Development of Advanced Technology Roadmaps
in Photonics and Industrial Adaption to SMEs

PhotonicRoadSME

R&D report on **Nanoparticles**

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SEVENTH FRAMEWORK PROGRAMME

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STEINBEIS-EUROPA-ZENTRUM

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1. Introduction

1.1. Definition of the material category:

The nanoparticles are ultrafine particles in the size of nanometer order. “Nano” is a prefix denoting the minus 9th power of ten, namely one billionth. Here it means nanometer (nm) applied for the length. One nm is extremely small length corresponding to one billionth of 1m, one millionth of 1mm, or one thousandth of 1 μm.

The definition of nanoparticles differs depending upon the materials, fields and applications concerned.

In the narrower sense, they are regarded as the particles smaller than 10–20 nm, where the physical properties of solid materials themselves would drastically change. On the other hand, the particles in the three digit range of nanometer from 1 nm to 1 μm could be called as nanoparticles. In many cases, the particles from 1 to 100 nm are generally called as nanoparticles, but here they will be regarded as the particles smaller than those called conventionally “submicron particles”, and concretely less than the wavelength of visible light (its lower limit is about 400 nm) as a measure, which need to be treated differently from the submicron particles. Fig. 1 shows examples of nanoparticles (metal, inorganic, organic, bio, pharmaceutical, and aerosol) and the related phenomena [1].

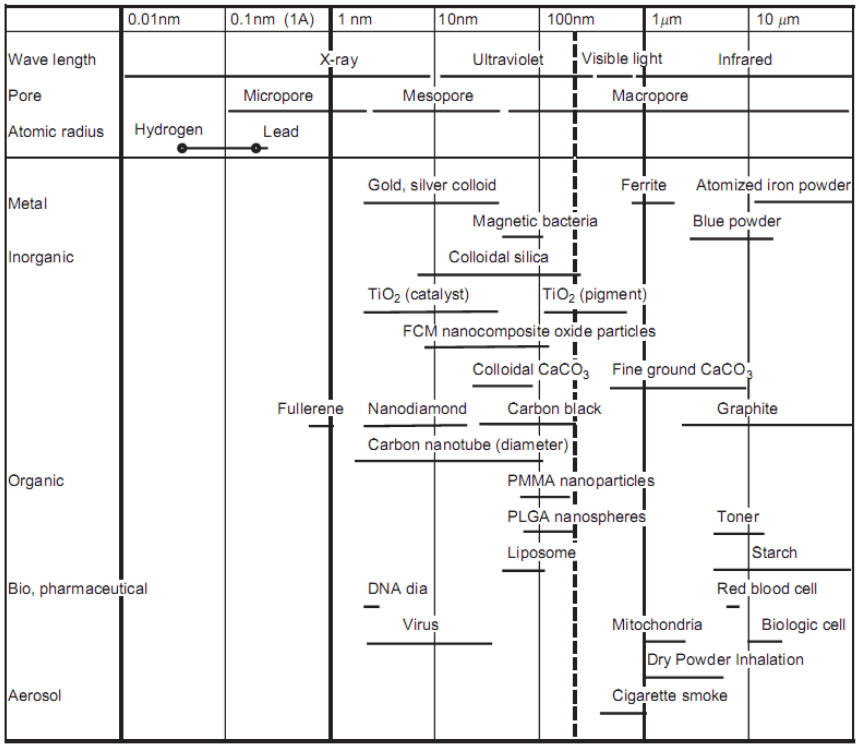

Figure 1. Examples of nanoparticles and related phenomena

1.2. Overview:

There are several different types of nanomaterials (nanoparticles, quantum dots, and nanotubes) devided by nature, growth methods and industrial application (see table 1) [2]:

Material class	Applications
Buckyballs and CNTs	Production of SWNTs Gas sensors Memory chips (RAM) Nanotube production Fullerene production Nanotube composites
Metal nanoparticles:	
Au Ag Au/Ag nanorods Al Si Fe, activated carbon Various metals	Biosensors Antimicrobial Security bar codes Rocket fuel Displays Drug delivery Propellants etc.
Oxide nanoparticles:	
Various oxides TiO2 Al_2O_3 nanowires Silicas (porous) CeO_2 Silsesquioxanes Ln-doped oxides	Particle production Coatings Polymer composites Displays and batteries Particle production Photovoltaic cells Sunscreens Purification filters Delivery Fuel additive Composites Phosphors
Other inorganic nanoparticles:	
Talc, $CaCO_3$ $BaCO_3$ Ln phosphates Ca phosphate Clays Various minerals	Nanocomposites Coatings filler Security printing Bone replacement Nanocomposites Composites

Zeolites	Catalysis
MoS_2	Lubrication
SiC	Ceramics
ZrO_2	Gas sensor
ZrO_2 doped with TM, RE	White LEDs
TiO_2 doped with TM, RE	High efficiency phosphores
HfO_2 doped with TM, RE	High-k materials for electronics
II-VI quantum dots and wires:	
CdSe	Production
CdSe	Biosensors
CdSe and Si	Photovoltaic cells
ZnS doped with TM, RE	High efficiency phosphores
	Biological labeling
	Magnetic markers
Organics:	
Nanoparticle	Delivery systems

Table 1. Some important classes of nanomaterials and their emerging applications

There are several important nanoparticles properties which give possibility to mark out significant fields of use of these nanoparticles [1, 2, 3], such as:

