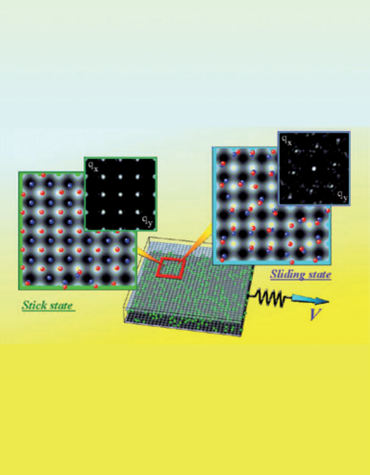
FANAS

Friction and Adhesion in Nanomechanical Systems



The understanding of friction by atomistic simulations.
Groups of Profs J. Klafter and M. Urbakh, School of Chemistry, Tel Aviv University, Israel, (ACOF and AQUALUBE Projects)

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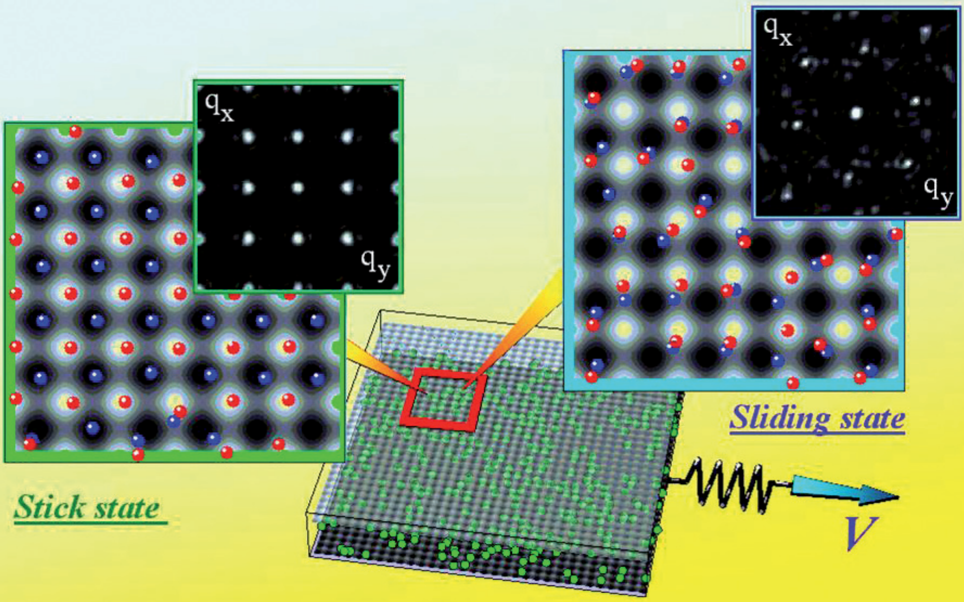

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Friction and Adhesion in Nanomechanical Systems (FANAS)

Interfacial friction is one of the oldest problems in physics and chemistry, and certainly one of the most important from a 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 non-equilibrium processes occurring at the molecular level to determine what happens at the macroscopic level.

The aim of the FANAS EUROCORES programme is to gain a better insight into the origins of friction and adhesion and to learn how to control them. In particular:

- understanding relationships between adhesion and friction at the nano and micro scales and mechanisms of energy dissipation in tribological systems,
- bridging the gap between the nano, micro and macro scales in friction, lubrication and adhesion, control and modification of frictional properties,
- nanomanipulations at interfaces,
- studies of biomimetic tribological systems and tribochemistry.

To meet these goals, FANAS brings 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.

List of funded Collaborative Research Projects (CRPs)

An Integrated Framework for Engineering Bio-Mimetic Adhesive Interface (EBioAdI)

(CNR, CNRS, DFG, FNRS, SNF, TÜBITAK)

The main objective of the EBioAdI Collaborative Research Project (CRP) is the development of an integrated framework for the engineering of bio-mimetic surfaces with superior adhesive and friction performances through (i) the development of predictive theoretical models (heterogeneous multi-scale models), (ii) the fabrication of artificial bio-mimetic prototypes (hierarchically structured surfaces and surfaces with a controlled roughness over multiple scales) and (iii) the testing of natural systems as well as artificial bio-mimetic prototypes against their friction and adhesive performances. These surfaces will have applications in different fields spanning from the automotive to the biomedical industry, from micro/nano-technology to robotics and print industry. The present CRP involves partners with different scientific backgrounds spanning from biology to applied and theoretical physics, from biomedical to electrical and mechanical engineering, with specific research expertise in friction and adhesion.

