EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

EUROCORES Programme
European Collaborative Research

Friction and Adhesion in Nanomechanical Systems (FANAS)

Call for Outline Proposals

What is EUROCORES?

The ESF European Collaborative Research (EUROCORES) Programmes offer a flexible framework for researchers from Europe to work on questions which are best addressed in larger scale collaborative research programmes. The EUROCORES Programmes allow excellent researchers from different participating countries to collaborate in research projects 'at the bench'. They also allow, when appropriate, colleagues from non-European countries, for example the US, to participate. The Programmes encourage and foresee networking and collaboration of researchers to achieve synthesis of scientific results across the programme, to link to related programmes, and to disseminate results.
EUROCORES Programmes allow national research funding organisations in Europe and beyond to support top class research in and across all scientific areas, by matching the needs articulated by the scientific community with their strategic priorities.
Funding decisions on the projects and the research funding remain with the national research funding organisations, based on international peer review operated by ESF. ESF also provides support for networking the researchers and for the scientific synthesis of research results and their dissemination[(1)]. This way, the EUROCORES Scheme complements the EC Framework Programme and other collaborative funding schemes at European level.

For further information see:
http://www.esf.org/eurocores

[(1)] Currently supported through a contract with the European Commission under the Sixth Framework Programme (EC Contract no. ERAS-CT-2003-980409).

Funding initiative in the field of Friction and Adhesion in Nanomechanical Systems (FANAS)

Following agreement with funding organisations in *Belgium, Czech Republic, Estonia, France, Finland, Germany, Ireland, Israel, Poland, Portugal, Spain, Slovakia, Switzerland, Turkey,* the European Science Foundation is launching a Call for Outline Proposals for Collaborative Research Projects (CRPs) to be undertaken within the EUROCORES Programme FANAS. FANAS will run for 3-4 years and it includes national research funding, as well as support for networking and dissemination activities provided by the ESF[1].The Programme aims to support high quality multidisciplinary research.

Outline Proposals are to be submitted by 4th June 2007. It is expected that Full Proposals will be invited by 6th July 2007 with 17th September 2007 as expected deadline for submission.

A Programme-specific website can be consulted for the latest updates at **http://www.esf.org/fanas**

Background and objectives

Interfacial friction is one of the oldest problems in physics and chemistry, and certainly one of the most important from the practical point of view. Everyday operations on a broad range of scales, from nanometer and up, depend upon the smooth and satisfactory functioning of countless tribological systems. Friction is intimately related to both adhesion and wear, and all three require an understanding of highly nonequilibrium processes occurring at the molecular level to determine what happens at the macroscopic level.
Over the last decade the fast developments of micromechanics in general, and magnetic storage systems in the computer industry, in particular, has brought up the need for a more basic understanding of the origins and behaviour friction. Friction imposes serious constraints and limitations on the performance and lifetime of micro-machines and, undoubtedly, will impose even more severe constraints on the emerging technology of nano-machines. Standard lubrication techniques used for large objects are expected to be less effective or even not applicable in the nano-world. Novel methods for control and manipulation are therefore needed.
Another rapidly growing application of tribology is in the general field of biosystems, in particular the lubricanting mechanism prevalent in living and artificial human and animal joints. Via the process of natural selection, nature appears to have outclassed the engineer with her natural joints. This is an aspect that should not be overlooked.
What has been missing so far is a molecular understanding of processes occurring between and close to interacting surfaces which is needed to first understand, and later manipulate friction.

Scientific goals

The aim of this EUROCORES programme on FANAS is therefore to gain a better insight on the origins of friction and adhesion and to learn how to control them. To meet such goals, FANAS must bring together *theoretical* and *experimental* tools, as well as, *engineering* approaches which help transfer the basic understanding gained to questions of practical relevance. For this type of research a strong interdisciplinary collaboration is required that covers physical, chemical and material science aspects of tribology over a broad range of time and length scales.

