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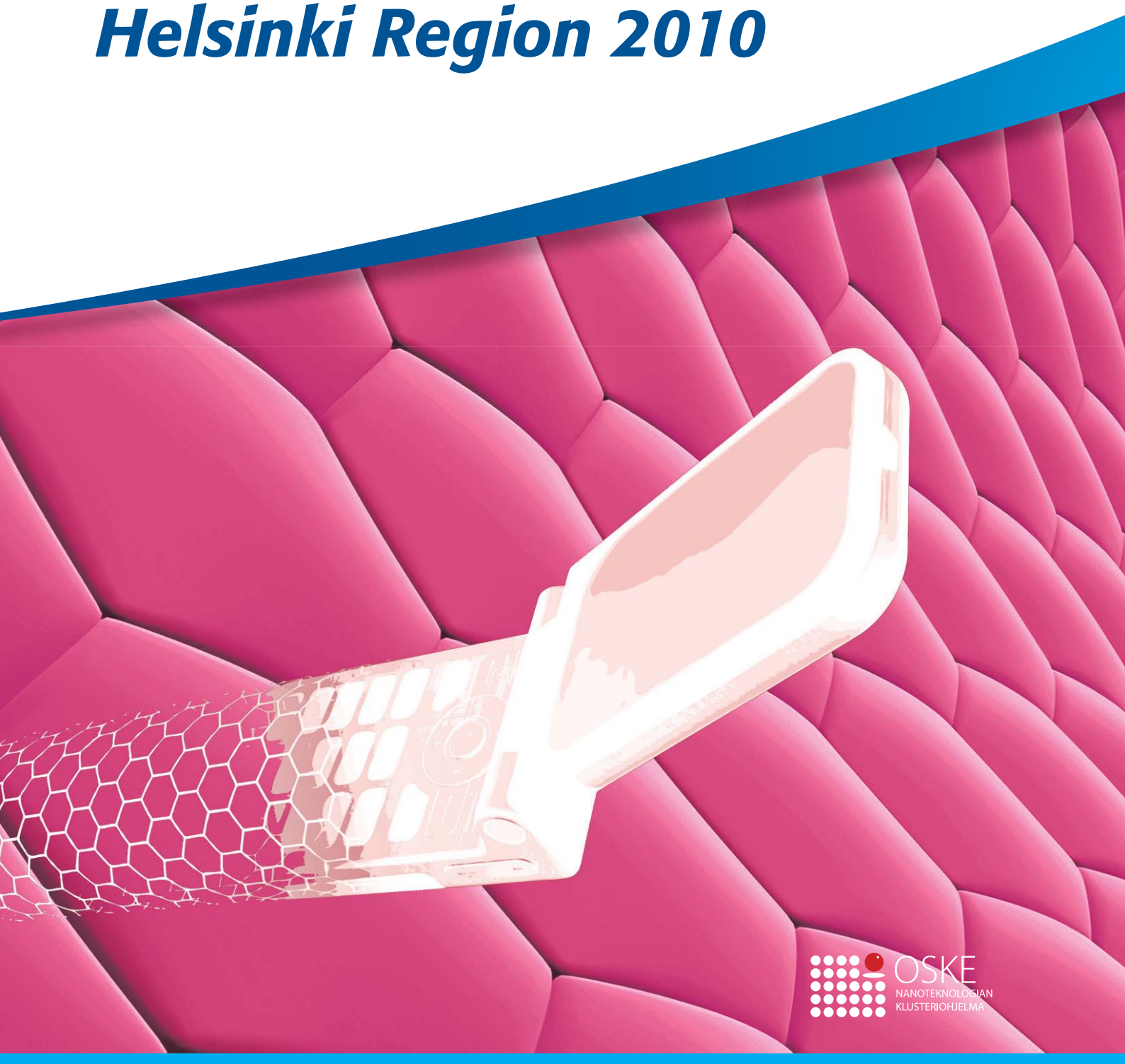
HelsinkiNano – Nanotechnology Research in Helsinki Region 2010



OSKE
NANOTEKNOLOGIAN
KLUSTERIOHJELMA

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Welcome to explore the high-class nanoscience and –technology research network operating in Helsinki region. The publication "HelsinkiNano – Nanotechnology Research in Helsinki Region 2010" illustrates the nanotechnology research conducted in the universities and in other public institutions in the capital area and provides a pathway to distribute the knowledge to domestic companies but also to international companies looking forward to collaborating with Finnish universities and companies or exploring the opportunities to set operations in Finland.

To paint a comprehensive picture of the magnitude and quality of the nanotechnology expertise in Helsinki region over eighty research group leaders or responsible researchers were successfully contacted and the the research of their groups is now compressed in a form of seventy five research group profiles. The research groups represent Aalto University, University of Helsinki, VTT, Centre for Metrology and Accreditation (MIKES), Finnish Institute of Occupational Health, Finnish Environment Institute (SYKE) and Finnish Meteorological Institute and the profiles are organized under to the universities, faculties and departments.

In order to maximize the probability to find relevant information the profiles are also categorized according to the areas of research and according to the potential user segments on page 76. In addition, a number of keywords describing technologies and applications have been extracted from the profiles and they are given at the end of the publication on page 78.

The collected profiles include, in addition to the expertise and achievements of the research groups, also the goal of the current research. This is done to maximize the probability of finding the relevant partners for future co-operation. When planning the collaboration with promising partners it is advisable to pay attention to the recommended actions for maximized benefits of collaboration given on page E.

Based on the statistics, it appears that the most potential users of the research lie within the electronics and sensors industry followed by pharmaceutical and medical industry. These are the users of the research in Helsinki region, but the overall picture of the nanotechnology research in Helsinki Region is a good representation of the nanotechnology research in Finland on the whole as it has been estimated that over half of the Finnish nanotechnology research is conducted in Helsinki Region.

This publication is prepared with the funding from Uusimaa Regional Council and the material has been collected and processed by Nanotechnology Centre of Expertise that is hosted by Culminatum Innovation Oy Ltd.

It should be pointed out, that even though the profiles include the expertise of each research group, the actual research infrastructure is omitted. The lack of this information is complemented with a comprehensive database that is maintained by Finnish Nanotechnology Cluster with a partial funding from Nanotechnology Centre of Expertise in Helsinki Region, Culminatum Innovation Oy Ltd and Uusimaa Regional Council. This database can be found at www.findnano.fi.

Mika Koskenvuori, D.Sc.(Tech.)

Culminatum Innovation Oy Ltd
mika.koskenvuori(a)culminatum.fi
nanobusiness(a)culminatum.fi

Tips to Commercial Success Story

Our operational environment is under continuous change. This means among others changes in market and competition field. Even for this reason there is need for continual regeneration in many ways. Enterprises are seeking competitive advantage more than ever by developing and preparing their services and products in respect to their uniqueness. The uniqueness helps them to separate themselves from others in the market and to secure the existence and development of business operations. The uniqueness usually relates to use of new know-how and technology for production of existing product or service and thus in the features thereto.

Starting point

Finnish development work on the field of nanotechnology is producing opportunities which the enterprises can directly utilize in their own research and development.

Ideally, the cooperation may for instance arise in the situation where the enterprise contacts research units requiring help for its own research and development.

Partnership

Good cooperation between enterprises and research units comprise among others of openness, good understanding of each other's methods and goals as well as the clear and mutually agreed rules.

In concrete

In the beginning of and during the cooperation various different issues shall be taken into account and agreed **in writing**.

Written agreement strengthen the partnership since the potential problematic situations of the partnership have been reviewed already during the negotiations of agreement.

In addition, the concrete details of the common activities often clear for both of the parties first during the contract negotiation phase.

It is important to agree on the responsibilities of both parties in detail. It is useful to set up detailed timetable for the common activities, according to which the parties shall preceed. In such case both parties may already beforehand make preparations for fulfilling their obligations.

One of the most important issues to agree on is development and transfer of the intellectual property rights. In order to avoid surprises afterwards, it is important to agree on the foregoing expressly, so that the partners are aware of their obligations.

Procurement of work contribution to a common project shall be conducted carefully. Shall it be considered as own employee, leased staff or subcontractor; there is remarkable differences between the alternatives and not least regarding the expenses.

Assuring the funding for the project is important, so that the desired actions can be completed.

When obtaining financing it is important to understand what the consideration for the financing is: are the demands of the potential external financier known?

It is important to ensure the position of the partners before entering into an agreement and after the contract term has ended. For instance the competition by the other party after the project has ended should not be surprise for the partner.

Finally

In the foregoing some of the essential issues, which shall be taken into account when defining the cooperation and which shall also be gone through with own legal advisor are presented.

This presentation has been drafted by Kalliolaw Asianajotoimisto Oy – Attorneys at Law, which is specialized to advice growing and internationalizing enterprises.
For more information, please visit www.kalliolaw.fi

KALLIOLAW
Finding Solutions *Getting Results*

Kalliolaw Asianajotoimisto Oy
– Attorneys at Law
Eteläranta 12, FIN-00130 Helsinki
Tel +358 9 6812 930
www.kalliolaw.fi

The best Nordic Small Law Firm of the Year 2009
(The ACQ Finance Magazine)

E

CLASSIFICATION

The following numbers are used throughout the publication to classify the research of the groups.

1	Nanosurfaces and coating
2	Nanomaterials
3	Aerosols
4	Nano in human well-being (pharmacy, medical diagnostics, safety etc.)
5	Nano in built environments
6	Nano in electronics, MEMS, NEMS, optics
7	Characterization
8	Fabrication
9	Theory and modeling
10	Nano related services
11	Something else

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Biotechnology and Chemical Technology

Group name	Classifications
Industrial chemistry	*1, 2, 7, 9, 11* *(Functional nanomaterials)*

Leader

Prof. Outi Krause

Special know-how of the group:

1) Development of catalytic materials, including catalyst synthesis, characterization and activity testing (e.g. preparation of catalysts by atomic layer deposition, in situ characterization of catalysts under reaction conditions).
2) Modeling of the catalytic phenomena taking place during reactions and development of new modeling tools, e.g. for the utilization of temperature-programmed methods in transient kinetic modeling.

Objectives of the research:

Our research group concentrates on the phenomena present in the chemical reactor. This includes studies on catalytic nanomaterials and catalytic processes. The objective of the research is to utilize the fundamental knowledge obtained on catalytic phenomena in the development of processes that are environmentally benign and important for the society. Special emphasis is in the production of hydrogen for fuel cells and of chemicals and liquid fuels from biomass.

Most significant results during 2008-2009:

Several papers have been published in high-ranking scientific journals. Fundamental information has been obtained on several catalytic systems. Methods have been developed for extracting information from temperature-programmed experiments

Possible utilization of the results:

The results can be utilized by industrial companies in e.g. the development of environmentally benign and more efficient catalytic processes for production of chemicals and fuels. Results are also beneficial for further fundamental research work.

Contact

Dr. Tuula-Riitta Viljava (tuula-riitta.viljava(a)tkk.fi)
www : http://chemtech.tkk.fi/en/research/industrial_chemistry/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Biotechnology and Chemical Technology

Group name	Classifications
Polymer Technology group	*1, 2, 6, 7*

Leader

Prof. Jukka Seppälä

Special know-how of the group:

1) Polymerization engineering and chemical modification of polymers **2**) Polymer tailoring, structure/property correlations **3**) Compatibilization of nanostructural composites; nanoclay, carbon nanotubes and nanocellulose **4**) Polymerization of biodegradable polymers for controlled release and tissue engineering applications **5**) New polymerization routes for amphiphilic block polymers **6**) Rheological and thermomechanical characterization of polymers, polymer composites and dispersions with state of the art equipment

Objectives of the research:

Research is focused on synthesis and characterization of polymers, development of new materials utilizing polymerization techniques and composite technology, structure/property correlation research of nanostructured polymers and composites, and compatibilization of heterophasic systems.

Most significant results during 2008-2009:

Silane functionalized polyolefins via metallocene catalysis; synthesis and use in polyolefin coposites, Preparation of polymeric nanocomposites and their structure-property relationships, Poly(ester-anhydrides) Based on Polylactone Precursors. Also the following awards have been received: **1**) Millennium Distinction Award **2**) New Materials Invention Award **3**) TKK Most Prominent Inventor Award **4**) Several scientific articles and patents/ invention claims.

Possible utilization of the results:

1) New properties for products of forest industry with amphiphilic block copolymers **2**) Novel composite materials for electronic applications **3**) Novel materials for controlled drug release applications and tissue engineering scaffolds **4**) Nanocellulose; use and composites

Contact

Prof. Jukka Seppälä (jukka.seppala(a)tkk.fi)
www : http://chemtech.tkk.fi/en/research/polymer_technology

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Chemistry

Group name	Classifications
Analytical Chemistry	*1, 2, 4, 7, 8*

Leader

Prof. Sakari Kulmala

Special know-how of the group:

Luminescence methods in general.

Objectives of the research:

Electrochemiluminescence, mainly Hot electron-induced Electrohemiluminsescence, and its analytical applications but also applications of some other fields of luminescence.

Most significant results during 2008-2009:

1) Color tunability and electrochemiluminescence of silver nanoclusters **2**) Hot Electron-induced Electrogenerated Chemiluminescence **3**) Ultrathin tunnel insulator films on silicon for electrochemiluminescence

Possible utilization of the results:

Mainly in IVD applications.

Contact

Prof. Sakari Kulmala (sakari.kulmala(a)tkk.fi)
Tel: +358 9 470 22600
www : http://chemistry.tkk.fi/fi/tutkimus/analyyttinen/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Chemistry

Group name	Classifications
NewMaterial Group	*1, 2, 6, 7, 8*

Leader

Acad. prof. Maarit Karppinen

Special know-how of the group:

Systematic new-material design concept, inorganic materials chemistry, functional oxide materials, atomic layer deposition (ALD) technology

Objectives of the research:

Atomic-level layer-by-layer design and synthesis of novel (functional) materials.