Visualization	
Light source	LED
	Phosphores
	Luminophores
Displays	OLED
	Head-Up
	Matrices
	Flexible matrices
Diagnosis and treatment	Luminescent markers
	Magnetic markers
	Biological labels
	Delivery
	Biosensors
	Lab-on-chip

Table 2. Visualization areas

2. European and national R&D activities

2.1. Summary of European and national R&D funded projects

In this section, a list of some representative European and National initiatives (Germany, France, Spain, Finland, Austria, Switzerland, Poland, UK) in the field of nanoparticles during the last years is presented. A project search was conducted using following keywords:

keyword	hits in Germany	hits in France *)	hits in Spain	hits in Finland *)	hits in Austria	hits in Switzerland	hits in Poland	hits in UK *)	hits in Cordis
nanoparticles	254	2	27	3	14	39	40	1	147
+ photonics	0		0		0	0	2		4
+ light	2		1		0	5	1		23
+ emit	0		0		0	0	1		0
+ emitter	0		0		0	0	1		1
+ phosphors	0		0		0	0	1		0
+ luminescence	1		0		0	0	1		5
+ luminophors	0		0		0	0	1		0
+ displays	0		0		0	0	0		3
+ matrix	4		1		0	1	0		12
+ labels	5		0		0	0	0		3
+ solar	0		1		0	1	1		3
+ photovoltaics	1		0		0	0	1		1
+ optoelectronics	2		0		0	0	1		1
+ OLED	0		1		0	0	0		0
+ marker	5		0		0	0	0		4
+ lasers	1		6		0	0	1		4
+ fibres	0		0		0	1	1		7
+ waveguides	0		0		0	0	1		0
+ health	1		0		0	5	0		39
+ environment	1		0		0	14	0		25
+ safety	1		0		0	2	0		12
+ security	1		0		0	0	0		4
+ communication	0		0		0	0	2		2

*) there was no database available, project search was undertaken “by hand” (web search)

**) database available but not searchable in a systematic manner

Following databases have been searched:

- DFG Germany: http://gepris.dfg.de/gepris/
- BMBF Germany: http://foerderportal.bund.de/foekat/jsp/SucheAction.do?actionMode=searchmask
- Madri+D database Spain: http://www.madrimasd.org/Investigadores/buscador-proyectos-investigacion/default.asp
- FWF Austria: http://www.fwf.ac.at/de/projects/projekt_datenbank.asp
- ARAMIS Switzerland: http://www.aramis.admin.ch/Default.aspx
- Ministry of Science and Education Poland (2007 -): http://nauka-polska.pl/dhtml/raportyWyszukiwanie/wyszukiwaniePraceBadawcze.fs?lang=pl
  Ministry of Science and Education Poland (2006 - 2007): http://www.nauka.opi.org.pl/granty/zaawansowane.htm
- Pôle Optique & Photonic France: http://www.popsud.org/
- Ministère de l'Enseignement supérieur et de la Recherche France: http://www2.enseignementsup-recherche.gouv.fr/appel/index.htm
- FinNano 2005-2010 Finland: http://akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/NANO/en/etusivu.html
- Engineering and Physical Sciences Research Council EPSRC database UK: http://gow.epsrc.ac.uk/ListProgrammes.aspx
- Cordis Project database for FP7: http://cordis.europa.eu/fp7/projects_en.html
- Cordis Project database for FP6: http://cordis.europa.eu/fp6/projects.htm

A total of **76** national and international R&D funded projects have been identified, examined and summarized. The table shown below gives an idea of the domain of applications of the projects mentioned (indicated in grey color) as well as the origin of funding.

Project #	ICT	Environment	Health & Well-Being	Safety & Security	Funding origin
1			biosensors		EC
2	spintronics, data storage				EC
3		sensors			EC
4			molecular imaging		EC
5		biosensors	biosensors		EC
6			MRI probes, MRI guided drug delivery		EC
7		single molecule detection in biosensors	single molecule detection in biosensors		EC
8	NPs based light sources, NPs based memories	NPs based light sources			EC
9					EC
10	electromagnetic			electromagnetic	EC

	shielding, data storage, displays			shielding	
11		LEDs	biomedical applications		EC
12	power metre for lasers	power metre for lasers	power metre for lasers		EC
13			Alzheimer disease detection		EC
14			cell imaging, cell-labeling		EC
15					EC
16		ions sensor, biosensors	biosensors		EC
17		nanophosphors	nanophosphors		EC
18					EC
19		photovoltaics			EC
20	displays, electromagnetic shielding		sensors	electromagnetic shielding	EC
21					EC
22		biosensors enhancement	biosensors enhancement		EC
23					EC
24					EC
25			opto-acoustic biosensor		EC
26		nanophosphors	nanophosphors		EC
27	optical switching, single-photon switching				EC
28					EC
29			biosensors		EC
30					EC
31		nanophosphors	nanophosphors		EC
32			cancer diagnostics, photodynamic therapy		EC
33		solar cells			Poland
34		luminescent nanoparticles	luminescent nanoparticles	luminescent nanoparticles	Poland
35	fiber amplifier	white light emitter			Poland
36		solar cells			Poland
37			bio-imaging, contrast agents		EC
38	optical switches				EC
39	optical data storage, displays, EM shielding	sensors	sensors	sensors	EC
40	LEDs	LEDs			EC
41		photovoltaics			EC
42		solar cells			Austria
43					Austria
44					Austria
45			imaging		Finland