Research topics

To address the objectives outlined above the programme will focus on the following topics:

(i). Adhesion and friction at the nano and microscales
(ii). Mechanisms of energy dissipation in tribological systems
(iii). Bridging the gap between the nano, micro and macro scales in friction, lubrication and adhesion
(iv). New approaches to control and modify frictional properties
(v). Nanomanipulations at interfaces
(vi). Tribochemistry
(vii). Novel tribological systems

(i). Adhesion and friction at nano and microscales

Both adhesion and friction originate from the interaction of multiple nanoasperities between two bodies in sliding contacts. The relationship, however, between these processes is still not well understood. It has been demonstrated that high adhesion is not necessarily accompanied by high friction, and vice versa; low friction is not always accompanied by small adhesion. Adhesive forces play an important role in material science as well as a leading role in the field of biology and life science, e.g., protein folding, locomotion of living objects and membrane assembly. Molecular force spectroscopy provides an ability to measure adhesive interactions under different environmental conditions with unprecedented resolution, and to achieve deeper insight in the underlying mechanisms at the molecular level. To both explore the results of force spectroscopy experiments and to reveal a molecular scale energy landscapes, one has to establish relationships between equilibrium properties of the nanoscale systems and the characteristic features measured under non-equilibrium conditions.

Among the most important direction which should be studied are: adhesion of surfaces with controlled roughness; influence of wetting and non-wetting liquids on adhesion and friction; adhesion and tribology properties of nanoelectromechanical systems; use of single-molecular force spectroscopy to probe the complex relationships between force-lifetime-and-chemistry in adhesion complexes; and development of biologically inspired devices of technological relevance.

(ii). Mechanisms of energy dissipation in tribological systems

The mechanisms of energy dissipation during friction remain controversial and as yet poorly understood. Possible sources for dissipation include elastic instabilities, plastic deformations, breaking and rebinding of atomic bonds, losses to phonon and electron-hole excitations, and more. Dissipation occurs in both contact and non-contact modes of atomic force microscopy. Recent experiments have shown that dissipation depends not only on the front-end atom of the tip, but also on the detailed structure of the tip apex. Another important tool for probing of dissipation is the quartz crystal balance, where the dissipation of adsorbed layers can be measured.

In order to identify and make use (for instance, for imaging) of relevant mechanisms of energy dissipation at the nano-scale further experiments and simulations are needed. These should include studies of microscopic mechanisms involved in the dissipation measured with dynamic AFM techniques, development of new methods to identify nanoscale energy dissipation processes by amplitude modulation AFM, and investigation of elemental dissipation mechanisms by the QCM technique including effects of surface corrugation, adsorbate coverage, interface anisotropy, disorder and temperature.

(iii). Bridging the gap between the nano, micro and macro scales in friction, lubrication and adhesion

Nanotribology has developed in the past decade interesting approaches indicating that wearless conditions and superlubricity can be achieved. One major problem is that our actual understanding on how to translate these approaches in field operating conditions is still far from being suitable. Indeed, there is a real difficulty in bridging the gap between different nanotribological tests with e.g. atomic and lateral force microscopes, and current tribological tests (like pin-on-disk or V-block-on-cylinder testers). AFM-tips induce stresses in the GPa-range while macrotesters operate in the kPa-range, while AFM/LFM operates typically at sliding amplitudes of a few µm, and macrotesters operate at scales ranging from hundreds of µm up to tens of cm. The challenge is now to bring the atomistic

studies and the friction and wear testing approaches closer to each other. To address this problem it is essential to study tribological properties of large ensembles of asperities, the effect of confinement on the properties of embedded liquids, to perform combined MEMS-nanotribology research and to investigate wear at nano- and meso scales under dry and wet sliding conditions.

(iv). New approaches to control and modify frictional properties

The ability to control and manipulate frictional forces is extremely important for many applications. One may wish to reduce or enhance friction, eliminate chaotic and stick-slip regimes of motion, and instead, to achieve smooth sliding. The difficulties in realizing an efficient control of friction are related to the complexity of the task, namely dealing with systems with many degrees of freedom under a strict size confinement that leaves very limited access for perturbation of the system in order to achieve control.