Most significant results during 2008-2009:

1) Atomic layer deposition of both hexagonal and orthorhombic YMnO3 thin films **2**) Atomic layer deposition of stable inorganic-organic hybrid thin films **3**) Atomic layer deposition of gas-barrier coatings for fiber-based packaging materials **4**) Conformal ALD coating of nanoscale topographies of with thin ZnO films for photo-controlled wettability switching **5**) Progress in nanoscale area-selective ALD

Possible utilization of the results:

Scientific communities in new material research and ALD technology; Future spintronics industry; (Food and pharmaceutical) packaging industry

Contact

Acad. prof. Maarit Karppinen (maarit.karppinen(a)tkk.fi)

In addition to the mentioned leader, the research profile includes the research of:

prof. Matti Putkonen

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Chemistry

Group name	Classifications
Physical Chemistry and Electrochemistry	*1, 2, 7, 8, 11 (Nanotechnology in energy conversion)*

Leader

Prof. Kyösti Kontturi

Special know-how of the group:

In general, the laboratory's research focus is on electrochemical applications of nanotechnology such as catalytic materials, antibacterial coatings, memory devices, diagnostics, sensors, etc. Group consists of the following persons: **Prof. Kyösti Kontturi**: transport processes at interfaces, electrochemistry **Dr. Lasse Murtomäki**: drug delivery **Dr. Christoffer Johans**: nanoparticle synthesis and mechanisms of nanoparticle nucleation and growth **Dr. Tanja Kallio**: energy conversion **Dr. Kirsi Yliniemi**: functional nano-interfaces **Dr. Benjamin Wilson**: nanoscale oscillators

Objectives of the research:

1) Functional nanocoatings: how tight attachment of nanoparticles influences on their properties **2**) Scale-up fabrication of nanoparticles: mechanisms of nanoparticle nucleation and growth **3**) New synthetic routes for Co/Fe nanoparticles **4**) Nanoscale electrochemical oscillators for memory applications **5**) Catalytic materials for fuel cell applications

Most significant results during 2008-2009:

1) Fabrication of monodisperse Co nanoparticles (patent pending) **2**) Induced electrochemical oscillations on Pt surface and glucose oxidase enzyme (GOD) coated surface **3**) Nucleation and growth mechanism of metallic nanoparticles **4**) Functional nanocoatings based on polymers and Ag nanoparticles

Possible utilization of the results:

To great extent the research in the group is basic research which finds its use in the scientific community. Additionally, some research areas are closely related to industry, for example the fabrication of nanoparticles in large scale as well as functional nanocoatings can be useful for metal industry.

Contact

Prof. Kyösti Kontturi (kyosti.kontturi(a)tkk.fi)
www : http://chemistry.tkk.fi/en/research/physical/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Chemistry

Group name	Classifications
Laboratory of Organic chemistry	*4, 7, 8, 9*

Leader

Prof. Ari Koskinen

Special know-how of the group:

Synthetic organic chemistry

Objectives of the research:

Synthesis of natural products, development of novel synthetic methods capable of being transferred into industrially applicable synthetic technologies

Most significant results during 2008-2009:

The latests publications are good examples of the latest results: **1**) Highly Chemoselective Copper Catalyzed Conjugate Reduction of Stereochemically Labile α,β-Unsaturated Amino Ketones **2**) indolizidine alkaloids - synthesis of dideoxycastanospermine **3**) Towards the total synthesis of Calyculin C: preparation of the C13-C25 spirocyclic core **4**) Catalytic Activity Dependency on Catalyst Components in Aerobic Copper-TEMPO Oxidation **5**) Chiral 3-(4,5-dihydrooxazol-2-yl)phenyl alkylcarbamates as novel FAAH inhibitors: insight into FAAH enantioselectivity by molecular docking and interaction fields **6**) Synthesis and agonist properties of novel quinoline and isoquinoline derivatives toward the cannabinoid receptor CB2 **7**) The Synthesis and Biological Evaluation of para-Substituted Phenolic N-Alkyl Carbamates as Endocannabinoid Hydrolyzing Enzyme Inhibitors **8**) A Simple Organocatalytic Enantioselective Synthesis of Pregabalin **9**) 'Synthesis of DEFG Ring System of Cneorins **10**) Aldol-Tischenko Reaction **11**) Development of Di-(2-picolyl)amine Zinc Chelates for Imidazole Receptors **12**) Stereoselective Total Synthesis of Pachastrissamine (Jaspine B) **13**) A New Application for PyOX-ligands: The Asymmetric Henry Reaction **14**) Mild and Efficient Synthesis of 2-indole-2′-Oxazolines at Room Temperature – a Simple Access to Novel IndOX-ligands

Possible utilization of the results:

Pharmaceutical industry can use some of our methodologies

Contact

Prof. Ari Koskinen (ari.koskinen(a)tkk.fi)
Tel: +358 50 555 3310
www : http://users.tkk.fi/akoskine/index.htm

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Active and Functional Materials	*1, 2, 7, 8*

Leader

Prof. Simo-Pekka Hannula

Special know-how of the group:

1) Synthesis metal nanoparticle modified silica particles **2**) Spark plasma sintering of bulk nanocrystalline materials **3**) Sub-Å HR-TEM electron diffraction, EELS, EDX **4**) Hysitron nanoindenter with the heat stage (max 400°C)

Objectives of the research:

1) Developing metal-nanoparticle modified ceramic powders **2**) Understanding the SPS compaction of the nanocrystalline materials of nanopowders **3**) Structure characterization of nanopowders and nanocrystalline materials and coatings **4**) Application of nanopowders in sol-gel coatings and paints as well as in paper and textiles

Most significant results during 2008-2009:

1) Development of novel nanocrystalline ceramic coatings **2**) Development of antibacterial light coloured nanopowders for coating applications **3**) SPS compacts with the nanocrystalline structures **4**) Characterization of nano-alfa-alumina with novel morphology **5**) Characterization of the nanomechanical properties of nanocomposites

Possible utilization of the results:

In antibacterial coatings for building industry. In coatings for demanding conditions in various machinery.

Contact

Prof. Simo-Pekka Hannula (simo-pekka.hannula(a)tkk.fi)
www : http://materials.tkk.fi/fi/tutkimusryhmat/uudet_materiaalit_ja_niiden_ominaisuudet/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Materials Processing and Powder Metallurgy	*1, 4, 7, 9, 10*

Leader

Prof. Michael Gasik

Special know-how of the group:

The research activities of the MVT are recently concentrated in fields of powder metallurgy and advanced materials processing, fuel cells and catalysts, functionally gradated materials (FGM), biomaterials, thermodynamic data bank and modelling, light alloys and intermetallic composites development, processes simulation (CFD, FEM, etc.), environment and recycling, etc. It is for instance internationally recognised for its work on FGM design, processing and evaluation. The group has extensive expertise in combined thermal analysis (dilatometry, thermogravimetry, coupled FTIR, calorimetry, DMA, thermal conductivity), powder processing and characterisation (from 0.6 nm up), materials performance evaluation (aggressive environments) and special processing (such as microwave hybrid treatment). The essential know-how is also in data processing and modelling (mathematical, thermodynamical, CFD and FEM).

Objectives of the research:

The group of materials processing and powder metallurgy (MVT) performs international research in the field of materials processing and powder metallurgy, related physical-chemical phenomena, computer based and experimental modelling, and new materials solutions. The core competence of the group is in the chain 'materials design - processing – structure - properties - testing – applications' research, management and modelling. The research are concentrated on various industrial processes, their modelling and design, materials design, their optimisation and modelling, materials thermodynamics and kinetics, analysis and testing, applied materials processing technology and powder metallurgy, as well as specific contract research.

Most significant results during 2008-2009:

1) New ceramic and coated prostheses made of combined and FGM materials with better wear resistance (5 times) and strength (+75%) were designed, optimised and manufactured, giving also significant increase in strength. Also new algorithm and model for calculation of the non-uniform sintering kinetics and residual stresses in FGM were developed, implemented and applied for several systems. This study was selected to CORDIS technology marketplace and as EU feature article. **2**) New method of fast (50-100 times) manufacturing of carrier-integrated nano-structured MnCo2O4 spinel and doped Raney-type nickel catalysts using focussed microwave radiation-assisted synthesis has been developed (power density was increased by 30-35% vs. traditional catalysts). **3**) For applications with aggressive environments and high temperatures, protective coatings have been developed in cooperation with Japan. An excellent performance of these FGM solutions (life time improved over 100 times, hot corrosion stability over 100-150 times) lead to extensive testing of these coatings in Japanese industry (JIS H 7851 standard was developed). **4**) Development of advanced analyticla FEM models for CFD and multiphysics modeling of materials behaviour, pyro- and hydrometallurgical processes, including the validation of these models.

Possible utilization of the results:

Industrial applications (power generation, metallurgy, electronics, corrosion protection, etc.), health care (orthopaedics, dental).

Contact

Prof. Michael Gasik (mgasik(a)cc.hut.fi)
Tel: +358 9 470 22769
www : http://materiaali.tkk.fi/en/LMP/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Microfabrication group	*1, 2, 4, 6, 8*

Leader

Prof. Sami Franssila

Special know-how of the group:

1) Materials and fabrication methods of micro- and nanodevices **2**) Surfaces and coatings **3**) Fluidic devices for chemistry and biology

Objectives of the research:

To develop novel fabrication methods for micro- and nanodevices

Most significant results during 2008-2009:

1) Control of wetting by micro- and nanostructured surfaces **2**) New focused ion beam (FIB) nanofabrication method **3**) Novel CNT transistor fabrication process **4**) Suspended and thermally insulated micro- and nanostructures

Possible utilization of the results:

In chemical and biochips for analytical chemistry, protein chemistry, diagnostics

Contact

Prof. Sami Franssila (sami.franssila(a)tkk.fi)
Tel: +358 50 536 1699
www : http://nano.tkk.fi/en/research_groups/microfabrication/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Physical properties of surfaces and interfaces	*1, 8*

Leader

Prof. Jari Koskinen

Special know-how of the group:

Plasma assisted coating methods, PVD, carbon based coatings

Objectives of the research:

To develop thin films with functional properties and to tailor the coating substrate interface.

Most significant results during 2008-2009:

Textured surface of a diamond-like carbon coating allowing the reduction of friciton in lubricated conditions. It should be noted, that the group was found less than one year ago.

Possible utilization of the results:

Components and tools

Contact

Prof. Jari Koskinen (jari.koskinen(a)tkk.fi)

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Forest products surface chemistry	*1, 2, 7, 9*

Leader

Prof. Janne Laine

Special know-how of the group:

1) Surface science of cellulosic materials **2**) Characterization, utilization and modification of nanocellulose **3**) Interactions and adsorption at various cellulose surfaces. The cellulose may be cellulose fibre or thin films made from nanocrystalline cellulose, nanofibrillar cellulose or regenerated cellulose **4**) Surface modification **5**) Polyelectrolyte multilayers

Objectives of the research:

1) Nanotechnological applications in the forest products sector **2**) Surface modification of macroscopic material like paper or wires, surface modification of cellulose fibers and surface modification of nanomaterial.

Most significant results during 2008-2009:

Establishing the Finnish Centre for Nanocellulosic Technologies together with UPM and VTT. The centre aims at creating new applications for cellulose as a raw material, substance and end product.

Possible utilization of the results:

The results can be applied in paper making, packaging and in developing new materials from wood. The results may also be applied in material science. Industries benefiting from the results are the paper industry, chemical suppliers, and any company interested in developing new materials from sustainable resources.

Contact

Prof. Janne Laine (janne.laine(a)tkk.fi)
www : http://puu.tkk.fi/en/research/research_groups/forest_products_surface_chemistry/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Paper Converting and Packaging	*1, 2, 7, 8, 9*

Leader

Prof. Jouni Paltakari

Special know-how of the group:

1) Paper and paperboard converting and coating **2**) Behaviour of fibre-based packaging materials **3**) Production of microfirillated and nano-scale lignocellulose material

Objectives of the research:

Development of bio-/fibre based materials and composites including nano-scale fractions for novel paper and paperboard structures for converting and packaging end uses.

Most significant results during 2008-2009:

1) Start-up of a production unit for micro- and nanofibrillated cellulose at TKK **2**) Research and investigation of the behaviour of micro- and nanofibrillated cellulose in paper and paper board furnishes, and as a component in coating colours.

Possible utilization of the results:

Results are directly applicable in industrial processes within forest products industry and in other relevant application areas.

Contact

Prof. Jouni Paltakari (jouni.paltakari(a)tkk.fi)
Tel: +358 9 470 24218
www : http://puu.tkk.fi/en/research/research_groups/paper_converting/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of chemistry and materials science
Department of Materials Science and Technology

Group name	Classifications
Paper technology	*1, 2, 8*

Leader

Prof. Hannu Paulapuro

Special know-how of the group:

1) Fiber and paper physics **2**) Process technology **3**) Control and diagnostic methods of papermaking processes

Objectives of the research:

1) Improve the properties of fibers and paper **2**) Develop new paper manufactoring technology (especially forming technology, reducing the energy consumption of papermaking)

Most significant results during 2008-2009:

1) Use of fibrils (nanomaterial) in papermaking **2**) New ways of fiber treatment for improving paper properties **3**) Increasing the filler (pigment) content in paper (up to 60 %) without deteriorating paper properties **4**) Improving the optical properties of fillers (nanocoated filler particles) **5**) Developing the air dynamic forming concept for waterless papermaking **6**) Developing the ultra high forming (up to 15 %) concept for paper- and board making.

Possible utilization of the results:

The results are partly revolutionary to papermaking. They can be directly applied in paper and board mills. Especially when developing new paper and board products the results with nanomaterials (fibrils, nanocoated fillers) are essential.