Project Leader:

Professor Paolo Decuzzi
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Principal Investigators:

Professor Eduard Arzt
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CNRS, Laboratoire PPMD-UMR 7615, ESPCI, Paris, France

Dr. Pascal Damman
Laboratoire de PhysicoChimie des Polymères, Université de Mons-Hainaut, Mons, Belgium

Dr. Stanislav Gorb
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Dr. Bo N.J. Persson
Institute of Solid State Research, Forschungszentrum Jülich GmbH, Jülich, Germany

Professor Ralph Spolenak
Department of Materials, Laboratory of Nanometallurgy, ETH Zurich, Zurich, Switzerland

Nanomanipulation of Metallic Clusters on Insulating Substrates (NOMCIS)

(AKA, CNR, DFG)

Nanoclusters have become a focal system in nano-scale research due to their far-reaching applications and flexibility for studying different areas of science. The ability to tune the properties of the nanoclusters by controlling the number of atoms they contain remains a powerful investigative tool, but this has been recently coupled with the ability to modify the nanocluster's physical properties via adsorption to a surface. NOMCIS will use Scanning Probe Microscopy (SPM) manipulation to study the lateral mobility and dissipation of nanoclusters adsorbed on surfaces as a function of nanocluster size and charge, ambient environment, temperature, adsorption site and surface material. The NOMCIS project brings together a fully multidisciplinary consortium including groups specialised in physics and chemistry, with a complementary contribution from theory and experiment.

Project Leader:

Professor Adam Foster
Laboratory of Physics, Helsinki University of Technology, Helsinki, Finland

Principal Investigators:

Dr. Friedrich Esch
CNR-INFM TASC National Laboratory, Trieste, Italy

Dr. Ulrich Heiz
Department of Chemistry, Technical University of Munich, Munich, Germany

Associated Partner:

Dr. Clemens Barth
Centre de Recherche en Matière Condensée et Nanosciences, CRMCN, Marseille, France

Atomic Friction (AFRI)

(AKA, CNR, DFG, IRCSET, MCI, SNF, TÜBITAK)

The aim of AFRI is to understand friction and wear properties in the extreme case of atomic scale friction, where only a few atoms constitute the tip-sample contact. Despite recent successes in the understanding of atomic friction processes, where the velocity dependence, load dependence and new effects like superlubricity (structural and externally induced) have been targeted, many phenomena are still under dispute. AFRI will investigate atomic friction in the vicinity of defects under ultrahigh vacuum conditions and compare it with theoretical studies. Non-contact Atomic Force Microscopy (nc-AFM) experiments with small amplitudes will be performed and directly compared with simulations as well as experiments as a function of load and speed and to extend contact areas with the use of a UHV-microtribometer to explore the behaviour of multi-asperity contacts.

Project Leader:

Professor Ernst Meyer
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Professor Erio Tosatti
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Active Control of Friction (ACOF)

(CNRS, DFG, ISF, MNISW, SNF)

The ability to control and manipulate frictional forces is extremely important for a variety of applications. Controlling frictional forces has been traditionally approached by chemical means, usually by supplementing base lubricants with friction modifying additives. Standard lubrication techniques, however, are expected to be less effective in the micro- and nano-world. Novel methods for control and manipulation are therefore needed. ACOF is a joint experimental, theoretical and computational project aimed at designing methods and algorithms to control friction by both mechanical means (via externally imposed vibrations of small amplitude and energy) and surface modification. To accomplish these goals, it is essential to understand the internal dynamics, i.e. the internal rates of structural rearrangement of confined systems under shear. In this project new advances in experimental and theoretical techniques will be used to both acquire a detailed understanding of fundamental frictional processes and manipulate them. The interrelation between friction at the nano-, micro- and macroscopic scales will be explored.

Project Leader:
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Water-Based Lubricants: theory and experiment (AQUALUBE)
(IRCSET, ISF, SNF)

It is clearly of importance to reduce friction to the lowest possible levels in lubricated machines, since frictional losses constitute a major cause of energy wastage. Examples of very low friction are to be found among the lubrication mechanisms of nature, which are exclusively based on water, involving complex biomolecules (e.g. mucins) that appear to generate brush-like structures on surfaces, and which impart highly lubricious properties. Attempts to imitate this have been quite successful, both on the nano and the macro scales, although the reasons for the low-friction behaviour are not completely understood. The objectives of the AQUALUBE project are to synthesize novel, brush-forming molecules, which closely mimic those found in nature; to investigate their properties as lubricant additives; to investigate the properties of the water in and around the brush systems, in the presence and absence of charge, and to model the tribological behaviour of the brush systems, with and without shear.