46			antibacterial photoactive coatings		Finland
47	optical data storage				Finland
48			MRI imaging		Switzerland
49			imaging		Switzerland
50		solar H2 production			Switzerland
51		sensors	sensors	sensors	Switzerland
52					Switzerland
53					Switzerland
54					Germany
55					Germany
56		photovoltaics			Germany
57					Germany
58					Germany
59					Germany
60		biosensors	biosensors	biosensors	Germany
61					Germany
62			bio-imaging		Germany
63					Germany
64			bio-imaging, tumor detection		France
65					France
66					UK
67					Spain
68					Spain
69		sensors	sensors	sensors	Spain
70			MRI		Spain
71		biosensors	biosensors	biosensors	Spain
72		biosensors	biosensors	biosensors	Spain
73					Spain
74					Spain
75		sensors	sensors	sensors	Spain
76					Spain
Total	**11**	**28**	**35**	**10**	

2.1.1 Portable and disposable biosensor microarray based on FETs with a biofunctional gate to detect VOCs in breath (BIOFET)

Objective:

The growing interest in medicine in connecting different volatile organic compounds (VOCs) patterns in breath with diseases and disorders has increased the demand on breath tests devices. Nowadays, the required apparatus for breath analysis in the market a re bulky and difficult to operate and handle, they need a large amount of sample and several hours are needed to obtain a result. In addition, they are expensive (ranging from 600 to 25.000euro).

Therefore, the project focus on developing a breath test dev ice which is fast, portable, extremely sensitive, with low cost and easy to miniaturize. The main challenge of the BIOFET project is the use of a tailor made biofunctional nanomaterial for gas-sensing purposes in a silicon micromachined array based on field effect transistors (FET). The biofunctional material consists in a coiled-coil peptide-based assembly of gold nanoparticles and it is possible to synthesize it using different types of peptides having the possibility of designing a more selective device.

The transducer device, a silicon FET microarray, can provide a lot of key benefits for sensing target gases such as low fabrication costs and mass production (standard CMOS process), low power consumption, compact size, small weights, fast response (milliseconds) and the ability to readily integrate with signal conditioning electronics and other devices.

The core of the multidisciplinary research project BIOFET converges on biological recognition mechanisms, nanosciences, materials research and techniques of analysis at a common research frontier. This innovative multidisciplinary technologically relevant research is crucial in forging strong links between industry and research as outlined in the Lisbon strategy and indeed throughout FP6.

Funding institution or country: European Union (FP6), United Kingdom

Materials:

Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 168798.00 EURO

Industrial partners: 0

Research partners: 0

2.1.2 Self-Organised Complex-Spin Magnetic Nanostructures (NANOSPIN)

Objective:

The NANOSPIN project will study complex magnetic nanostructures consisting of a central core with one or more surrounding shells that will be functionalised to self-order on surfaces for applications in classical and quantum ultra-high density informat ion storage. The advanced manufacturing technique we propose uses metal condensation in superfluid He droplets, which is a technology with enormous flexibility. It enables the production of core-shell particles with a free choice of ferromagnetic and a ntiferromagnetic core and shell materials and an arbitrary number of shells. This degree of control will allow us to engineer the internal spin configuration of an individual nanocluster and to create spin structures that have never been produced before, either naturally or artificially, with a wide range of

magnetic properties. The technique will also allow us to coat the nanoparticles with a final shell to promote the ordering of arrays of the designed nanoparticles on surfaces for specific applicat ions. This ability will have an enormous impact on the technological areas of spintronics and magnetic storage. Examples include particles smaller than 5nm that are blocked at room temperature enabling classical data storage densities higher than 10Tb/c m2, and particles embedded in superconducting matrices in states of quantum superposition on which quantum qubits can be stored. Single-particle read/write processes and a new method to erase all data in a nanoparticle assembly using microwaves will be demonstrated. We will also assess the functionalised nanoparticles as qubits in quantum information processing systems. The programme brings together 8 partners from 2 INCO and 6 EU countries. It combines state-of-the-art instrumentation with advances i n cluster production technology and will provide the fundamental understanding required to bring highly advanced technologies close to the market.

Funding institution or country: European Union (FP 6), United Kingdom
Materials:
Budget: *Project Cost:* 2.36 million EURO; *Project Funding:* 1.87 million EURO
Industrial partners: 1
Research partners: 7
Participants:

- NANOTECHNOLOGY-MDT CO. Country: RUSSIAN FEDERATION
- THE UNIVERSITY OF READING Country: UNITED KINGDOM
- UNIVERSITAT DE BARCELONA Country: SPAIN
- NATIONAL CENTRE FOR SCIENTIFIC RESEARCH "DEMOKRITOS" Country: GREECE
- SUMY STATE UNIVERSITY Country: UKRAINE
- CONSIGLIO NAZIONALE DELLE RICERCHE Country: ITALY
- UNIVERSITY OF SURREY, UK Country: UNITED KINGDOM
- INSTITUTE FOR PHYSICS OF MICROSTRUCTURES OF RUSSIAN ACADEMY OF SCIENCES (IPMRAS) Country: RUSSIAN FEDERATION

2.1.3 Innovative sensor-based processing technology of nanostructured multifunctional hybrids and composites (MULTIHYBRIDS)

Objective:
The main aim of this IP proposal is to develop innovative factory of the future integrating technologies for the preparation of advanced specialty materials based on industrially important new polymer hybrids and nanocomposites whereby the synthesis and modification of the inorganic phase is achieved through the use of precursors that are to be made easily dispersible in the organic polymer matrix.