Contact

Prof. Hannu Paulapuro (hannu.paulapuro(a)tkk.fi)
Tel: +358 50 555 4216

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Automation and Systems Technology

Group name	Classifications
Micro- and Nanorobotics Group	*4, 6, 7, 8*

Leader

Doc. Quan Zhou

Special know-how of the group:

1) Microrobotics **2**) Nanomanipulation inside SEM **3**) Optical quality control robots for microcomponents, assembly methods for RFIDs, microgrippers and optical actuation methods

Objectives of the research:

1) Develop tools and automation for micro- and nanomanufacturing, including new micro- and nanoassembly methods based on robotics and/or self-assembly, new handling strategies for micro- and nanocomponents, new actuation principles and quality control in micro- and nanomanufacturing **2**) Use the aforementioned methods for manufacturing autonomous and mobile micro- and nanorobots

Most significant results during 2008-2009:

1) Nanomanipulator inside a SEM **2**) New microhandling strategy combining robotics and self-assembly based on droplet self-alignment **3**) swallowable wireless biotelemetry device ("intelligent pill") for the analysis of gastrointestinal tract

Possible utilization of the results:

Researchers who need precise handling of nanoscopic samples, RFID or heterogeneous IC companies, biomedical device manufacturers

Contact

Doc. Quan Zhou (quan.zhou(a)tkk.fi)
Tel: +358 9 470 25241
www : http://autsys.tkk.fi/en/MicroNanorobotics

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
Nanotechnology Group	*1, 2, 4, 6, 7, 8, 9*

Leader

Prof. Harri Lipsanen

Special know-how of the group:

1) Nanofabrication, advanced materials, functional surfaces, materials characterization **2**) Nanofabrication methods including electron beam lithography, focused ion beam lithography, nanoimprint lithography, atomic layer deposition (ALD), metalorganic vapour phase epitaxy (MOVPE) and other advanced deposition and dry etching processes combined with standard microfabrication techniques **3**) Semiconductor nanostructures such as quantum dots and nanowires are also processed by self-assembly **4**) Fabrication methods for graphene are developed **5**) Novel nanomaterials are developed from structures based on nanolaminates, plasmonic structures, functional nanostructures and bioinspired structures **6**) Nanocharacterisation methods covers techniques such as scanning probe microscopy, SEM, TEM, advanced X-ray diffraction, Raman spectroscopy, photoluminescence and various electrical methods.

Objectives of the research:

1) World-class research on nanostructures, nanomaterials and nanocharacterization **2**) Application of nanotechnology in advanced devices and materials for nanoelectronics, nanophotonics and sensors.

Most significant results during 2008-2009:

1) Ballistic graphene devices **2**) New gallium nitride nanostructures for LEDs **3**) New plasma-ALD processes **4**) Semiconductor nanowire structures **5**) ALD nanolayers for surface passivation **6**) Novel genetic fitting algorithms and statistical error analysis methods for x-ray reflectivity analysis **7**) Photonic crystal waveguides for silicon integrated optics

Possible utilization of the results:

The results can be applied in the development of new devices and functional surfaces. The expertise in nanofabrication and characterization has a wide field of applications.

Contact

Prof. Harri Lipsanen (harri.lipsanen(a)tkk.fi)
Tel: +358 9 470 23123
www : http://nano.tkk.fi/en

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
The electron physics group	*2, 6, 7, 8 ,9*

Leader

Prof. Pekka Kuivalainen

Special know-how of the group:

1) Fabrication of Mn-doped InAs magnetic quantum dots on a GaAs substrates using molecular beam epitaxy
2) Fabrication of SETs using e-beam lithography **3**) Modelling of the spintronic devices

Objectives of the research:

We are carrying out basic research in the field of semiconductor spintronics, studing especially the magnetic semiconductor single electron transistors (SETs) made of ferromagnetic semiconductor quantum dots. The objective is to show, by fabricating and modelling the SETs, that the electrical and magnetic properties of these transistors can be controlled simultaneously by the gate voltage. This provides, e.g. new highly miniaturized non-volatile memory elements.

Most significant results during 2008-2009:

1) The modelling results predicting many novel features for magnetic SETs **2**) Fabrication of the ferromagnetic InAs quantum dots on a GaAs substrate, where the dots had Curie temperatures higher than the room temperature

Possible utilization of the results:

The above mentioned results may be useful in novel non-volatile memories or in solid state quantum computers, but of course these applications are far in the future.

Contact

Prof. Pekka Kuivalainen (pekka.kuivalainen(a)tkk.fi)
www : http://www.micronova.fi

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
Micro and Quantum Systems Group	*1, 2, 6, 7, 8, 9*

Leader

Prof. Ilkka Tittonen

Special know-how of the group:

1) Theoretical skills in quantum optics **2**) Micro- and nanofabrication **3**) Clean room use **4**) Numerical modelling of microsystems

Objectives of the research:

1) International status in the fields of micromechanical applications, optically active biomolecules and micro- and nanofabrication **2**) Development of thermoelectric materials and systems

Most significant results during 2008-2009:

1) New fabrication method using focused ion beam and deep reactive ion etch **2**) Development of new lasers **3**) Development of photoacoustic sensors **4**) Coupled micromechanical resonators

Possible utilization of the results:

Photoacoustic sensors are already in commercial use, thermoelectric materials will benefit almost any company who wants to convert heat back to electricity, FEM modelling of microsystems will benefit many sensor companies, new fabrication methods make prototyping of some microsystems orders of magnitude faster

Contact

Prof. Ilkka Tittonen (ilkka.tittonen(a)tkk.fi)
Tel: +358 40 543 7564
www : http://www.micronova.fi

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
Fiber Optics Group	*1, 2, 6, 7, 9*

Leader

Doc. Hanne Ludvigsen

Special know-how of the group:

The Fiber Optics Group has extensive expertise in optical measurement techniques, spectroscopy, and photonic device construction. The group has made extensive studies of supercontinuum generation in microstructured fibers and is currently developing novel device and sensor applications that are based on the new possibilities offered by these fibers.

The group is located in Micronova, the largest micro- and nanotechnology center in Finland, which provides state-of-the-art fabrication and characterization facilities for modern material science.

Objectives of the research:

1) To develop novel sensor concept based on microstructured optical fibers **2**) To design and construct new supercontinuum sources and find new applications for these broadband light sources.

Most significant results during 2008-2009:

1) We proposed a novel surface-plasmon resonance concept based on a microstructured optical fiber coated with a gold layer on the inner surface of the holes.

2) We demonstrated the use of a supercontinuum source in a scanning white-light interferometer to perform 3D profile measurements of a MEMS component.

3) We demonstrated that a hollow microstructured optical fiber filled with a highly nonlinear liquid can support single-mode guiding at wavelengths longer than 600 nm in a 4-μm-diameter liquid core.

Possible utilization of the results:

High quality control of MEMS devices
Microelectronics
Biology
Medicine (OCT)

Contact

Doc. Hanne Ludvigsen (hanne.ludvigsen(a)tkk.fi)
Tel: +358 9 470 22282
www : http://nano.tkk.fi/en/research_groups/fiber_optics/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
Optoelectronics Group	*1, 4, 6, 7, 8, 9*

Leader

Prof. Markku Sopanen

Special know-how of the group:

1) Epitaxy (growth) of III-V semiconductor layers, device strutures and nanostructures **2**) Fabrication of optoelectronic components (LEDs, diode lasers, detectors, solar cells, etc.) **3**) Growth of quantum dot, quantum wire and quantum well structures **4**) Optical spectroscopy, atomic force microscopy and X-ray diffraction.

Objectives of the research:

1) To improve optoelectronic devices by utilizing new materials and nanostructures **2**) To design devices and systems intended for applying optoelectronic devices in biological, chemical and physical measurements.

Most significant results during 2008-2009:

1) Enhancement of visible LED efficiency **2**) UV LED matrices for DNA studies

Possible utilization of the results:

Companies involved in our TEKES projects. Spin-off companies. Our graduatees.

Contact

Prof. Markku Sopanen (markku.sopanen(a)tkk.fi)
Tel: +358 9 470 23124
www : http://nano.tkk.fi/en/research_groups/optoelectronics/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Micro and Nanosciences

Group name	Classifications
Photonics Group	*1, 2, 4, 6, 7, 8, 9*

Leader

Prof. Seppo Honkanen

Special know-how of the group:

1) Investigation of the photodarkening effect in Yb-doped fibers **2**) Integration of Atomic Layer Deposition (ALD) with Si-nanophotonics and studies of Ag nanoparticles embedded in glass **3**) In general, strong expertise on guided-wave nanophotonics

Objectives of the research:

World-class research on nanophotonics with applications on telecommunications, fiber lasers and guided-wave sensors.

Most significant results during 2008-2009:

1) Photodarkening studies of Yb-doped fibers **2**) Demonstration of Surface Enhanced Raman Scattering (SERS) with Ag nanoparticles partially embedded in glass with an ion exchange process **3**) Integration of ALD-deposited materials with Si-nanoslot waveguides

Possible utilization of the results:

The results can be applied in the development of improved fibers for fiber lasers, in novel biosensors and in all-optical devices for telecommunication.

Contact

Prof. Seppo Honkanen (seppo.honkanen(a)tkk.fi)
Tel: +358 50 384 1769
www : http://nano.tkk.fi/en/research_groups/photonics/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Electronics, Communications and Automation
Department of Radio Science and Technology

Group name	Classifications
Artificial electromagnetic materials and applications	*1, 2, 6, 7, 9*

Leader

Prof. Sergei Tretyakov

Special know-how of the group:

World-class expertise in the electromagnetic theory, analytical modelling of artificial electromagnetic materials and surfaces including metamaterials and metasurfaces, electromagnetic computations in both radio and optical frequency ranges, microwave, millimeter and submillimeter electromagnetic characterization of natural and artificial material samples, waveguides, antennas and components of wireless techniques. The key personnel of the team is internationally well-known for the books and papers referring to the applied electromagnetics and artificial materials. E.g. "Analytical modelling in applied electro-magnetics" (2003) was the first known monograph where the properties of metamaterials were studied and explained. The leaders of metamaterial research at Aalto University School of Science and Technology are **professors Sergei Tretyakov, Constantin Simovski** and **Dr Igor Nefedov**.

Objectives of the research:

Design, realization, and investigations of artificial electromagnetic materials (metamaterials), posessing exotic and useful properties, not available in natural materials. The focus is on metamaterials formed by inclusions on the nanoscale, which could result in innovative collective responses at optical and THz frequencies.

Most significant results during 2008-2009:

New approaches to cloaking of objects from electromagnetic fields, new principles of the design of artificial materials for transformational electromagnetics and optics, compact antennas utilizing artificial magnetic counductors and magnetic nanocomposites, non-reflecting microwave lenses, new principles and devices for sub-wavelength imaging at microwaves, in the THz and optical ranges, new theory of electromagnetic characterization of micro- and nano-structured materials taking in account the resonant properties of constituents, new metamaterials for nanosensing, metamaterial tips for near-field microscopes enabling the field-enhanced Raman scattering and fluorescence.

Possible utilization of the results:

Main applications are in the field of nanophotonics, including optical nanoimaging and nanosensing. Medicine, biology, security, space optics and prospective telecommunications systems can benefit from new devices designed in our group and based on metamaterial components.

Contact

Prof. Sergei Tretyakov (sergei.tretyakov(a)tkk.fi)
www : http://users.tkk.fi/sergei/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Biomedical Engineering and Computational

Group name	Classifications
Engineered nanosystems, BECS	*2, 6, 7, 9, 11 (Thermophotonics)*

Leader

Prof. Jukka Tulkki

Special know-how of the group:

1) Semiconductor optics **2**) Modeling of electronic structure carrier dynamics in nanostructures **3**) Device level multiphysics modeling in optoelectronics

Objectives of the research:

To develop generic multiphysics modelling tools for nanometerscale crystals and related optoelectronic and thermophotonic devices.

Most significant results during 2008-2009:

1) Introduction of a new device concept the thermophotonic heat pump **2**) Research of drooping in high efficiency LEDs **3**) research of quantum trajectory model of photon fields

Possible utilization of the results:

Optoelectronics, thermophotonics

Contact

Prof. Jukka Tulkki (jukka.tulkki(a)hut.fi)

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
NanoMaterials Group, NMG	*2, 3, 4, 5, 6, 7, 8*

Leader

Prof. Esko I. Kauppinen

Special know-how of the group:

1) SWCNT (Single wall carbon nanotube), CNT (Carbon nanotube) and CNB (Carbon nanobud) synthesis **2**) Optical characterisation (Raman, absorption): 1 Å resolution HRTEM, electron diffraction, EELS; EDS **3**) Aerosol flow reactors **4**) Nanoparticle synthesis and measurement **5**) Manufacturing and characterisation of TFT-FET and transparent electrodes **6**) Inhalation drug delivery materials and technologies

Objectives of the research:

1) Develop new carbon nanomaterials (SWCNTs, CNB) -synthesis, structure characterisation and transparent, flexible electronics applications (transparent conductors, TFT-FETs, field emission sources) **2**) Develop novel drug delivery technologies (inhalation, injection) based on nanoparticles as well as on nanostructured microparticles

Most significant results during 2008-2009:

1) World record conductivity transparent flexible electrode based on SWCNTs: sheet resistance 40 ohms/sq when transparency 80 % (compare to best graphene which has 10 times lower conductivity with similar transparency) i.e. better than ITO on polymer **2**) Flexible, transparent TFT-FETs with both electron and hole mobilities better than those of best organic thin film TFTs and which are much more stable **3**) Lithograhy free manufacturing of SWCNT TFT-FETs **4**) Method to manufacture free standing SWCNT films which are transparent and highly conductive, can be used e.g. as loadspeaker and are excellent nanoparticle filters **5**) Method to produce N-doped SWCNTs - SWCNTs with extremely high crystallinity as verified by STM and HRTEM **6**) Electron diffraction method to determine chirality of SW, DW, and TWCNTs **7**) Peptide coated, easily flowable microparticles for inhalation delibvery of drugs & related manufacturing method **8**) Novel, simple method to grow metal oxide nanowires **9**) Novel CNT-cement hybride material for the production of super-strong, electrically conductive concrete **10**) Temperature dependent Raman studies of SWCNT and CNBs **11**) Simulataneous HRTEM, ED and Raman studies of an individual carbon nanobud (CNB)

Possible utilization of the results:

Transparent electrodes and transistors have billion eur + markets in e.g. e-paper, flexible displays, touchscreens, haptic user interfaces, solar cells etc. TKK spin-off Canatu is commercialising these technologies Peptide coated drug particles have billion level end markets in the fields of both local (asthma, COPD) as well as systemic (e.g. insulin, pain killers) drug delivery systems. TKK spun off Teicos Pharma Oy to commercialise the technology developed at NMG.