FANAS aims to meet this challenge by addressing the following issues: tuning friction through modification of interfaces, in particular preparation of nanopatterned mating surfaces and surfaces with deliberately structured or templated roughness; control of frictional forces supplementing base lubricants by friction modifier additives and investigations of the possibility to control friction by mechanical means, e.g.: via externally imposed vibrations.

(v). Nanomanipulations at interfaces

The ability to manipulate individual atoms, molecules and clusters with scanned probes has opened new fascinating areas of research which may enable us to perform “engineering” operations at the ultimate limits of fabrication. Another possibility to perform controlled manipulations at the nanoscale is by applying temporal and/or spatially asymmetric forces with zero mean.These approaches can be used to build new molecular suprastructures, to explore the influence of the environment on a molecule, or to realize and test concepts for new nanodevices. To reach such goals we must investigate and model nanotribological properties of adsorbed particles and clusters, study dynamics of nanoparticles and droplets on nanostructured surfaces, to determine the leading factors that allow to control nano-manipulation at surfaces by scanning probes, and develop and study possible mechanisms that are suitable to transform the supplied energy into directed translational or rotational motion without applying an external constant bias.

(vi). Tribochemistry

The field of tribochemistry focuses on the chemical reactions occurring on surfaces under tribological stress. This is central to the understanding and development of lubricants and lubricant additives with greater environmental compatibility, while not compromising their performance. In a given tribological system it is important to investigate various reactions that occur between a lubricant additive and the tribopair, as a function of the applied conditions (load, relative velocity, humidity, temperature, etc.). Tribochemical activation may lead not only to changes in the reaction rates but also give rise to new paths of the reactions. Hence, friction could also be used to voluntarily activate specific reactions resulting in tribo-catalysis or tribo-polymerization. To address these problems it is important to develop new technique for in situ studies of tribological systems, to investigate tribochemical formation (tribocorrosion) of wear-reducing compounds from lubricant additives, to work out novel computational methods for tribochemical reaction dynamics simulations. A full understanding of the nature and origin of chemical and electrochemical reactions are necessary to predict and control friction and wear.

(vii). Novel tribological systems

Studies of novel nano-tribological systems and conditions which, to date, have not been systematically investigated so far present one of most important challenges of this programme. Among the new direction which should be studied are: lubrication with water and some (biomimetic) lamellar systems, which lead to very low friction coefficients; aqueous lubrication by nanoscale brushes; sliding versus rotating friction at the nanoscale; temperature dependence of atomic friction.

Water is not generally considered to be a useful lubricant in technological systems. On the other hand molecular layers of water or aqueous solutions are often found between contacting surfaces under natural conditions, pertaining both to technological and biological systems. Natural sliding partners are frequently elastomeric in nature, rather than the hard surfaces often employed by man.

The effect of rolling friction on the macro-scale has been investigated by many scientists due to its great importance in engineering and natural sciences. Coefficients of rolling friction are generally 10^2 to 10^3 times lower than those of sliding friction for corresponding materials. In this context the following intriguing question emerges: may a similar mechanism work at a microscopic scale; i.e., could ball-shape molecules (fullerenes) or nanotubes work as a ‘‘molecular bearing’’.

It is well-known that the coefficient of friction on the macroscopic scale changes when the surfaces in contact are heated or cooled down. On the nanoscale, the important role of thermal fluctuations has been recognized, for instance, in the velocity dependence of friction, but direct proofs of these effects at various temperatures are still missing.

Guidelines for applications

(Outline and Full Proposals)

Collaborative Research Project (CRP) proposals from individual scientists or research groups eligible for funding by the agencies participating in the Programme will be accepted for consideration in the EUROCORES Programme FANAS.
Proposals must, as a minimum, involve three eligible Principle Investigators (PIs) from **three different countries.** At the same time, a maximum of 50 % of Individual Projects (IPs) in a Collaborative Research Project (CRP) from one country is accepted. A maximum of seven IPs per CRP can be accepted. Scientists or groups not applying for or not eligible to apply for funding from these agencies (including applicants from industry), can be associated with a proposal where their added scientific value is demonstrated. Their participation as Associate Partners in a project must be fully self-supporting and will not be financially supported by the participating funding agencies.
Applications should normally be for three years although applications for shorter or longer time periods may be considered depending on the rules of the participating funding agencies. Taking into account the selection and approval processes, the successful projects are expected to begin their activities in **March 2008**.