The objective-driven approach is the in-process tailoring of materials with successive validation of the app roach through on-line characterisation of the process, characteristics and targeted performance of the newly produced nanomaterials.

This IP will produce new applicable knowledge to support the transformation industry through the following technological breakthroughs:

- Developing methodology for sensor based in-line monitoring and control of processing of new multifunctional nanomaterials based on organic polymers and nanofillers;
- In-extruder (in-situ during processing) synthesis and functionalisation of nanofillers and hybrids;
- In-situ grafting of nanofillers in flowing polymer melts and in-process analysis of the influence of compatibilising agents and processing parameters on dispersion and distribution of nanoparticles;
- Validation of robustness (consistency and reliability) and the successful application of the process to the production of useful nanomaterials through on-line characterization of the processing methodology and off-line examination of the characteristic and targeted performance properties of the new nanomaterial products.

An IP was chosen as the most appropriate form for these S&T developments because of the need of multidisciplinary expertise in different fields (nanomaterials, processing and manufacturing). It will be structured on 3 levels, i.e. 'fundamental research', 'development & transfer of technology' and 'industrial application'.

Funding institution or country: European Union (FP6), Italy

Materials:

Budget: *Project Cost:* 6.32 million EURO; *Project Funding:* 4.2 million EURO

Industrial partners: 16

Research partners: 5

Participants:

- UNIVERSIDADE DO MINHO Country: PORTUGAL
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS) Country: FRANCE
- ASTON UNIVERSITY Country: UNITED KINGDOM
- LEISTRITZ EXTRUSIONSTECHNIK GMBH Country: GERMANY
- COMPAGNIA EUROPEA APPARECCHI SCIENTIFICI TORINO S.P.A. Country: ITALY
- PEMU MUANYAGIPARI RESZVENYTARSASAG Country: HUNGARY
- SCHNEIDER ELECTRIC INDUSTRIES SAS Country: FRANCE
- BASELL POLIOLEFINE ITALIA SPA Country: ITALY
- ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS - ARMINES Country: FRANCE
- UNIVERSITA DEGLI STUDI DI TRIESTE Country: ITALY
- OSRODEK PRODUKCYJNO WDROZENIOWY DOSKOMP SP. ZOO Country: POLAND
- BUDAPESTI MUSZAKI ES GAZDASAGTUDOMANYI EGYETEM Country: HUNGARY
- UNIVERSITE LOUIS PASTEUR Country: FRANCE

- COMMISSARIAT A L'ENERGIE ATOMIQUE (CEA) Country: FRANCE
- ELETTRONICA CONDUTTORI SRL Country: ITALY
- PLASTIQUES RG SAS Country: FRANCE
- CENTRO EUROPEO PER I POLIMERI NANOSTRUTTURATI SCARL Country: ITALY
- LEIBNIZ-INSTITUT FUR POLYMERFORSCHUNG DRESDEN E.V. Country: GERMANY
- TOPAS GMBH TECHNOLOGIE-ORIENTIERTE PARTIKEL-, ANALYSEN UND SENSORTECHNIK Country: GERMANY
- SYNPO, AKCIOVA SPOLECNOST Country: CZECH REPUBLIC
- M.D.P. MATERIALS DESIGN & PROCESSING SRL Country: ITALY

2.1.4 Molecular Imaging for Biologically Optimised Cancer Therapy (BIOCARE)

Objective:

Early tumour detection and response monitoring require maximum sensitivity and specificity of the imaging methods. The programme focuses on the clinical evaluation and development of new more specific molecular tracers for the early detection of tumour cells. A large number of new and potentially more specific tracers than fluorodeoxyglucose (FDG) will be tested including amino-acid analogues, small tumour-binding peptides, aptamers, peptides binding to mutant p53 proteins and nanoparticles. The more tumour specific the tracer, the more accurately it will be possible to image the true tumour cell density, and more importantly, the true response of the tumour to therapy. There is also a need to consolidate the experience in the use of recently developed molecular tracers to assess radiotherapy and chemotherapy response in order to improve on state of the art treatments. To maximise the sensitivity and tumour image quality, a high-resolution, wide field-of-view, ultra-sensitive PET-CT camera, capable of imaging half the human body in a few minutes, will be developed. New adaptive therapy planning and biological optimisation codes and a dedicated PET-CT detector for incorporation in treatment units will be designed in close corporation between university researchers and SME's. This will allow an efficient clinical integration and high patient throughput. The associated increase in accuracy of tumour imaging and three-dimensional in vivo tumour responsiveness data will hopefully allow the clinical introduction of accurate biologically based adaptive treatment optimization methods. Some of the work-packages will try to conenct to teh Genpe, Emir and Enlight programmes but do not depend on these programmes.