Contact

Prof. Esko I. Kauppinen (esko.kauppinen(a)tkk.fi)
Tel: +358 40 509 8064
www : http://tfy.tkk.fi/nanomat/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Multiscale Statistical Physics Group	*1, 2, 9, 11 (Biomolecular applications)*

Leader

Prof. Tapio Ala-Nissilä

Special know-how of the group:

Theoretical and computational multi-scale and coarse-graining methodologies; various simulation methods on all scales from nano to macro.

Objectives of the research:

Theoretical and computational multi-scale modeling of micro- and nanosystems, and their application in thin films, surface coatings, microfluidistics, and controlling microstructure of materials (metals and polymers).

Most significant results during 2008-2009:

1) Development of a new method to model multiphase flows in microchannels **2**) Construction of a computationally efficient model for water molecules **3**) Construction of a computationally efficient model for the study of microstructures in metals **4**) Unraveling the influence of various physical parameters (such as polymer-pore interactions) on the translocation dynamics of DNA through nanopores

Possible utilization of the results:

Coating industries, lab-on-a-chip technology, microcircuit cooling

Contact

Prof. Tapio Ala-Nissilä (Tapio.Ala-Nissila(a)tkk.fi)
Tel: +358 40 541 2983
www : http://www.fyslab.hut.fi/~ala

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Nanomagnetism and Spintronics	*2, 6, 7*

Leader

Prof. Sebastiaan van Dijken

Special know-how of the group:

The NanoSpin Group has an extensive expertise in thin film and multilayer growth, nanoscale device fabrication, and structural, magnetic, and ferroelectric characterization. The experimental infrastructure consists of a pulsed-laser deposition system for high-quality multilayer oxide growth, a multi-target magnetron sputtering system with in-situ patterning capability, and several dedicated setups for magnetic, ferroelectric, and magnetotransport analysis. Besides, the group utilizes state-of-the-art equipment at the Micronova cleanroom (lithography) and the recently established Nanomicroscopy Centre.

Objectives of the research:

The Nanomagnetism and Spintronics (NanoSpin) Group focuses on the experimental investigation and utilization of magnetic phenomena and spin transport in new functional materials and hybrid nanoscale structures. Current projects include studies on magnetoelectric coupling in ferromagnetic/ferroelectric thin film composites, tunnel junctions with active tunnel barriers, current-induced spin-torque switching in MgO-based magnetic tunnel junctions, and high-speed domain wall dynamics.

Most significant results during 2008-2009:

1) Strong magnetoelectric coupling in hybrid BaTiO3/thin magnetic film structures **2**) Fabrication of all-oxide tunnel junctions with magnetic and ferroelectric functionality **3**) Current-induced magnetic switching in nanopillar tunnel junctions with ultrathin MgO barriers **4**) Development of a new method based on magneto-optics for studying dynamic domain wall motion in thin magnetic films

Possible utilization of the results:

The application areas of our research include magnetic sensors, magnetic and ferroelectric storage, and tunable microwave device technology.

Contact

Prof. Sebastiaan van Dijken (sebastiaan.van.dijken(a)hut.fi)
Tel: +358 50 316 0969
www : http://tfy.tkk.fi/nanospin/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Quantum Dynamics	*2, 6, 7, 8, 9*

Leader

Prof. Päivi Törmä

Special know-how of the group:

1) Nanoelectronics and nanofabrication **2**) Plasmonics **3**) Many-body quantum physics, analytical and numerical methods

Objectives of the research:

1) Nano- and molecular electronics **2**) Programmable materials, especially DNA self-assembly **3**) Plasmonics and nanophotonics **4**) Theory research on many-body quantum physics

Most significant results during 2008-2009:

The titles of the latest articles are good examples of the latest results: **1**) Field induced nanolithography for high-throughput pattern transfer **2**) Fermi Condensates for Dynamic Imaging of Electromagnetic Fields **3**) Hopping modulation in a one-dimensional Fermi-Hubbard Hamiltonian **4**) High speed memory from carbon nanotube field-effect transistors with high-K gate dielectric **5**) Vacuum Rabi splitting and strong coupling dynamics for surface plasmon polaritons and Rhodamine 6G molecules **6**) Induced interactions for ultra-cold Fermi gases in optical lattices **7**) DNA origami as a nanoscale template for protein assembly **8**) Spectral signatures of the Fulde-Ferrell-Larkin-Ovchinnikov order parameter in one-dimensional optical lattices **9**) Dielectrophoretic Trapping of DNA Origami

Possible utilization of the results:

In nanodevices using carbon nanotubes (the carbon nanotube memory), in assembly of nanodevices (the work on DNA origami), and in coherent plasmonics (the work on Rabi splitting).

Contact

Prof. Päivi Törmä (paivi.torma(a)hut.fi)
Tel: +358 50 382 6770
www : http://tfy.tkk.fi/qd/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
New Energy Technologies	*2, 5, 7, 8, 11 (Energy)*

Leader

Prof. Peter Lund

Special know-how of the group:

1) Material, characterization and device know-how on solar cells and fuel cells **2**) Nanomaterial integration into energy deviced

Objectives of the research:

1) Nanoscience and nanotechnology integration into energy applications **2**) Future energy technologies such as fuel cells and solar energy

Most significant results during 2008-2009:

1) Nanosolar cells on flexible substrates (dye sensitized nanostructured TiO_2 cell) **2**) Scaling up of laboratory solar cells into a technology scale **3**) Nanotechnology enhanced thin solar cells

Possible utilization of the results:

Small scale energy applications, mobile and portable power production Solar energy applications, built

Contact

Prof. Peter Lund (peter.lund(a)tkk.fi)

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Computational Soft Matter Research Group	*2, 9*

Leader

Academy Research Fellow Emppu Salonen

Special know-how of the group:

The group's expertise lies in molecular modeling of carbon-based nanomaterials (fullerenes and carbon nanotubes; both pristine and functinalized) and biological systems. The methods used range from ab initio quantum chemistry calculations to classical atomistic and coarse-grained molecular dynamics simulations.

Objectives of the research:

1) Provide insight on the basic interactions between carbon-based nanomaterials and biological macromolecules, such as proteins/peptides, nucleic acids, lipids, and carbohydrates. **2**) Assess the solubilization, transport, and uptake mechanisms of nanomaterials in laboratory conditions as well as in the environment (especially natural water sources). **3**) Develop novel methods for simulations of nanomaterial-biomaterial interactions.

Most significant results during 2008-2009:

Together with our experimental colleagues at Clemson University (SC, USA), we characterized the solubilization of fullerenes C_{70} by gallic acid (GA), a phenolic acid that is commonly found in plants. This was followed by exposing live human tumor cells to the GA-solubilized fullerene clusters, resulting in rapid cell death. Another study with the same experimental collaborators demonstrated the inhibition of DNA polymerase reaction by the water-soluble fullerene derivative $C_{60}(OH)_{20}$. This was concluded to result from the direct interaction of $C_{60}(OH)_{20}$ with the polymerase enzyme. A detailed investigation to uncover the mechanism of enzyme inhibition at the atomic scale is now in progress. In addition to applications, the group has worked on the development of state-of-the-art models of fullerenes and fullerene derivatives to be used in classical molecular dynamics simulations.

Possible utilization of the results:

The group's focus is on basic research related to nanomaterial-biomaterial interactions. The aim is to provide complementing insight on systems and processes studied in experiments, and to motivate further experimental work on topics that have been first investigated in modeling studies.

Contact

Dr. Emppu Salonen (emppu.salonen(a)tkk.fi)
Tel: +358 9 470 23370
www : http://tfy.tkk.fi/soft/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Quantum Computing and Devices	*6, 7, 8, 9*

Leader

Dr. Mikko Möttönen

Special know-how of the group:

1) Theory of quantum systems **2**) Nanoelectronic devices **3**) Josephson devices **4**) Experimental low-temperature physics

Objectives of the research:

We study fundamental quantum mechanical phenomena in nanoscale systems and aim to use them in practical applications such as quantum bits, current sources, and microwave detectors.

Most significant results during 2008-2009:

1) Demonstration of a single-electron turnstile for quantum metrology **2**) Experimental determination of the Berry phase in a superconducting charge pump **3**) Suggestion for experimental realization of Dirac monopoles **4**) Demonstration of a single-atom transistor.

Possible utilization of the results:

Redefinition of the international system of units (SI), fundamental knowledge of Nature, and emerging computational devices.

Contact

Dr. Mikko Möttönen (mikko.mottonen(a)tkk.fi)
Tel: +358 50 594 0950
www : http://tfy.tkk.fi/qcd/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Molecular materials/Ruokolainen	*2, 4, 7*

Leader

Prof. Janne Ruokolainen

Special know-how of the group:

1) High resolution microscopy for soft materials **2**) Self assembly materials

Objectives of the research:

1) Develop new functional materials and smart materials. Currently the main focus is in responsive materials such as hydrogels and vesicular structures e.g. for drug delivery applications We use polymers, liquid crystals, polypeptides, electrospun nanofibers, aerosol polymer nanoparticles as structural units in supramolecular assemblies. **2**) Second objective is to set up experimental facilities for high resolution microscopy characterization and especially cryo electron microscopy for materials science applications.

Most significant results during 2008-2009:

Development of new self-assembly materials based on dendron and dendrimer supramolecular liquid crystals

Possible utilization of the results:

Scientific community

Contact

Prof. Janne Ruokolainen (janne.ruokolainen(a)tkk.fi)
Tel: +358 50 347 0759
www : http://tfy.tkk.fi/molmat/

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AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Optics and molecular materials	*1, 2, 4, 5, 6, 8*

Leader

Acad. Prof. Olli Ikkala

Special know-how of the group:

Learn from biological material to obtain new extraordinary materials properties

Objectives of the research:

Biomimetic and functional materials based on self-assemblies

Most significant results during 2008-2009:

1) Steel-strong nanostructured materials based on biological concepts **2**) New biological concepts for self-propulsion of miniaturized devices **3**) New self-cleaning surfaces **4**) Functional material based on nanocellulose **5**) Metal nanoclusters for sensing and diagnostics

Possible utilization of the results:

Lightweight but strong construction for telecommunication and other constructs, coating industry

Contact

Acad. prof. Olli Ikkala / Dr. Robin Ras (olli.ikkala(a)tkk.fi / robin.ras(a)tkk.fi)
www : http://omm.tkk.fi/en/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Biological Physics group	*1, 2, 4, 9,11 (Biological matter in nano-scale)*

Leader

Prof. Ilpo Vattulainen

Special know-how of the group:

Multi-scale modeling of biological matter, including quantum-mechanical, atomistic classical and coarse-grained modeling of biological systems.

Objectives of the research:

The group focuses on the theory and modeling of biologically relevant soft and condensed matter systems. The research includes the development of theoretical and computational techniques for coarse graining and multiscale modeling, the development of force fields for atomistic simulations of biological matter, and applications of these methods to study physicochemical properties of biological systems over a multitude of scales in time and space. The area of research covers lipid membranes (as well as interactions of these systems with e.g. drugs, alcohols, and sterols), drug delivery, nanomaterials, structure and dynamics of protein-membrane complexes, lipoproteins, glycosystems, and nanocellulose.

Most significant results during 2008-2009:

1) Structure of lipid rafts **2**) Structure of lipoproteins **3**) Atomistic models for nanocellulose **4**) Determination of activation mechanisms for membrane proteins **5**) Determination of nanomaterial induced cell death.

Possible utilization of the results:

Understanding of the mechanisms of nanomaterial-induced cell death allows better design of safer nanomaterials. Development of functionalized nanocellulose paves way for novel nanomaterials with user-tuned properties. Understanding of ways to govern protein activation and functionality allows the design of biological nanoengines, for example, as biosensors. Determination of lipoprotein structures and their functions allows one to better understand why and how cardiovascular diseases emerge, and to find means to treat these diseases.

Contact

Prof. Ilpo Vattulainen (ilpo.vattulainen(a)tut.fi)
www : http://tfy.tkk.fi/bio/ and www.tut.fi/biophys/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Surface Science Group	*1, 6, 7*

Leader

Doc. Jouko Lahtinen

Special know-how of the group:

Structural and chemical characterization of solid surfaces using ultra high vacuum techiques like XPS, LEED and STM

Objectives of the research:

1) To understand adsorption on atomic level on some catalytic processes **2**) To understand and model adhesion processes **3**) To build up a model for light emission in Si nanocrystals

Most significant results during 2008-2009:

Showing how an increase in the surface roughness decreases adhesion in general and especially on medically used salbutamol sulfate particles

Possible utilization of the results:

Our results will be useful for researchers who work closer to the industrial applications.

Contact

Doc. Jouko Lahtinen (jouko.lahtinen(a)tkk.fi)
www : http://www.fyslab.hut.fi/surface/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
Electronic properties of Materials / COMP	*1, 2, 6, 7, 9*

Leader

Prof. Martti Puska

Special know-how of the group:

First-principles electronic structure calculations on the atomistic scale. Longer length and time scales are modeled by methods such as the lattice kinetic Monte Carlo.