Project Leader:
Professor Nicholas Spencer
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Conway Institute of Biomolecular and Biomedical Research, University College Dublin, Dublin, Ireland
Professor Joseph Klafter
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Professor Michael Urbakh
School of Chemistry, Faculty of Exact Sciences,
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Nanoparticle Manipulation with Atomic Force Microscopy Techniques (NANOPARMA)
(DFG, ETF, FCT, APVV)

Atomic force microscopy (AFM) has proven to be a powerful tool to investigate frictional forces of nano-scale contacts. Unfortunately, this technique reveals some drawbacks when applied to study chemical and structural properties of two rubbing surfaces. Questions concern the contact area dependence as well as the influence of the material on tribological properties. The contact area dependence of friction is crucial in bridging the gap between nano-scale and micro-scale friction, which eventually will allow to understand and control macroscopic friction. The right choice of materials, on the other hand, is expected to lead to new friction effects, like, e.g., superlubricity. In this Collaborative Research Project AFM will be used to investigate nanoparticles with different sizes, shapes and functional groups on their surfaces, as well as substrates with different roughness, structure and chemical composition in different environments, from liquids to ultrahigh vacuum. The experimental studies are harmonised with theoretical investigations concerning the manipulation process itself, as well as the interfacial atomic processes during particle translation.

Project Leader:

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Professor Karine Mougin
CNRS, Institut de Chimie des Surfaces et Interfaces, Mulhouse, France

Professor Udo D. Schwartz
Department of Mechanical Engineering, Yale University, New Haven, United States

Fundamentals of Tribology – Correlation between Wear Characteristics and Material Properties of Polymers Ranged from Sub-Micro to Macro Scale (FUNDTRIBO)

(DFG, FWO, MCI)

The investigation about the fundamentals of tribology deals with three different effects regarding wear and friction phenomena. In wear experiments on large, macro and nano scales, the differences and similarities between the wear mechanisms of different scales will be examined and compared. The nano-scale tests are carried out with an atomic force microscope (AFM) in order to find basics about the wear characteristics. The stress and energy dissipating factors inside the polymer material are investigated by FEM simulations. An artificial neural network (ANN) based software tool correlates wear results and materials' properties. The overall aim of this project is the prediction of the wear behaviour of different nano-particle reinforced polyetheretherketone (PEEK) composite materials based on the gained experimental results on large, macro and nano scales.

Project Leader:

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Fundación TEKNIKER, Eibar, Spain

Professor Patrick De Baets
University of Gent – Laboratorium SOETE, Gent, Belgium

Associated Partner:

Professor Andrea Danani
University of Applied Sciences of Southern Switzerland (SUPSI), Manno, Switzerland

The aim of the European Collaborative Research (EUROCORES) Scheme is to enable researchers in different European countries to develop collaboration and scientific synergy in areas where European scale and scope are required to reach the critical mass necessary for top class science in a global context.
The scheme provides a flexible framework which allows national basic research funding and performing organisations to join forces to support excellent European research in and across all scientific areas.
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Research Foundation Flanders, Belgium

Eesti Teadusfond (ETF)
Estonian Science Foundation, Estonia

Suomen Akatemia (AKA)
Academy of Finland, Finland

Centre National de la Recherche Scientifique (CNRS)
National Centre for Scientific Research, France

Deutsche Forschungsgemeinschaft (DFG)
German Research Foundation, Germany

Irish Research Council for Sciences, Engineering and Technology (IRCSET),
Ireland

Israel Science Foundation (ISF),
Israel

Consiglio Nazionale delle Ricerche (CNR)
National Research Council, Italy

Ministerstwo Nauki I Szkolnictwa Wyzszego (MNISW)
Ministry of Science and Higher Education, Poland

Fundacao para a Ciência e a Tecnologia (FCT)
Foundation for Science and Technology, Portugal

Agentúra na podporu výskumu a vývoja (APVV)
Slovak Research and Development Agency, Slovak Republic

Ministerio de Ciencia e Innovación (MCI)
Ministry of Science and Innovation, Spain

Schweizerischer Nationalfonds (SNF)
Swiss National Science Foundation, Switzerland

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