Online submission of applications

Outline and Full Proposals will be submitted online. Applicants should follow the proposal structure as indicated in the application template for outline proposals available on the Programme website at: **http://www.esf.org/fanas**.

On this Programme website, links to information on national funding eligibility and requirements as well as to a EUROCORES Glossary and Frequently Asked Questions (FAQs) are available.

Prior to submitting Outline Proposals, all applicants have to contact their national funding agencies in order to verify eligibility and to ensure compliance with their relevant agencies' granting rules and regulations (see contact persons listed on page 8).
At the time of online submission of the Outline Proposals, the Project Leader is asked to confirm this on behalf of all the participants in the CRP.

Outline Proposals

Outline Proposals are invited by 4th June 2007.
Outline Proposals will be examined by the participating funding agencies for formal eligibility. Therefore, it is crucial that all applicants contact their national funding agency prior to submitting their proposals.
In compliance with the rules and regulations of the participating national funding agencies, the requested funds under the EUROCORES Programme FANAS can include salaries for scientific and technical staff, equipment as well as travel costs and consumables within the project, specifying the amount requested from each Funding Agency. National policies may also require the proposal to contain additional specific information. Applicants should be aware that the participating funding agencies can make significant adjustments to the requested funds in order to bring these in line with their rules and regulations.

Applications will be assessed according to a set of criteria in a two-stage procedure, as to ensure a thorough selection of scientifically excellent proposals. At the outline stage, the Review Panel will select proposals with potential for scientific excellence, by applying the following criteria:
- Relevance to the Call for Proposals
- Novelty and originality
- European added value (scientific)
- Qualification of the applicants

An Outline Proposal submitted must comprise:
- A short description of the CRP (max. 1200 words, including objectives, milestones, methodologies (for example experiments and fieldwork);
    - Short description of how (and why) the partners contributing to the CRP will work together;
- Short CVs of Project Leader (PL), all PIs and Associate Partners (max. one page each, including five most relevant publications);
- Estimated budget (consistent with the rules of relevant national funding agency) tabulated according to a provided template.

Associated Partners (APs) are also considered part of a CRP and will be assessed as such at both the Outline and Full Proposal stage.

It will be assumed that arrangements for the handling of IPR (Intellectual Property Rights) will be in place within projects, following the applicable national legislation and national funding agency rules. Applicants are strongly urged to have such arrangements in place, covering all research groups (including any associated groups) before the start of the projects. It is expected that the results obtained by the projects supported under this EUROCORES Programme will be placed in the public domain.
It is also expected that all relevant clearance of other national or international committees (for example ethics) has been obtained before funding is granted. It is the responsibility of applicants to clarify any such matters (if applicable) with their national contact points.

Full Proposals

Full Proposals will be invited following the recommendations of the Review Panel. The deadline for full proposals will be announced later, but is expected to be around 17th September 2007.

Please note that only applicants who submitted an Outline Proposal can submit a Full Proposal.

For the Full Collaborative Research Project (CRP) proposals, the most important selection criterion is "Scientific quality". Other criteria include interdisciplinarity (according to the scope of the call), qualification of applicants, level of integration and collaboration, feasibility, European added value and relation to other projects (risk of double-funding and track record for collaboration).

The Full Proposals will be assessed by at least three independent external expert referees who are selected by the ESF from a pool of scientists suggested by the participating funding agencies and the Review Panel. A list of all referee names used for the international peer review will be published once the selection process is complete.

After receiving all referee reports, they will be made available (anonymous) to the applicants for their information and for commenting (optional). The Review Panel will rank all Full Proposals based on the assessment of the Full Proposal, the anonymous referee reports and the applicant's responses to these.

The Review Panel will create a ranked list consisting of the best Full Proposals and will subsequently make recommendations to the Management Committee for the funding of these proposals. The actual granting of the funds to the Individual projects on the ranked list will depend on the total amount of funds available in each country by the participating Funding Agencies. The use of funds in a project will be subject to the rules and regulations of each participating Funding Agency as well as to the national laws of those countries.