Objectives of the research:

Modeling of materials and nanostructures on the basis of first-principles electronic-structure calculations. The modeling includes properties and phenomena. Electronic (including e.g. those of defects in semiconductors and electron transport through nanostructures), mechanical and optical properties are considered. Time-dependent (non-adiabatic) phenomena in nanostructures are modeled.

Most significant results during 2008-2009:

1) Modeling of electronic properties of defects and interfaces in semiconductor materials including Si, GaAs, GaN, InGaN, ferroelectric materials, and transparent conducting oxides **2**) Modeling of novel carbon materials: nanotubes, graphene etc. **3**) Development and implementation of first-principles electronic-structure methods: Time-dependent density-functional theory, van der Waals density functional, application of the finite element method in electronic-structure calculations

Possible utilization of the results:

Design of materials and systems for nanoelectronics

Contact

Prof. Martti Puska (martti.puska(a)tkk.fi)
www : http://tfy.tkk.fi/epm

In addition to the mentioned leader, the research profile includes the research of:

prof. Antti-Pekka Jauho

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Information and Natural Sciences
Department of Applied Physics

Group name	Classifications
COMP	*1, 2, 6, 7, 9*
Leader	

Prof. Risto Nieminen

Special know-how of the group:

Theory, modelling and simulation of nanomaterials, processes and devices

Objectives of the research:

Center of Excellence in Computational Nanoscience consists of 7 research groups: - Electronic Properties of Materials (**Prof. Puska**) - Surfaces and Interfaces at the Nanoscale (**Prof. Foster**) - Quantum Many-Body Physics (**Dr. Harju**) - Multiscale Statistical Physics (**Prof. Ala-Nissilä**) - Complex Materials and Systems (**Prof. Alava**) - Biological Physics (**Prof. Vattulainen**) - Quantum Computing and Devices (**Dr. Möttönen**)

Most significant results during 2008-2009:

1) Basic-research publication activity, method development, researcher training, visitor program, workshop program **2**) Nanostructured carbon materials and devices, nanoscale ferroelectricity, oxide materials **3**) Interpretation of scanning-probe microscopies **4**) Membrane biophysics **5**) Physical realisations for quantum computing

Possible utilization of the results:

Applications in functional materials for sensors and other devices -Interpretation of various nanoscale characterisations -Switching and memory elements in nanoelectronics

Contact

Prof. Risto Nieminen (risto.nieminen(a)tkk.fi)
Tel: +358 50 3500900
www : http://tfy.tkk.fi/comp

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Engineering and Architecture
Department of Engineering Design and Production

Group name	Classifications
Engineering materials	*2, 7, 8*

Leader

Prof. Hannu Hänninen

Special know-how of the group:

1) Synthesis of metal and oxide nanocomposites of CNTs and CNFs (Carbon nanofibers) using electroless methods **2**) Mechanical testing of engineering materials and strain localization studies using in-situ loading equipment in FEG-SEM **3**) Optical strain measurement **4**) Modelling of load transfer and strain accomodation at the interfaces **5**) Anelasticity of nanocomposites.

Objectives of the research:

CNT- (Carbon Nanotube) metal and CNT-oxide nanocomposites: synthesis, characterisation and modelling

Possible utilization of the results:

Machine construction

Contact

Prof. Hannu Hänninen (hannu.hanninen(a)tkk.fi)
Tel: +358 50 501 4089
www : http://www.tkk.fi

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Faculty of Engineering and Architecture
Department of Structural Engineering and Building Technology

Group name	Classifications
Nanomaterials in building technology	*2, 5*

Leader

Prof. Vesa Penttala

Special know-how of the group:

Production of carbon nanotube concrete composites.

Objectives of the research:

To improve the properties of building materials by modifying their microstructure by carbon nanofibers or by carbon nanotubes.

Most significant results during 2008-2009:

The compressive strength of the carbon nanotube concretes was improved to nearly double value in comparison with the reference concrete. The electrical resistivity was lowered by on order of magnitude classifying this material as a semiconductor.

Possible utilization of the results:

If the mass production of these new carbon nanotube modified cements can be innovated, it benefits the whole concrete industry.

Contact

Prof. Vesa Penttala (vesa.penttala(a)tkk.fi)
Tel: +358 9 451 23770

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Independent Institutions
Low Temperature Laboratory

Group name	Classifications
NANO-group	*2, 6, 8, 9*

Leader

Prof. Pertti Hakonen

Special know-how of the group:

Microwave measurements at millikelvin temperatures

Objectives of the research:

The research work of the NANO group is focused on three areas: **1**) Mesoscopic quantum amplifiers and qubits, **2**) Quantum transport in carbon nanotubes and graphene, and **3**) Current fluctuations and fast dynamics in quantum circuits.

Most significant results during 2008-2009:

Noise characterization of ballistic graphene at GHz frequencies

Possible utilization of the results:

The scientific community working on graphene devices

Contact

Prof. Pertti Hakonen (pjh(a)boojum.hut.fi)
www : http://boojum.hut.fi/nano/

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY

Independent Institutions
Low Temperature Laboratory

Group name	Classifications
PICO-group	*6*

Leader

Prof. Jukka Pekola

Special know-how of the group:

1) Physics of single-electron tunneling **2**) Superconducting nanostructures **3**) Quantum nanoelectronics **4**) Electron-beam lithography **5**) Low temperature techniques.

Objectives of the research:

We aim at understanding the physics of quantum nanostructures at low temperatures. In particular we focus on single-electron tunneling and heat transport properties in superconductors, normal metals and in hybrids of them. We are developing quantum metrological standards for electric current and for thermometry based on single-electron tunneling.

Most significant results during 2008-2009:

1) Hybrid single-electron turnstile as a source of quantized electric current **2**) Measurement of the quantum of heat conductance

Possible utilization of the results:

In metrology and eventually in the system of units. In the work of other scientists in related fields.

Contact

Prof. Jukka Pekola (jukka.pekola(a)tkk.fi)
Tel: +358 9 470 24913
www : http://ltl.tkk.fi/PICO/

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AALTO UNIVERSITY SCHOOL OF ECONOMICS

Department of Marketing and Management
Organization and Management

Group name	Classifications
Research group on nanotechnology business	*11 (Nanotechnology in the society)*

Leader

Dr. Nina Granqvist

Special know-how of the group:

The members of the group have a wide understanding on the dynamics of emergence of novel businesses and industries. The research group members have conducted close to 150 interviews with the key stakeholder in the field both in the Nordic Countries and Silicon Valley. Other data includes a major database on news stories on nanotechnology, both publicly and privately accessible reports, and scientific articles on nanotechnology.

Objectives of the research:

The aim of the research conducted in this group is to understand how nanotechnology contributes to the emergence of novel business activities and to the renewal of existing industries. The research ranges from studying the local local emergence of new scientific and commercial activities, to investigating the origins and processes that induce technology hypes, and to understanding executives' decisions to engage with novel technologies.

Most significant results during 2008-2009:

n.a.

Possible utilization of the results:

n.a.

Contact

Dr. Nina Granqvist (nina.granqvist(a)hse.fi)
Tel: +358 50 5951759

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Soft matter physics	*1, 2, 7*

Leader

Prof. Ritva Serimaa

Special know-how of the group:

Synchrotron radiation and x-ray based methods for characterization of the structure of materials like wide and small angle x-ray scattering, grazing incidence x-ray diffraction and reflectivity, x-ray absorption spectroscopy, x-ray microtomography

Objectives of the research:

Studies on the structure and properties soft nanomaterials using x-ray based methods. The applications include nanofibrillated cellulose, natural polymer based nanocomposites and two-dimensional protein coatings.

Most significant results during 2008-2009:

1) Structure of self-assembled films of hydrophobin proteins HFBI and HFBII in situ at the air/water Interface was characterized using synchrotron radiation. **2**) Nanocomposites of transition metal nanoparticles and cellulose was prepared and characterized using anomalous scattering and absorption spectroscopy in co-operation with Inst. of Macromolecular Compunds, St. Petersburg. **3**) Drying and crystallization of natural polymer based film was followed using combined ultrasonics and x-ray experiments **4**) The nanostructure of nanofibrillated cellulose was characterized from nanometer to micrometer scale using x-ray scattering and microtomography.

Possible utilization of the results:

Food and paper industry.

Contact

Prof. Ritva Serimaa (ritva.serimaa(a)helsinki.fi)
Tel: +358 9 191 50630
www : http://www.materials.physics.helsinki.fi/

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Materials science simulations	*1, 2, 6, 7, 8, 9*

Leader

Prof. Kai Nordlund

Special know-how of the group:

1) Molecular dynamics simulations **2**) Density functional theory calculations **3**) Analytical theory **4**) Interatomic potential development **5**) Kinetic Monte Carlo simulations

Objectives of the research:

Understand the ion and cluster ion beam processing of materials on the atomic scale and use these insights to enable development of improved and new materials

Most significant results during 2008-2009:

Combined theoretical and experimental proof that **1**) swift heavy ion tracks in silica are underdense in the core **2**) That ion beams can be used to densify nanocrystalline thin films **3**) That pure metals can sputter chemically

Possible utilization of the results:

1) Development of ways to grow nanowires in swift heavy ion tracks **2**) development of nanocrystalline thin films made a new kinds of materials **3**) plasma processing of materials

Contact

Prof. Kai Nordlund (kai.nordlund(a)helsinki.fi)
www : http://www.acclab.helsinki.fi/sim/

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
X-ray Spectroscopy Group	*7, 9*

Leader

Prof. Keijo Hämäläinen

Special know-how of the group:

X-ray based techniques in materials characterization using synchrotron radiation

Objectives of the research:

Fundamental studies of electronic structure in novel materials

Most significant results during 2008-2009:

Development of various experimental and computational tools for electronic structure studies

Possible utilization of the results:

In linking the materials macroscopic and electronic structure level properties

Contact

Prof. Keijo Hämäläinen (keijo.hamalainen(a)helsinki.fi)
www : http://www.materials.physics.helsinki.fi/english.html

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Ion beam group	*2, 7, 8*

Leader

Prof. Juhani Keinonen

Special know-how of the group:

The research aims to understand the interaction of energetic ions with atoms of materials and slowing-down of ions in solids, effects of ion implantations on the structure of matter, interaction of defects, host atoms and implanted atoms in matter, and diffusion and solubility of doping atoms. The experimental work on materials physics is complemented by atom-level computer simulations, which can describe both the high-energy collisions induced by ion beams, and the subsequent modification of the equilibrium properties of materials.

Objectives of the research:

The main interests are to obtain new information about physical processes taking place in materials during and after implantation and the development of better processing methods of materials and development of new materials.

Most significant results during 2008-2009:

1) Changes of mechanical and electric properties were defined in single-walled carbon nanotube (SWNT) networks (SWNT paper) irradiated with high energy heavy ion beams. **2**) New photoactive defect structures were defined in alpha-quartz doped by ion implantation.

Possible utilization of the results:

Results are essential for continuous development of nano-materials and related devices, e.g. in nanophotonics.

Contact

Prof. Juhani Keinonen (juhani.keinonen(a)helsinki.fi)

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Biophysics	*9*

Leader

Prof. Arto Annila

Special know-how of the group:

Statistical physics of open systems.

Objectives of the research:

To acquire holistic understanding of nature from first principles.

Most significant results during 2008-2009:

Derivation of evolutionary equation of motion.

Possible utilization of the results:

The natural law of maximal energy dispersal is general. It can be applied to rationalize diverse processes and phenomena.

Contact

Prof. Arto Annila (arto.annila(a)helsinki.fi)
Tel: +358 9 191 50629
www : http://www.physics.helsinki.fi/~aannila/arto/

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Division of atmospheric sciences and geophysics	*3, 7, 8, 9*

Leader

Acad. prof. Markku Kulmala

Special know-how of the group:

1) Modeling of atmospheric clusters using molecular level methods **2**) Aerosol dynamic modeling of atmospheric particle formation **3**) Measurement of world's longest time series in atmospheric nanoparticle formation events and nano-particle size distributions **4**) Detecting and uncovering the chemical identity of atmospheric nanoscale condensation nuclei **5**) Instrument and model development **6**) Intercomparison of theory and experiment

Objectives of the research:

Uncovering the formation mechanisms of atmospheric nanoparticles and their effect on climate and air quality.

Most significant results during 2008-2009:

1) Reduction in aerosol, particle concentrations might enhance to global warming **2**) Developed techniques to detect electronically neutral aerosol particles below 3 nanometers in diameter **3**) Quantitative measurements of the ability of 1-3 nanometer particles act as condensation nuclei **4**) Ion-induced nucleation is not the major particle formation channel in the atmosphere **5**) Developed techniques to measure chemical composition of atmospheric ions **6**) Molecular modeling results of atmospheric nanoclusters confirmed with experiments, theory also assisting instrument development and data analysis

Possible utilization of the results:

The results narrow down the uncertainties related to atmospheric aerosols in predicting climate change. They increase information on airborne nanoparticles and nanoparticle physics in general, benefiting materials research. Aerosol dynamic models have a wide range of applications from industrial processes to assesment of environmental issues. End users of the results are policy makers, climate modellers ,process engineers, risk analysts.

Contact

Prof. Hanna Vehkamäki (hanna.vehkamaki(a)helsinki.fi)
Tel: +358 9 191 50710
www : http://www.atm.helsinki.fi/

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Physics

Group name	Classifications
Nano-aerosols, health and safety	*2, 3, 5, 7, 9*

Leader

Prof. Kaarle Hämeri

Special know-how of the group:

1) Measurement techniques of nano-aerosols **2**) Real-time and on-line methods **3**) Aerosol fundamental physics

Objectives of the research:

1) Safety and risks of engineered and pollution nanoparticles **2**) Instrumentation and characterization of the physico-chemical properties of nano-aerosols

Most significant results during 2008-2009:

1) Exposure characteristics of nano-particles in several occupational areas **2**) Exposure characteristics of nano-particles on mice

Possible utilization of the results:

The results can be utilised in developing protection to nanoparticles, in estimating the exposure and investigating the potential risks. The results can be used by all enterprices that are concerned about the risks of their production.