Funding institution or country: European Union (FP6), Sweden

Materials:

Budget: *Project Cost:* 6.62 million EURO; *Project Funding:* 6 million EURO

Industrial partners: 8

Research partners: 12

Participants:

- AARHUS UNIVERSITY HOSPITAL Country: DENMARK
- UNIVERSITY OF TECHNOLOGY DRESDEN Country: GERMANY

- THE UNIVERSITY OF MANCHESTER Country: UNITED KINGDOM
- FORSCHUNGSZENTRUM DRESDEN-ROSSENDORF E.V. Country: GERMANY
- UNIVERSITEIT MAASTRICHT Country: NETHERLANDS
- STICHTING KATHOLIEKE UNIVERSITEIT, UMC ST RADBOUD Country: NETHERLANDS
- INSTITUT GUSTAVE ROUSSY Country: FRANCE
- UNIVERSITY OF HAMBURG Country: GERMANY
- UNIVERSITE CATHOLIQUE DE LOUVAIN Country: BELGIUM
- UNIVERSITY HOSPITAL GASTHUISBERG Country: BELGIUM
- THE NETHERLANDS CANCER INSTITUTE Country: NETHERLANDS
- THE ANDRZEJ SOLTAN INSTITUTE FOR NUCLEAR STUDIES Country: POLAND
- UNIVERSITY OF TURKU Country: FINLAND
- C-RAD INNOVATION AB Country: SWEDEN
- PEVIVA AB Country: SWEDEN
- RAYCLINIC AB Country: SWEDEN
- EUROPEAN SOCIETY FOR THERAPEUTIC RADIOLOGY AND ONCOLOGY Country: BELGIUM
- EUROPEAN ORGANIZATION FOR NUCLEUR RESEARCH Country: SWITZERLAND
- C-RAD IMAGING AB Country: SWEDEN
- RAY SEARCH LABORATORIES AB Country: SWEDEN

2.1.5 Multiparametric detection of bio-molecule conjugated nanoparticles for the diagnostic investigation of mycobacterial infections of humans and animals (NANOMYC)

Objective:

WHO reports that tuberculosis results to millions of deaths or disabilities each year, especially in poorer areas of the planet. The problem is exacerbated by the AIDS epidemic that increases disease incidence in developed countries too. However in addition to tuberculosis, exposure to mycobacteria has also been linked to the pathogenesis of sarcoidosis and Crohn's disease that affect millions of people in Europe only.

Diagnostic investigation of mycobacterial infections is hampered by the difficulty to detect in a specific manner low populations of mycobacteria or the immunology markers associated with the infections they cause. The NANOMYC project aims to develop a highly sensitive and specific, quantifiable detection system for molecular and immunology diagnostic markers associated with infection caused by M. tuberculosis complex (human and animal tuberculosis, implicated in sarcoidosis) and M. paratuberculosis (animal paratuberculosis, implicated in Crohn's disease).

Funding institution or country: European Union (FP6), Greece

Materials:

Budget: *Project Cost:* 3.25 million EURO; *Project Funding:* 2.19 million EURO

Industrial partners: 6

Research partners: 3

Participants:

- UNIVERSITY OF CRETE Country: GREECE
- UNIVERSITA DEGLI STUDI DI SASSARI Country: ITALY
- VINCA INSTITUTE OF NUCLEAR SCIENCES Country: SERBIA AND MONTENEGRO
- EYGENIDION INFIRMARY AGIA TRIAS SA Country: GREECE
- BIOSURE RT CELL&CO Country: GREECE
- BIOTECGEN Country: ITALY
- MEDIZONE GERMANY GMBH Country: GERMANY
- Participant: MALAMIS & MALAMIS CO Country: GREECE
- AKTSIASELTS QUATTROMED Country: ESTONIA

2.1.6 Targeted delivery of nanomedicine (MEDITRANS)

Objective:

MEDITRANS will develop systems for targeted delivery of nanomedicines, which will be broadly applicable to disease. The focus is on chronic inflammatory disorders and cancer. Such industrially developed targeted products will improve therapy and in vivo visualisation of drug delivery/release processes.

Nanocarriers (nanoparticles, nanotubes, fullerenes), endowed with high targeting capabilities, will be designed in parallel with MRI probes that report on localisation of the targeted nanoparticulates, specific bio-markers, and the drug release process (MRI-guided drug delivery).

For reproducible behaviour in vivo, these nanomedicines containing drug payloads (e.g. pDNA, siRNA, small molecular weight agents) will have their physicochemical/stability properties characterised. 'Smart' delivery systems, tested in vitro, able to recognise the target, and to cross-relevant biological barriers, will be investigated for their responsiveness to the microenvironment of the target site (e.g. local pH).

Control of drug re lease, triggered by external physical means (e.g. temperature, light, magnetism, ultrasound) or by local stimuli within the pathological site (e.g. pH, enzymatic activity) will be investigated in vitro. Ways to direct the intracellular trafficking of nanocarriers, to achieve improved interaction with the intracellular target location, will be investigated.

In vivo applicability will be evaluated in clinically relevant models of disease. Toxicology aspects, industrial scale-up feasibility, long term stability, and feasibility to prepare clinical grade material will be covered.

Dissemination, training and exploitation will be done. MEDITRANS, duration 4 years, is a timely, interdisciplinary IP at the forefront of targeted nanomedicine, with a budget of 16.1M Euro, a grant of 11M Euro (68%), and 1581.75 person-months effort.

The 30 partners (12 European countries) are from industry (8), SMEs (5), universities (11), and research institutes (6).