Full proposals must include a well-argued scientific case (both for the collaboration envisaged and for the individual contributions), a list of participants, a detailed tabulated budget and other supporting information. A single, common scientific case must be made throughout the proposal to demonstrate an aim for scientific synergy and integration of multinational expertise. In addition, the amount requested from each national funding agency has to be clearly and separately specified. Detailed instructions on requirements and how to complete the application forms will be made available once Full Proposals are being invited.

The **Project Leader** will be the main CRP proposal contact point for ESF for the duration of the project. He/she will be responsible for representing the Collaborative Research Project, for its participation in programme activities, and for any reporting requirements placed on the project as a whole.

All **Principal Investigators** will be responsible for dealing with the requirements attached to the contributions of their own funding organisation.

Programme Structure and Management

Programme Structure

The overall responsibility for the governance of the programme lies with a *Management Committee*, whose membership is formed by one representative from each participating funding agency (usually a senior science manager) together with an ESF representative.

Proposal assessment and selection are the responsibility of an international, independent *Review Panel*. The members of this panel are leading scientists, appointed by ESF following suggestions from participating Funding Agencies. The membership of the Review Panel will be available on the Programme website for information. The Review Panel is also expected to monitor the overall scientific progress of the programme.

The Scientific Committee which is formed by the Project Leaders of all funded CRPs will be responsible for proposing networking activities for scientific synergy in the EUROCORES Programme. They will also advice and support the EUROCORES Programme Coordinator in the coordination of networking activities.

Programme Networking

Networking activities are designed to strengthen the science objectives of this EUROCORES Programme by promoting coherence in the activities of the science community involved. This will provide the European added-value which is the central objective of any EUROCORES Programme.

Networking and collaboration within EUROCORES Programmes takes place at two levels:

1. between the various Individual Projects within each Collaborative Research Project (CRP) and
2. between the funded CRPs within the programme as a whole.

The intra-CRP activities are supported through the research grants each participant receives from the participating funding agencies in the given CRP. The cross-CRP activities are funded through contributions to the EUROCORES Programme.

The intra-CRP collaboration is motivated by the nature of the CRP's research objectives, i.e., by the scope and the complexity of the questions it deals with. In a CRP, the participating groups have the opportunity to gather the required critical mass to successfully address the objectives and challenges of their project.

The cross-CRP networking and collaboration is stirred by the aims and the nature of the particular EUROCORES Programme. The theme which was the basis of this EUROCORES Programme has been selected for its clear need of collaboration in the proposed field. The funded CRPs will collectively set up and further streamline this new collaboration. To this end, the CRPs will engage the programme participants and, when of clear benefit, colleagues from outside the programme in joint activities such as:

- Working Group meetings for the exchange of information and results across the CRPs;
- Joint scientific meetings or summer schools;
- Short term visits;
- Development and delivery of joint training schemes;
- Seminars, Workshops, symposia, invited sessions either stand-alone or as part of other larger events;
- Common web-facilities and publications.

Through active participation of scientists in the above mentioned activities, not only existing collaborations are enhanced but new and strategic partnership opportunities are also identified.
Furthermore, these activities may provide opportunities to explore aspects of the programme which are not covered by the funded research projects.

The integrative activities between the CRPs will help to strengthen the field by building coherence within this emerging research community and will serve as a platform for the research work which is done in the programme.

Project members are expected to participate annually in at least one cross-CRP activity.

When submitting your proposal, please note that the costs for networking within your CRP should be budgeted for in your proposal. Funds for networking between the CRPs will be centrally managed by the ESF through contributions from the participating member organisations.

Programme evaluation

A Mid-Term evaluation, conducted by the Review Panel, will evaluate the overall progress of the Programme, based on the progress of the funded CRPs. Here, the Review Panel has a steering function and can comment on the CRPs' work plan in relation to the objectives of the overall Programme. A final evaluation will assess the achievements of the whole EUROCORES Programme.

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**CNR's final decision for participation is expected by the end of March 2007. For further details and latest information please contact Dr. Anna D'Amato at CNR*

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