Contact

Prof. Kaarle Hämeri (kaarle.hameri(a)helsinki.fi)
Tel: +358 40 568 4487
www : http://www.atm.helsinki.fi

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Chemistry

Group name	Classifications
Optical and surface properties of nanoparticles, OPNA	*2, 3, 7, 8, 9*

Leader

Prof. Markku Räsänen

Special know-how of the group:

1) Molecular spectroscopy **2**) Infrared, raman, time-resolved luminescence **3**) Cryogenic techniques from 3 K

Objectives of the research:

1) To understand light amplification in Si-nanoparticles embedded in SiO_2 and structure of the interface between these. **2**) Excited states **3**) To develop further optical memory based on Si nanoparticles embedded in solid SiO_2: Pressure dependence of the phonon band measured by Raman scattering and data density of such memories and integration to known silicon technology. **4**) Chemical compounds formed by noble gases and connection to xenon anesthesia and to the missing xenon problem. **5**) Selective control of molecular conformations **6**) Chemical differences of different conformers **7**) Molecular level optical memory

Most significant results during 2008-2009:

1) Writing data to Si/SiO_2 nanoparticles **2**) Synthesis of HXeOXeH, very high energy species **3**) Stabilization of the higher-energy conformer of formic acid by complexation with water.

Possible utilization of the results:

Future electronics industry. Connected with the breakthrough of optical computing. May be connected with the molecular level mechanism of Xe-anesthesia. Deepends our understanding of the operation of our nervous system. Paves the way to control chemical reactions selectively. Very high potential value.

Contact

Prof. Markku Räsänen (markku.rasanen(a)helsinki.fi)
Tel: +358 9 191 50281
www : http://www.helsinki.fi/kemia/matrix/index_eng.htm

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Chemistry

Group name	Classifications
Inorganic Chemistry	*1, 2, 6, 7, 8*

Leader

Prof. Markku Leskelä

Special know-how of the group:

The group has long experience in ALD. The material selection and number of processes studied in ALD is high. Besides ALD, deposition of thin films are made also by other techniques: SILAR, evaporation, spin-coating. In situ reaction mechanism studies in ALD is one of the specialities of the group. Electrospinning of nanofibers and preparation of nanoporous materials are carried out in the group. Synteses of a variety of layered double hydroxide (LDH) based inorganic-organic nanocomposites has been recently developed in the group.

Objectives of the research:

The materials under study are thin films and nanomaterials. The common basis is synthetic chemistry and the synthesis products are used precursors for thin films and nanomaterials. The thin films are aimed for microelectronics, photvoltaics, photocatalysis, optics, MEMS, protection etc. The function of the thin film materials can be dielectric, conducting, barrier, hydrophobic or catalytic. As materials they are oxides, metals, nitrides or chalcogenides. The research is basic in nature (new chemistry, reaction mechanisms) but basic properties for the selected appplication areas are characterized as well. The nanomaterials studied are nanotubes, nanofibers, nanoporous materials and nanocomposites. Nanomaterial studies are mostly curiosity driven.

Most significant results during 2008-2009:

1) New ALD processes for selenide and telluride films **2**) New ALD processes for metal fluorides **3**) Use of polymers in selective area ALD **4**) Low-temperature processes for noble metal ALD **5**) New ways for making LDH based norganic-organic nanocomposites

Possible utilization of the results:

The ALD films and processes studied are applicable in microelectronics, optical and protective coatings. Nanocomposites may find applications as biomaterials and in cosmetics.

Contact

Prof. Markku Leskelä (markku.leskela(a)helsinki.fi)
Tel: +358 9 191 50195
www : http://www.helsinki.fi/kemia/epaorgaaninen

In addition to the mentioned leader, the research profile includes the research of:

prof. Mikko Ritala

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Chemistry

Group name	Classifications
Miniaturised instruments and neoteric techniques, MINT	*1, 3, 4, 9*

Leader

Prof. Marja-Liisa Riekkola

Special know-how of the group:

1) Development of miniaturized versatile instrumental techniques applicable to nanodomain interaction studies **2**) Coating of different surfaces with human materials **3**) Exploitation of complementary and multidisciplinary approaches, and simultaneous computational and experimental studies.

Objectives of the research:

1) To develop novel/neoteric miniaturised instruments/instrumental techniques vital at nanoscale. **2**) To apply advanced computational and numerical approaches for deeper understanding of nanoscale bioprocesses at tomistic and molecular level.

Most significant results during 2008-2009:

Capillary electromigration techniques can be exploited, in addition to separation techniques, as biomimicing instrumental techniques applicable to studies on the understanding of the molecular properties of human surface nanodomains. In the studies, it has been shown that human microemulsions, and several lipoproteins can be employed as stationary phase in electrochromatography (CEC). CEC has also revealed to be an efficient tool for the isolation of apolipoprotein B-100 (apoB-100), the main protein of low density lipoprotein particles (LDL) that, as a coating, is then available for broad interaction studies. Proteoglycans (PGs) are the most abundant compounds of the extracellular matrix (ECM). It is evident that an organized, tight PG network, formed from glycosaminoglycans, has the potential to bind lipoproteins, and the atherogenicity of especially LDL particles is linked to their affinity towards the intimal proteoglycans, and in the interactions and entrapment at least chondroitin-6-sulfates play an important role. In the studies the coating procedures for human proteoglycans have been developed, and interactions of proteoglycan with carefully selected peptide fragments of apoB-100 (the major apoprotein of low-density lipoprotein) have been preliminary clarified. In addition, our studies were dedicated to the construction/parameterization of a PRODRG derived force field for chondroitin-6-sulfate polysaccharide allowing further glycosaminoglycan studies. Density probability analysis on extended dynamics simulations and the subsequent derived dihedrals averages were found to be in a good agreement compared to experimental data. The availability of a force field for a polysaccharide chain of C6S enables other simulations related to C6S - apoB-100 interactions.

Possible utilization of the results:

The neoteric instrumental techniques developed will be beneficial in nanodomain studies. Combination of advanced chemical, molecular and computational concepts with novel instrumental microanalytical techniques will be helpful in the elucidation of nanoscale functions of lipoproteins. Computational studies carried out hand in hand with experimental ones will open new avenues for carbohydrate studies, and especially for the elucidation of diseases in which polysaccharides play an important role. The project will generate also a new knowledge useful in separation technology, and in modeling of modern miniaturized systems.

Contact

Prof. Marja-Liisa Riekkola (marja-liisa.riekkola(a)helsinki.fi)
www : http://www.helsinki.fi/kemia/analyyttinen/research/index.html

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UNIVERSITY OF HELSINKI

Faculty of Science
Department of Chemistry

Group name	Classifications
Polymer chemistry	*1,2,4,5,6,7*

Leader

Prof Heikki Tenhu

Special know-how of the group:

1) Synthesis of polymers and various nanomaterials **2**) Polymer characterization mainly by NMR, light scattering, rheological (dynamic mechanical), and thermoanalytical methods.

Objectives of the research:

The main objective is to apply advanced chemistry to create new materials and to master the methods of their characterization. This includes **1**) Modern methods to synthesize "smart", self-assembling polymers **2**) Water-soluble and/or amphiphilic polymers **3**) Use of the polymers e.g. as carriers for various active substances **4**) Development of the methods to characterize the polymers mainly in aqueous surroundings **5**) A new important group of new materials include various hybrid materials and nanocomposites based on for example gold, silver, copper, or montmorillonite nanoparticles. **6**) Also, water-dispersible conducting polymers are of interest.

Most significant results during 2008-2009:

1) New environmentally responsive star and block copolymers which react strongly to temperature, light, pH, even electric field **2**) Several new hybrid materials/nanocomposites **3**) Stereocontrol in radical polymerization

Possible utilization of the results:

The materials under study should find several applications ranging from controlled dug delivery to wood preservatives or even non-linear optics. Nanosized copper was prepared to manufacture conducting patterns on paper, polymer-modified silver nanoparticles have been prepared to obtain safe antibacterial coatings.

Contact

Prof. Heikki Tenhu (heikki.tenhu(a)helsinki.fi)
Tel: +358 9 19150334
www : http://www.helsinki.fi/polymeerikemia/english

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UNIVERSITY OF HELSINKI

Faculty of Pharmacy
Division of Pharmaceutical Technology

Group name	Classifications
Nanotechnology in Drug Development	*1, 2, 4, 7, 9*

Leader

Prof. Jouni Hirvonen

Special know-how of the group:

Prof. Jouni Hirvonen: Pharmaceutical research and development, mechanisms of drug release and absorption, controlled release drug formulations

Doc. Leena Peltonen: Manufacture and characterization of pharmaceutical nanosystems, polymeric nanoparticles and layer-by-layer functionalization, pharmaceutical formulations

Dr. Timo Laaksonen: Physical Chemistry, nanoparticle synthesis and functionalization, drug release modeling, gold nanoparticles.

Dr. Heldér Santos: Nanoporous silicon-based materials, pharmaceutical and physicochemical characterization, mechanisms of oral drug release and absorption, nanotoxicology.

Objectives of the research:

The group studies and develops biodegradable and biocompatible nanoparticles, nanocrystals and nanoporous materials in collaborative national and international projects. Controlled release formulations have been prepared/manufactured, e.g., by nanocrystallization (pure drug substances), nanoprecipitation (interfacial polymer deposition method for PLA- and PGA-type polymers that may further be coated by polyelectrolytes), electrospray (synthetic and natural polymers, nanocoating) and electrochemical etching (nanoporous silicon materials). Improving dissolution/solubility and permeability properties of drugs are key areas of research. Toxicity of the nanomaterials is also investigated.

Main objective of the current research is to reach fundamental understanding on the manufacturing and process parameters of nanosystems. Special focus is targeted to functionalized nano(particle)systems to reach optimal therapeutic response and safety profiles in nanomedicinal applications

Most significant results during 2008-2009:

Large number of high quality publications in the field of (pharmaceutical) nanotechnology.

Albert Wuokko Award for a young pharmaceutical research scientist in 2008: Samuli Hirsjärvi, thesis Preparation and Characterization of Poly(Lactic Acid) Nanoparticles for Pharmaceutical Use

2008 Gust. Komppa prize for the best chemical sciences related thesis of 2007 by Suomalaisten kemistien seura (Association of Finnish Chemists): Timo Laaksonen, thesis Noble Metal Clusters: Electrostatics, Stability and Applications

Possible utilization of the results:

Major beneficiaries are drug discovery and drug development companies together with service oriented enterprises. The results are also applicable to other industries dealing with the delivery of molecules to people, animals etc., such as food industry.

Contact

Prof. Jouni Hirvonen (jouni.hirvonen(a)helsinki.fi)
Tel: +358 9 191 59139

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UNIVERSITY OF HELSINKI

Faculty of Pharmacy
Division of Pharmaceutical Chemistry

Group name	Classifications
Division of Pharmaceutical Chemistry	*1, 4, 7, 8, 11 (Lab on a chip)*

Leader

Prof. Risto Kostiainen

Special know-how of the group:

Analytical techniques: Miniaturization of analytical devices, mass spectrometry, liquid separation, sample preparation, ion mobility spectrometry.

Objectives of the research:

1) Development of analytical instrumentation using micro- and nanotechnologies **2**) Surface fuctionalizing Brain metabolomics

Most significant results during 2008-2009:

Integrated liquid chromatography - heated nebulizer - mass spectrometry microchip, Surface functionalization by atmospheric discarge plasma, micropillar elctrospray ion source, proteomics on the chip.

Possible utilization of the results:

High throughput bio- and environmental analysis.

Contact

Prof. Risto kostiainen (risto.kostiainen(a)helsinki.fi)
Tel: +358 9 191 59134
www : http://www.helsinki.fi/farmasia/pharmchemistry/

In addition to the mentioned leader, the research profile includes the research of:

Prof. Tapio Kotiaho

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UNIVERSITY OF HELSINKI

Faculty of Pharmacy
Centre for Drug Research

Group name	Classifications
Drug Delivery and Nanotechnology	*2, 3, 4, 7, 8, 9*

Leader

Prof. Arto Urtti

Special know-how of the group:

Encapsulation of nanodrugs inside nanoparticles and the research on microencapsulated cells..

Objectives of the research:

Drug delivery and targeting with nanosystems and biomaterials. Interesting applications would be nanoparticles that target on to the cancer tissue or to the back of the eye.

Most significant results during 2008-2009:

Light sensitive nanoparticle for controlled drug release.

Possible utilization of the results:

Pharmaindustry and companies fabricating the microchips.

Contact

Prof. Arto Urtti (arto.urtti(a)helsinki.fi)
Tel: +358 9 191 59636
www : http://www.ddtc.helsinki.fi/research/group_urtti.htm

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UNIVERSITY OF HELSINKI

Faculty of Medicine
Haartman Institute

Group name	Classifications
Peptide and Protein Laboratory	*1, 2 ,4 6, 7, 10, 11 (Viruses as nanoparticles)*

Leader

Doc. Hilkka Lankinen

Special know-how of the group:

Doc. Hilkka Lankinen: Protein and peptide chemistry of viral proteins, virion isolations and virus-host cell interactions. **Prof. Antti Vaheri**: Basic, medical and diagnostic virology. Microarrays for detection of viral genomes and antibodies. **Prof. Olli Vapalahti**: Zoonosis virology and microarrays in virus diagnostics

Objectives of the research:

The group develops arrays for diagnostics of virus infections. The objective is to prepare combinatorial chips for detection of immune responses, viral and host nucleic acids as genetic markers of infections. We study photo-guided surface chemistries based on UV-LED materials in order to improve compatibility of biochips in diagnostics and diagnostic devices.