Funding institution or country: European Union (FP6), Netherlands
Materials:
Budget: *Project Cost:* 16.14 million EURO; *Project Funding:* 11 million EURO
Industrial partners: 17
Research partners: 13
Participant:

- PHILIPS ELECTRONICS NEDERLAND B.V. Country: NETHERLANDS
- UNIVERSITA DEGLI STUDI DI TORINO Country: ITALY
- STICHTING BIOMADE TECHNOLOGY Country: NETHERLANDS
- TECHNISCHE UNIVERSITEIT EINDHOVEN Country: NETHERLANDS
- COMMISSARIAT A L'ENERGIE ATOMIQUE Country: FRANCE
- MAGFORCE NANOTECHNOLOGIES AG Country: GERMANY
- CHARITE UNIVERSITATSMEDIZIN BERLIN Country: GERMANY
- STICHTING VOOR FUNDAMENTEEL ONDERZOEK DER MATERIE - FOM Country: NETHERLANDS
- CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPMENT Country: SWITZERLAND
- PCI BIOTECH AS Country: NORWAY
- UNIVERSITEIT GENT Country: BELGIUM
- UNIWERSYTET LODZKI Country: POLAND
- N. V. ORGANON Country: NETHERLANDS
- MOLECULAR PROFILES LTD Country: UNITED KINGDOM
- UNIVERSITAT DES SAARLANDES Country: GERMANY
- PHILIPPS-UNIVERSITAT MARBURG Country: GERMANY
- ACROSS BARRIERS GMBH Country: GERMANY
- BRACCO IMAGING SPA Country: ITALY
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE Country: FRANCE
- WEIZMANN INSTITUTE OF SCIENCE Country: ISRAEL
- CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS Country: SPAIN
- GUERBET S.A. Country: FRANCE
- DANMARKS FARMACEUTISKE UNIVERSITET Country: DENMARK
- PHILIPS TECHNOLOGIE GMBH FORSCHUNGSLABORATORIEN Country: GERMANY
- UNIVERSIDAD NACIONAL DE EDUCACION A DISTANCIA Country: SPAIN
- BAYER SCHERING PHARMA AG Country: GERMANY
- ISTITUTO DI RICERCHE BIOMEDICHE ANTOINE MARXER RBM S.P.A. Country: ITALY

- INTEGRATED DNA TECHNOLOGIES BVBA Country: BELGIUM
- INFUTURIA GROUP AG Country: SWITZERLAND
- COPENHAGEN UNIVERSITY Country: DENMARK
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2.1.7 Nano-engineered monolithic Optoelectronic transducers for highly sensitive and label-free biosensing (NEMOSLAB)

Objective:

The objective of this proposal is the development of silicon based integrated optical biosensors capable of detecting single binding events as well as label free biomolecular interactions. The transducer comprises arrays of monolithic silicon optocouplers interfaced with microfluidic channels directly integrated onto silicon. The optocouplers consist of nano-engineered silicon light emitting devices optically coupled to silicon nitride optical fibres and silicon detectors.

The optical fibres are specifically biofunctionalized with a variety of biological capture probes. Nanoparticles will be employed as labels for highly sensitive detection of analytes, including single binding event sensing, whereas label free detection will be targeted through patterning of the waveguide surface. Such an integrated optical device provides for the simultaneous detection of a number of biological analytes without the need of external optical components.

The main project output is a monolithic silicon microphotonic biochip integrated with microfluidic channels and recognition biomolecules as well as the associated readout and control electronics assembled in a portable bioanalytical microsystem to be tested with specific panels of pituitary hormones, steroid hormones and DNA. The main milestones are the sensitive and wide dynamic range detection of analytes through the monolithic optical transducer, affordable silicon multianalyte biochips, and portable readout and control electronics.

Funding institution or country: European Union (FP6), Greece

Materials:

Budget: *Project Cost:* 3.14 million EURO; *Project Funding:* 1.9 million EURO

Industrial partners: 5

Research partners: 3

Participant:

- FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. Country: GERMANY
- TECHNOBIOCHIP SOC. CONSORTILE A R.L. Country: ITALY
- STMICROELECTRONICS SRL Country: ITALY
- ALBERT-LUDWIGS-UNIVERSITAET FREIBURG Country: GERMANY
- KOBENHAVNS UNIVERSITET Country: DENMARK
- BIOMEDICA LIFE SCIENCES PHARMACEUTICAL PRODUCTS SOCIETE ANONYME Country: GREECE
- UNIVERSITATSKLINIKUM MUNSTER Country: GERMANY

- KINDERWUNSCHZENTRUM DORTMUND ASSOCIATION INFERTILITY CENTER DORTMUND Country: GERMANY

2.1.8 Metallic and semi-conducting nano-particle source for electronic and opto-electronic applications (NANOSOURCE)

Objective:

This ToK-IAP proposal aims at mutual technology transfer between two academic research laboratories and an industrial partner. NTUA and CEMES/CNRS have experience on the use of nanoparticles electronic memories and optoelectronic applications and MANTIS De position Ltd who has developed a nanoparticles source able to synthesize nanoparticles of extreme size uniformity. A main scientific goal of the project is the formation of 2-dimentional layer of nanoparticles with controlled size and density. The accomplishment of this target will enable the fabrication of nanocrystal memories and light emitting devices beyond the state-of-the-art. The academic partners will have the opportunity to advance their research in the above fields by acquiring knowledge in the nanoparticles manufacturing technique of Mantis. From this exchange of knowledge the SME will benefit from the investigation of its product applicability in these new fields. The complementarities of know-how of the partners which extends from the nanoparticles fabrication technology to device fabrication and characterization of electronic, optical and materials properties it is a solid background for the partners to develop this research capacity through mutual transfer of technology.

