new possibilities.
>
> Dr. Nick Archer
> Archer Technicoat Ltd., UK

For more information about the project, its progress as well as related publications and presentations at scientific conferences and industrial events, please visit the project website:

→ **www.extremat.org.**

Facts & Figures

ExtreMat is an Integrated Project, co-funded by the European Community under the NMP priority of the Sixth Framework Programme for Research and Technological Development:

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Budget: approx. 35 million €
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Website: www.extremat.org

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The ExtreMat project consortium currently comprises 37 institutions from 12 countries:

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