Most significant results during 2008-2009:

Isolation of a membranous virus, resolving of its structure, surface architecture and envelope protein chemistries in thiol-bridging. Multiplex-PCR and microarrray for detection of herpesvirus DNAs and antibodies. Proof-of-principles for use of peptide arrays in serodiagnostics. Employment of UV-LED photoactivation to capture macromolecules

Possible utilization of the results:

These results are of value for diagnostics of viral infections, in research and development of vaccines, antivirals and systems level technologies thereof.

Contact

Doc. Hilkka Lankinen (hilkka.lankinen(a)helsinki.fi)
Tel: +358 9 191 26306
www : http://www.hi.helsinki.fi

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UNIVERSITY OF HELSINKI

Faculty of Medicine
Haartman Institute

Group name	Classifications
Cancer Gene Therapy Group	*4*

Leader

Prof. Akseli Hemminki

Special know-how of the group:

Developing new virus based nanomachines for cancers lacking effective modalities.

Objectives of the research:

Our group develops oncolytic adenovirus based nanomachines to improve the treatment of cancers lacking currently available effective modalities.

Most significant results during 2008-2009:

Seven oncolytic adenoviruses built, tested and produced by our research group have been used with good results for cancer patients who have already gone through all currently available treatments. We have published over 20 articles in international peer-reviewed scientific publication series.

Possible utilization of the results:

Cancer patients who don't benefit from the traditional cancer treatments. Most of the patients treated with our oncolytic viruses have benefitted somehow from these treatments. In addition to several clinical objective responses viral treatments have enabled many patients to live longer or improve their quality of life.

Contact

K. Albin Johansson Research Prof. Akseli Hemminki (akseli.hemminki(a)helsinki.fi)
www : http://www.hi.helsinki.fi/cgtg/index.htm

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UNIVERSITY OF HELSINKI

Faculty of Medicine
Institute of Biomedicine

Group name	Classifications
Helsinki biophysics & biomembrane group	*2, 4*

Leader

Prof. Paavo Kinnunen

Special know-how of the group:

Biomaterial (lipids, proteins, nucleic acid) properties and self-assembly

Objectives of the research:

1) Development of nanoparticles for gene delivery and MRI (Magnetic Resonance Imaging) of the inner ear, and MRI-guided drug delivery into cancer cells **2**) Detection and abrogation of cancer metastases **3**) Mechanisms of action of cytotoxic peptides

Most significant results during 2008-2009:

1) Development of temperature sensitive drug encapsulating liposome nanoparticles **2**) Development of Gadolinium loaded liposomes for MRI of inner ear

Possible utilization of the results:

MRI-guided HIFU (high intensity focused ultrasound) triggered local drug delivery. Project coordinator is Philips medical, who manufactures MRI-HIFU equipment. Imaging of the inner ear and therapy of hearing loss.

Contact

Prof. Paavo Kinnunen (paavo.kinnunen(a)helsinki.fi)

UNIVERSITY OF HELSINKI

Faculty of Medicine
Institute of Biomedicine

Group name	Classifications
Klefstrom Group	*4*

Leader

Doc. Juha Klefström

Special know-how of the group:

1) Use of recombinant lentivirus technology for genetic perturbation analyses in vitro and in vivo **2**) Genetic programmable switches for inducible gene expression **3**) New 3D organoid cell culture platforms and genetic reprogramming of the mouse mammary gland

Objectives of the research:

1) Developing genetically programmable nanoparticles using recombinant lentivirus platform **2**) Improving lentiviral transduction efficacy to enable genetic perturbation analyses in vivo **3**) Modeling cancer gene specific circuits by genetic perturbation analyses using lentiviral carriers **4**) Exploring synthetic lethal genetic and small molecule interactions with cancer gene specific circuits to identify therapeutic strategies against cancer

Most significant results during 2008-2009:

1) Expanding the RNAi silencing technology to in vivo mouse tissues **2**) New inducible gene silencing constructs **3**) Mechanistic insights into genetic determinants of breast cancer development

Possible utilization of the results:

Better understanding of basic cell biology - Commercial technology-based offshoots - Pharmaceutical industry

Contact

Doc. Juha Klefstrom (juha.klefstrom(a)helsinki.fi)
Tel: +358 9 191 25493
www : http://research.med.helsinki.fi/gsb/klefstrom/

UNIVERSITY OF HELSINKI

Faculty of Medicine
Haartman Institute

Group name	Classifications
DNA virus research group	*4, 7*

Leader

Prof. Klaus Hedman

Special know-how of the group:

1) Development of novel diagnostic methods **2**) Recombinant expression of proteins and virus-like particles **3**) Immunobiology **4**) Nucleic acid detection and amplification techniques

Objectives of the research:

To assess the molecular biology, pathogenesis and clinical significance of the recently discovered "live nanomachines", i.e. DNA viruses of humans.

Most significant results during 2008-2009:

Analysing ex-vivo genomes of human parvovirus B19, we observed this single-straded (ss)DNA virus to have an astonishingly high evolution rate, ~10^{-4} nt/year, approaching that of RNA viruses. We developed comprehensive molecular tools and recombinant-protein-based serodiagnostics (IgG; IgM; IgG-avidity) for eight species of recently discovered human DNA viruses - Human bocaviruses (HBoV) 1-4, Parvovirus 4 (Parv4), and Polyomaviruses WU, KI and MC, and the entire genus of Anelloviruses - to elucidate the epidemiology, clinical significance and pathogenetic mechanisms of this "DNA microflora" infesting our tissues and cells. We (i) showed that the HBoV1 infections are systemic, and viremic, and can be diagnosed by qualitative PCR better in serum than in nasopharynx; and that (ii) Parv4 is extremely prevalent (80%) among HIV- or HCV-infected i.v. drug users; and that (iii) the cancer-causing MC polyomavirus occurs ubiquitously in the upper airways of young children, and with increasing prevalence through adulthood (pointing to persistence in tissues). Of note, our in-house-generated virus-like particles (currently existing for six of these species) will furthermore permit high-resolution surface topography studies of these emerging human viruses.

Possible utilization of the results:

Health-care units and clinical diagnostic laboratories throughout the world, as well as companies developing or manufacturing diagnostic methods.

Contact

Prof. Klaus Hedman (klaus.hedman(a)helsinki.fi)
Tel: +358 50 5249 086
www : http://www.hi.helsinki.fi/labhedmansoderlund/Site/Welcome.html

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UNIVERSITY OF HELSINKI

Faculty of Medicine
Protein Chemistry Core Facility

Group name	Classifications
Protein Chemistry/Proteomics/Peptide Synthesis and Array Unit	*1, 4, 7, 8*

Leader

Director Marc Baumann

Special know-how of the group:

1) Neuroscience **2**) Mico/nano-chip development **3**) Proteomics **4**) Protein/peptide arrays **5**) Mass spectrometry

Objectives of the research:

We are a group who has three main topics. **1**) We are studying neurosciences and especially interested in misfolding disorders. Through this we have long lasting experience in self-assembling molecules. **2**) We also study micro- and nano structures/surfaces for to produce selective biomolecular chip based devices for clinical diagnostics and medical and biochemical research. **3**) We are developing methods to provide sensitive and fast analyses on proteomic level. These would include secondary modification analyses, glycobiology and label-free quantitation.

Most significant results during 2008-2009:

1) We have shown that some of the known diseases are linked to molecular self-assembling. **2**) We have patented a new type of a micro-chip for protein analyses (automated 2D-gel electrophoresis micro-device for targeted proteomics). **3**) We have published two papers on nanostructures with biomolecular analyses.

Possible utilization of the results:

Scientists and companies who would be interested in selective molecule mapping of e.g. DNA/Proteins/phosphorylations/other secondary modifications incl. carbohydrates and lipids.

Contact

Director Marc Baumann (marc.baumann(a)helsinki.fi)
Tel: +358 50 567 1980
www : http://research.med.helsinki.fi/corefacilities/proteinchem/default.htm

Group name	Classifications
Nanobiomaterials	*1, 2, 4, 7, 11 (Biomaterials)*

Leader

Research Prof. Markus Linder

Special know-how of the group:

1) The group combines a knowledge of engineering biological molecules and their functional characterization. **2**) Recombinant DNA techniques are used for molecular engineering. **3**) Surface techniques are a special area of focus within biophysical characterization.

Objectives of the research:

The group works at the interface between biological and non-biological materials with a focus on molecular and nano-scale functions. The nanochemistry of biological molecules are used to create materials with new functions. The function of biological materials is studied with the aim of understanding underlying principles and use as a source for bioinspiration.

Most significant results during 2008-2009:

Current projects include; the use of biomolecuels to functionalize carbon nanostructures, the biological interface for sensor applications, specific molecular adhesion, self-assembly of biomolecules, bio-based composites, bioinspired tribology, nano-safety, and bio-based functionalization of cellulose nano-fibers. A biological question that we focus on is the structure and function of adhesive proteins called hydrophobins which are found in filamentous fungi.

Possible utilization of the results:

The results can be applied in various materials related fields, such as; senors, nanofabrication, adhesives, nanoencapsulation and lubrication. We also aim at understanding mechanisms for biointeractions and the satety of nanomaterials.

Contact

Research Prof. Markus Linder (markus.linder(a)vtt.fi)
www : http://www.vtt.fi

Group name	Classifications
Simulation of manufacturing processes	*2, 8*

Leader

Dr. Jari Larkiola

Special know-how of the group:

Metal forming technology and metallurgy. In addition we work in close co-operation with University of Strahclyde (UK) and TKK.

Objectives of the research:

To develope methods for industrial manufacturing of micro- and nanostrucured metals

Most significant results during 2008-2009:

We have manufactured ECAP-processed micro/nanostructured aluminium bars

Possible utilization of the results:

All components where ultimate high strength is required

Contact

Dr Jari Larkiola (jari.larkiola(a)vtt.fi)
Tel: +358 20 722 5591
www : http://www.vtt.fi

In addition to the mentioned leader, the research profile includes the research of:

Jouko Virta

Group name	Classifications
Nanoelectronics	*1, 2, 6, 7, 8, 9*

Leader

Prof. Jouni Ahopelto

Special know-how of the group:

1) Nanoscale electronics **2**) Nanoimprinting **3**) Characterisation

Objectives of the research:

1) Nanoelectronics **2**) Nanophotonics **3**) Nanophononics **4**) Nanofabrication

Most significant results during 2008-2009:

1) Demonstration of simultaneous existence of electron and hole gases in ultra thin silicon quantum well **2**) Demonstration of directed self-assembly of protein membrane on silicon subrate **3**) Large European project on nanofabrication (NaPa, coordinated by us) was selected as one of the success stories in FP6

Possible utilization of the results:

Nanostructured surfaces for lighting, nanobiosensors potentially for diagnostics, thermal management for nanoelectronics

Contact

Dr. Mika Prunnila (mika.prunnila(a)vtt.fi)
www : http://www.vtt.fi

Group name	Classifications
Functional coating and surfaces	*1, 7, 9*

Leader

Team leader Amar Mahiout

Special know-how of the group:

1) Sol-gel techniques and in general **2**) Surface treatment and engineering **3**) Characterization of coating properties

Objectives of the research:

1) To generate added-value for new (large scale) nanocoated metal products of metal industry and to establish a base for new business activity. **2**) To give additional value for thin metal coils used in different environments and facing different stresses by manufacturing protective nanocoatings for anti-graffiti purposes instead of conventional paints or lacquers. **3**) To get new functional properties for different applications for copper and stainless steel surfaces used in e.g. building and electronics industry **4**) To develop sol-gel coatings wihich are suitable for industrial roll-to-roll manufacturing **5**) To design and synthesise room light activated antibacterial (anti methicillin-resistant Staphylococcus aureus, MRSA) hygiene photocatalytic coatings.

Most significant results during 2008-2009:

1) Different conventional (degreasing, etching) and novel (atmospheric plasma, electric discharge) pretreatments were investigated and found to be applicable for sol-gel and ALD coatings **2**) Easy-to-clean, wear resistance and corrosion properties of many metallic products/coatings have been improved with the different developed coatings. **3**) Enhanced properties for coatings (hydrophobicity, easy-to-clean, corrosion and oxidation resistance, scratch resistance etc.) via different modifications and without changing the appearance of the treated materialsIt was proved that these coating techniques are suitable for large surfaces and industrial production **4**) Highly efficient photocatalytic coating materials which are capable of killing MRSA have been developed.

Possible utilization of the results:

The results can be applied in construction, processing, transport, electronic, wood and food industry, hospital surfaces, medical devices, etc.

Contact

Team leader Amar Mahiout (amar.mahiout(a)vtt.fi)
Tel: +358 50 375 26 42
www : http://www.vtt.fi

Group name	Classifications
Inorganic devices	*1, 2, 5, 6, 7, 8, 9*

Leader

Dr. Ari Alastalo

Special know-how of the group:

1) Application oriented electronic component design and development with a strong materials physics background **2**) Sintering processes

Objectives of the research:

Development of components, applications and technologies for inorganic printed electronics. These include, but are not limited to sintering processes, transistors and memories.

Most significant results during 2008-2009:

1) Development of a novel electrical nanoparticle sintering process **2**) Operational all-printed $BaTiO_3$ ferroelectric memory components on PET using Gravure-printing.

Possible utilization of the results:

Companies working on printed electronics. Companies fabricating for example conductors, antennae, circuit boards. Electronics and communication industry.