Funding institution or country: European Union (FP7), Greece
Materials:
Budget: ***Project Cost:*** 0.00 EURO; *Project Funding:* 0.00 EURO
Industrial partners: 1
Research partners: 1
Participant:

- MANTIS DEPOSITION LTD Country: UNITED KINGDOM
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE - DELEGATION MIDI-PYRENEES Country: France

2.1.9 Attosecond observation and control of collective electron dynamics in nanoparticles (KLING-CED)

Objective:

The generation and characterization of attosecond laser pulses has been significantly advanced in recent years and two major tools are now at hand that can be used to explore ultrafast physics.
The first is the ability to control electronic motion via waveform controlled laser fields. The second is the availability of single attosecond pulses that can be used to probe electronic motion in real-time. We want to use these tools to study collective electronic dynamics, which are of particular importance for the optical response of nanoparticles. These materials are of huge fundamental interest and have

wide applications ranging from markers in medicine and biology over catalysts in chemistry to quantum computers.

The motivation for studies on nanoparticles is r elated to the possibility of tailoring their dynamical behaviour on the basis of size and shape. For the first time, we will explore electron dynamics in nanoparticles with sub-femtosecond time resolution. This way, we can gain information on the collective electronic properties of these materials on the timescale on which they occur in nature. Our work can have a huge impact on the development of nanoplasmonic devices.

The proposed project will help the applicant to successfully reintegrate into academics and form the basis for his career as an independent scientist and group leader in attosecond science. The proposal will also contribute to keeping European research at the forefront in this quickly evolving scientific field.

Funding institution or country: European Union (FP6), Germany

Materials:

Budget: ***Project Cost:*** 0.00 EURO; *Project Funding:* 40000.00 EURO

Industrial partners: 0

Research partners: 0

2.1.10 Arrangement of Nanoparticles in Phase Separated Systems (ANAPHASES)

Objective:

Controlled arrangement of inorganic nanoparticles in polymeric matrixes is a crucial key in the generation of advanced nanocomposites for new technological applications. The controlled combination of nanoparticles with a host polymer offers tremendous options for the development of composites possessing novel catalytic, conductive, magnetic or optical properties. The extraordinary characteristics of these composites arise from the synergism between the properties of the components and from the interaction between nanoparticles and matrix. For this reason, the isolation of new routes for driving organic polymers and inorganic particles to assemble into nanocomposites is today considered a particularly important scientific challenge.

Here, we propose a different and completely novel way to tackle the problem of “controlled dispersion” through the use of polymerisation induced phase separation (PIPS). In this approach, nanoparticles coated with different organic or inorganic stabilizers will be initially dispersed in a reactive solvent. This solvent will be formed by a polymeric precursor (an epoxy monomer and an initiator) and a second component that phase separates during the polymerisation reaction. By proper selection of the nanoparticles stabilizer, dispersion in the initial reactive solution and subsequent preferential migration of the particles to one of the separated phases would be achieved.

The wide number of modifier/matrix combinations and the easy tuning of polymerisation variables would make possible t he rational design of a high variety of morphologies, reinforcing the value of the proposed approach. Potential 'short term' application areas for these composites include high-density information storage, electro-luminescence-displays, electromagnetic shielding, electronic devices, catalysis, sensing, etc.

Funding institution or country: European Union (FP6), Argentina

Materials:

Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 40000.00 EURO

Industrial partners: 0

Research partners: 0

2.1.11 Applications for semiconductor nanoparticles: from biomedicine to optics (NANBIOPTIC)

Objective:

Emphasis is put worldwide on the investigation of fluorescent semiconductor nanoparticles NPs (quantum dots). Some of the most profusely investigated materials are cadmium selenide CdSe and cadmium sulphide CdS.

As a result, a great knowledge on synthesis methods, surface chemistry, crystallinity and high photoluminiscent properties yields are on stage. These materials are best suitable for high fluorescence quantum yields, photostability, and colour control by size quantisation.

The research programme o f this proposal will concentrate on the synthesis CdSe/CdS core-shell nanoparticles in different configurations and the exploration of the photoluminescence properties in different environments for technological applications. In particular, CdSe/CdS core-shell NPs either in spherical or rod-like shell will be synthesized.

The former particles will be studied as fluorescence labels for biomedical applications and the effect of the latter will be explored in a 2D and 3D photonic environment out of microsphere arrangements. Further step will involve the use of these CdSe/CdS photonic structures as the active layer in a light emitting diode (LED).

The purpose of the proposal is to explore the potential applications of high quality optimized semiconductor NPs from biomedicine to optics. The present project represents a multidisciplinary scheme gathering semiconductor nanoparticles in both biological and photonic environments with very promising applications.

The objectives proposed on this project properly fit with the needs of the European Union to carry out world-class research by the availability of skilled researchers and their capacity to produce, transfer and utilize knowledge.

Funding institution or country: European Union (FP6), Germany

Materials:

Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 149722.00 EURO

Industrial partners: 0

Research partners: 0

2.1.12 Low-cost laser powermeter with ultra-fast response for continuous beam monitoring (LASERPOM)

Objective:

Over the years, lasers have become common tools for various fields of industry and medicine, as well as for basic and applied research. For many applications, it is necessary to precisely determine the output power of the laser in order to achieve optimum results. However, no commercial power meter exists, which allows laser power to be monitored "on-line" without the need for additional diffractive optical systems, designed for such applications.

Moreover, traditional power meters make use of thermoelectric or pyroelectric sensors, which are expensive (especially when used to measure high power lasers), and suffer from long response times. The proposed power meter prototype is based on the scattering of light by nanoparticles, either deposited, or embedded, in a transparent substrate. Most of the incident laser light is transmitted by the nanoparticle-containing substrate, but a small fraction of the laser light is scattered by the nanoparticles.