Contact

Senior research scientist, team leader Ari Alastalo (ari.alastalo(a)vtt.fi)
www : http://www.vtt.fi/inorganicdevices

Group name	Classifications
Quantronics	*6, 7, 8, 9*

Leader

Dr. Panu Helistö

Special know-how of the group:

1) SQUIDs and SQUID applications **2**) THz detectors and imaging **3**) Cryogenic electronics and multiplexing **4**) Superconducting junction devices

Objectives of the research:

1) High performance superconducting and quantum electronics **2**) Sensors and sensor systems for industrial and research applications

Most significant results during 2008-2009:

1) Demonstration of high field SQUIDs for MEGMRI **2**) Thermoacoustic sound source based on nanowires **3**) Superconducting video-rate THz imager

Possible utilization of the results:

Combination of MEG and MRI imaging, ultrasonics, space and security

Contact

Chief Research Scientist Panu Helistö (panu.helisto(a)vtt.fi)

Group name	Classifications
MEMS	*1, 6, 7, 8, 9*

Leader

Dr. Jyrki Kiihamäki

Special know-how of the group:

1) Silicon based MEMS device process development: deep silicon etching, thin film technology including ALD, wafer bonding and cavity-SOI device fabrication **2**) Combining of piezo materials into silicon processes **3**) Use of nanoimprint lithography to MEMS/NEMS fabrication

Objectives of the research:

Development of silicon MEMS processes, process integration, introduction and application of novel process technology and equipment into MEMS fabrication

Most significant results during 2008-2009:

1) Development of visible light Fabry-Perot interferometers **2**) Silicon microresonator development **3**) Studies on ALD nanolaminate layers **4**) Application of HF-vapor to sacrificial layer etching

Possible utilization of the results:

MEMS/NEMS device fabrication, suppliers of sensors and miniaturized instruments, semiconductor companies

Contact

Research coordinator Jyrki Kiihamäki (jyrki.kiihamaki(a)vtt.fi
Tel: +358 40 5069276
www : www.vtt.fi/mems

Group name	Classifications
Knowlegde centre: Functional Fibre Products	*1, 2, 4, 7*

Leader

Technology manager Pia Qvintus

Special know-how of the group:

1) Fibre matrices **2**) Biomaterial applications **3**) Surface tretament **4**) Printing techniques

Objectives of the research:

Development of fibre based products by the use on new biopolymers and addition on various functionalities by printing or coating techniques. Main application is packaging.

Most significant results during 2008-2009:

Activities related to the Centre of Nanocellulosic technologies.

Possible utilization of the results:

In development of new products and enhancement of competitiveness of existing products of forest industry.

Contact

Technology manager Pia Qvintus (pia.qvintus(a)vtt.fi)
Tel: +358 50 5634129
www : http://www.vtt.fi

Group name	Classifications
VTT Fine particles	*2, 3, 4, 6, 7, 8, 9*

Leader

Team leader Ari Auvinen

Special know-how of the group:

Aerosol based nanomaterials, measurement and characterization of airborne nanoparticles and gases

Objectives of the research:

Techniques for industrial synthesis of nanoparticles. Safe production and use of nanomaterials.

Most significant results during 2008-2009:

Development and patenting of aerosol based synthesis and coating methods for metallic nanoparticles. Development of direct sampling of gas phase nanoparticles for electon microscopy analyses. Development of portable calibration source for airborne nanoparticles.

Possible utilization of the results:

Results have already been applied by industry producing and using nanomaterials

Contact

Team leader Ari Auvinen (ari.auvinen(a)vtt.fi)
Tel: +358 20 722 5785

Group name	Classifications
Length group - Dimensional nanometrology	*7, 10*

Leader

Dr. Antti Lassila

Special know-how of the group:

1) Interferometry **2**) Scanning probe microscopy **3**) Error sources of SPM measurements **4**) Laser diffractometry **5**) Measurement instrument implementation **6**) Quantitative measurements

Objectives of the research:

1) Establish traceability chain for realization and transfer of the metre for nanometer scale instruments. **2**) Develop facilities to provide traceable calibrations of transfer standards useable for calibration of lateral and vertical microscope scales. **3**) Study phenomenon e.g. probe-sample interaction which affect to accuracy of microscopic measurements. **4**) Study methods for calibration of Scanning probe microscopes (SPM). **5**) Study improved techniques for realization of length in sub-nanometer scale by means of refined interferometry and advanced capasitive position sensors.

Most significant results during 2008-2009:

1) Implementation of interferometrically traceable SPM with sub-nanometer accuracy for transfer standard calibrations. **2**) Excellent results in international comparison EURAMET # 925 piloted by PTB. **3**) Implementation of laser diffractometer for grating pitch calibration with 10 picometer standard uncertainty.

Possible utilization of the results:

These result can be applied by using calibration services for transfer artifacts. MIKES is now capable to calibrate flatness standards, step height standards, 1-D and 2-D gratings at best international level. SPM user can guarantee or test measurement capability of his instrument by performing its calibration with traceably calibrated transfer artifacts. All research groups and companies in Finland with nanoscale instruments can benefit from this work by improved quality of the measurements after calibration.

Contact

Dr. Antti Lassila (antti.lassila(a)mikes.fi)
Tel: +358 40 767 8584
www : http://www.mikes.fi

Group name	Classifications
Thermal and Mass Quantities	*3, 7, 10*

Leader

Dr. Martti Heinonen

Special know-how of the group:

1) Measurement standards **2**) Traceability **3**) Evaluation of uncertainty **4**) Flow, temperature and mass measurements **5**) Design and validation of humid gas generators

Objectives of the research:

1) To establish traceability to number concentration measurements **2**) To improve understanding on the limitations of the filter based particle mass measurement methods **3**) Advance the understanding on particle/vapour interaction at different ambient conditions to gain progress in mass measurement

Most significant results during 2008-2009:

n.a.

Possible utilization of the results:

n.a.

Contact

Dr. Martti Heinonen (martti.heinonen(a)mikes.fi)
Tel: +358 10 605 4402
www : http://www.mikes.fi

Group name	Classifications
Electricity Group	*6*

Leader

Dr. Antti Manninen

Special know-how of the group:

1) Traceable and accurate electrical measurements both at room temperature and at cryogenic temperatures down to 15 mK **2**) Measurement standards including quantum standards

Objectives of the research:

Nanoelectronics: Application of nanoelectronic phenomena in electrical metrology

Most significant results during 2008-2009:

Experimental demonstration of 100 pA quantized current generated by a quantum current standard based on a nanoelectronic superconductor - normal metal hybrid single electron transistor (in collaboration with the Low Temperature Laboratory of TKK).

Possible utilization of the results:

New definitions of SI units will be based on fundamental constants of Nature, and after that the traceability of all electrical measurements will be based on quantum standards. Reliable and traceable measurement of very low currents is needed, e.g., in radiation detection and optical measurements.

Contact

Dr. Antti Manninen (antti.manninen(a)mikes.fi)
Tel: +358 10 605 4416
www : http://www.mikes.fi

Group name	Classifications
Nanosafety Research Consortium	*11 (Safety of engineered nanomaterials and nanotehnologies)*

Leader

MD, Prof. Kai Savolainen

Special know-how of the group:

Aerosol physics, Engineering, Occupational hygiene, Particle characterization by using both imaging and non-imaging techniques, A large variety of expertise for assessment of work place or exprerimental exposures, genetic toxicology, cell biology, molecular biology, proteomics, genomics, allergy and immunology, immunotoxicology, animal care, cell culture techniques, medicine, risk assessment

Objectives of the research:

1) Characterization of engineered nanomaterials (ENM) commonly occuring in occupational environments **2**) Developement of characterization techniques **3**) Assessment of exposure at workplaces and exposure modelling **4**) Development of exposure models for experimental research **5**) Research on health effects of ENM with a focus on in vivo and in vitro effects of different types of ENM on genotoxicity and immunotoxicity.

Most significant results during 2008-2009:

1) Several peer reviewed papers on dispersion of ENM is aquaeous media (e.g. TiO_2) **2**) Several peer reviewed papers on gentoxicity of ENM (e.g. TiO_2, single and multi walled carbon nanotubes) **3**) Several papers on immunotoxicity and allergies of ENM (TiO_2)

Possible utilization of the results:

In risk assessment and governance of these materials - As a basis for recommendations for regulators and companies and workplaces - As a basis for education of the public at large - Scientific community

Contact

Prof. Kai Savolaínen (kai.savolainen(a)ttl.fi)
Tel: +358 40 742 0574
www : http://www.ttl.fi

Group name	Classifications
SYKE nanotechnology and environment	*1, 5, 7, 10, 11 (Environmental fate and effects)*

Leader

Dr. Markus Sillanpää

Special know-how of the group:

1) Aquatic and terrestrial toxicity tests including (but not limited to) luminescent bacteria toxicity test, Daphnia magna acute and chronic toxicity, green algae growth inhibition, Lemna minor growth inhibition, zebra fish egg-larvae test, biochemical methods (EROD activity, vitellogenin induction), seed germination and soil invertebrates **2**) Development of analytical and characterisation methods such as dynamic light scattering for size and agglomeration characterisation and ICP techniques for the quantification of nanomaterials and elemental impurities **3**) Regulatory and harmonisation work in relation to nanomaterials (OECD/WPMN, REACH) **4**) Nanomaterials and environmental governance: innovation management, public engagement, emerging private - public relationships.

Objectives of the research:

Our research focuses on: **1**) The fate of nanomaterials in natural waters **2**) Bioaccumulation and effects of nanomaterials in the species of different trophic levels and **3**) Environmental regulation.

Most significant results during 2008-2009:

The group has recently studied the fate of titanium dioxide and silver nanoparticles in natural fresh and brackish waters. The measurement methods have been developed for the characterization of above-mentioned nanomaterials at the various stages of effect studies. The group has also made a review of the social scientific literature focusing of nanotechnology and nanomaterials.

Possible utilization of the results:

There are a number of gaps in basic knowledge on the environmental impacts of nanomaterials. The results can be applied in risk assessment and management of nanomaterials.

Contact

Dr. Markus Sillanpää (markus.sillanpaa(a)ymparisto.fi)
www : http://www.syke.fi

Group name	Classifications
Aerosols and climate	*3, 7, 9, 11 (Climate)*

Leader

Doc. Heikki Lihavainen

Special know-how of the group:

1) Aerosols and their effect to climate **2**) Formation of aerosols **3**) Thermodynamical properties of compounds and mixtures affecting to homogeneous and heterogeneous nucleation

Objectives of the research:

The objective of the research is to answer following questions: **1**) What is the direct radiative forcing in our environment? **2**) How does pollution in the atmosphere affect to the properties of clouds and indirect radiative forcing in northern latitudes? **3**) What is the ratio between direct and indirect forcing in our environment? **4**) What is the role of human activities to the radiative forcing by aerosols in our environment?

Most significant results during 2008-2009:

1) We showed that with sulfur acid the new particle formation events can be explained. **2**) We also studied extensively the very basics steps of the first order phase transition from vapor to liquid.

Possible utilization of the results:

Results can be applied in formation of particles or aerosol with wanted composition. Results can also be applied in climate studies through new parametrization of atmospheric new particle formation events.

Contact

Doc. Heikki Lihavainen (heikki.lihavainen(a)fmi.fi)
Tel: +358 9 1929 5492
www : http://www.fmi.fi

Classification of the groups by potential application areas of the research

	Surfaces	Nano-materials	Aerosols	Well-being	Built environments	Electronics	Characterization	Fabrication	Theory	Services	Other
Chemical industry	1, 9, 11, 51	1, 9, 11, 27, 48, 51	46, 48	6, 9, 51	27, 51	9, 51	1, 6, 11, 27, 46, 48, 51	6, 9, 27, 46, 48	1, 6, 11, 46, 48		1, 27
Forest industry	2, 11, 12, 13, 41, 51, 64, 68	2, 11, 12, 13, 41, 51, 68		51, 68	51	2, 51	2, 11, 12, 41, 51, 64, 68	12, 13	11, 12, 64		
Food industry	4, 41, 52, 64	4, 41, 52		52		4	4, 41, 52, 64	4	52, 64		
Pharma/ medical	2, 3, 4, 8, 9, 18, 20, 21, 24, 32, 49, 50, 51, 52, 55, 60, 63, 64	2, 3, 4, 9, 18, 20, 21, 23, 24, 32, 48, 49, 51, 52, 54, 55, 57, 63, 69	23, 48, 50, 54, 69	3, 6, 8, 9, 14, 20, 23, 32, 50, 51, 52, 54, 55, 56, 57, 58, 59, 60, 69	23, 51	2, 4, 9, 14, 18, 20, 21, 23, 49, 51, 55, 63, 66, 69	2, 3, 4, 6, 8, 14, 18, 20, 21, 23, 48, 49, 51, 52, 54, 55, 59, 60, 63, 64, 66, 69	3, 4, 6, 9, 14, 20, 23, 48, 49, 54, 60, 63, 66, 69	6, 8, 18, 20, 21, 24, 32, 48, 50, 52, 54, 63, 64, 66, 69	8, 55	24, 32, 55
Metal industry	5, 7, 8, 10, 61, 64	5, 7, 36, 61, 62		8, 61		31, 51	5, 7, 8, 36, 61, 64	5, 7, 10, 36, 62	8, 64	8, 61	5
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Research & metrology	1, 2, 4, 5, 19, 33, 35, 42, 50, 60, 74	1, 2, 4, 5, 28, 30, 35, 38, 42, 69	46, 50, 69, 75	14, 19, 30, 50, 60, 69	74	2, 4, 14, 19, 29, 33, 35, 38, 39, 42, 66, 69, 72	1, 2, 4, 5, 14, 19, 29, 30, 33, 35, 42, 43, 46, 60, 66, 69, 74, 75	4, 5, 14, 19, 29, 38, 42, 46, 60, 66, 69, 70	1, 19, 28, 29, 35, 38, 42, 43, 45, 46, 50, 66, 69, 75	70, 74	1, 5, 73, 74, 75
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Keyword index

Keyword	Group number
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drug delivery / controlled release	2, 5, 23, 30, 32, 52, 54, 57
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solar cells	19, 23, 27
spintronics	4, 16, 25
virus	55, 56, 58, 59

culminatum
INNOVATION

Culminatum Innovation Oy Ltd
Innopoli, Tekniikantie 12, FI-02150 Espoo Finland
Tel. +358 20 761 9550 • Fax +358 20 761 9551
www.culminatum.fi