The intensity of the scattered light and its angle-dependent distribution can be measured to determine the power of the transmitted laser radiation. The development of a low-cost system, which may be integrated in laser systems, will allow for a better control of processes, resulting in improvements in process quality and safety. An initial technical feasibility check of the proposed technology has been carried out by the University of Barcelona, with such promising results that all partners have envisaged a huge exploitation potential.

Funding institution or country: European Union (FP6), Spain

Budget: *Project Cost:* 1.36 million EURO; *Project Funding:* 821858.00 EURO

Industrial partners: 10

Research partners: 1

Participant:

- JCB ELECTROMECANICA, S.L. Country: SPAIN
- LASERPOINT SRL Country: ITALY
- JESUS CARCELLE SUAREZ Country: SPAIN
- SPECTRUM TECHNOLOGIES, PLC. Country: UNITED KINGDOM
- CERAMOPTEC GMBH Country: GERMANY
- UNIVERSITAT DE BARCELONA Country: SPAIN
- BAY ZOLTAN FOUNDATION FOR APPLIED RESEARCH Country: HUNGARY
- LASER COMPONENTS GESELLSCHAFT FUR DEN VERTRIEB UND DIE FERTIGUNG VON LASERN UND OPTOELEKTRONISCHEN KOMPONENTEN MBH Country: GERMANY
- TEMSA - DIAMOND DIE DIVISION Country: SPAIN
- VARADI & TARSA LTD Country: HUNGARY
- FELTALALOI ES KUTATO KOZPONT SZOLGALTATO KFT. Country: HUNGARY

2.1.13 Microfluidic total analysis system for the early diagnostic of neuro-degenerative disorders (NEUROTAS)

Objective:

The project aims to develop a prototype of a miniaturized system for diagnostics in the early stage of Alzheimer disease and other neuro-degenerative diseases, or as a point-of-care instrument for patient follow-up. The system to be developed belongs to the emerging field of 'lab-on-chip' systems. It incorporates several innovative enabling technologies, including microfluidic flow control, highly sophisticated nanobiodevices with integrated detection, and novel magnetic nanoparticles.

These approaches will lead to unprecedented integration and automation, and allow routine implementation of tests that can presently only be performed in a small number of specialized research laboratories. The system will use biomarkers present in blood, such as differently cleaved b amyloid peptides and post-translational modifications of the Tau protein. The miniaturization and integration of innovative detection technologies will greatly extend the sensitivity of biomarker detection, and thus improve the precocity of diagnosis.

This is of paramount importance for the treatment of neurodegenerative diseases, since therapeutic approaches able to retard the evolution of the diseases are progressing and promising, but little hope exists for the repair of existing brain damage. The method will also allow the simultaneous study of a wide range of markers, improving the early discrimination between different neurodegenerative diseases, and thus the choice of treatment. Indeed, the NeuroTAS system will have a modular and evolutive structure, and it will be able to progressively test and integrate into its diagnostic scheme new biomarkers that may be discovered during the prototype development.

The consortium is a combination of 4 academic, methodology-oriented laboratories with complementary competences in biochemistry, analytical chemistry, biophysics and microfabrication, two SMEs in the field of microfluidics, and two “end-users” directly involved in patient diagnosis and treatment.

Funding institution or country: European Union (FP6), Denmark

Materials:

Budget: *Project Cost:* 8.51 million EURO; *Project Funding:* 2.5 million EURO

Industrial partners: 1

Research partners: 5

Participants:

- UNIVERSITE PARIS-SUD Country: FRANCE
- UNIVERSITY OF PARDUBICE Country: CZECH REPUBLIC
- INSTITUT CURIE Country: FRANCE
- DIAGNOSWISS S.A. Country: SWITZERLAND
- FRIEDRICH-ALEXANDER-UNIVERSITAT ERLANGEN-NURNBERG Country: GERMANY
- UNIVERSITATSKLINIKUM ULM Country: GERMANY

2.1.14 Bio-imaging with smart functional nanoparticles (BONSAI)

Objective:

The overall objective is the development of ultra-sensitive bio-imaging techniques based on novel multifunctional nanoparticles (NPs) with tailored optical and magnetic properties for visualizing complex cellular structures, receptors, tumour cells and tissues. True innovation rests on the capability to combine the preparation of “ad-hoc” NPs, having different properties and functions, with the development of advanced bio-imaging techniques. The expected improvements of labelling cells and cellular structures with tailored NPs are sensitivity, speed and specificity in the visualization of biological systems. We plan the development of stable colloidal solutions containing non-cyto-toxic, colloidally stable Si-based NPs properly functionalised on the surface in order to improve and tune their optical properties and increase their selectivity in specific biological targets.

These NPs will be employed, in cooperation with two SMEs, for the development of optical bio-imaging techniques aiming at:

(i) understanding how the genome instructs and orchestrates the functions of cells, organs and organisms;

(ii) whole-cell labelling for cell or pathogen detection, cell tracking, cell sorting and cell lineage studies;

(iii) optical imaging of tumour cells for early cancer diagnostics.

A further task concerns the development of stable colloids of non-toxic, non-immunogenic NPs with:

(i) high magnetization, so that NP can be moved in the blood and accumulated in the target organ,

(ii) particle size small enough to remain in circulation after injection

(iii) narrow size distribution for differential uptake of various tissues.

The aim is the development of marketable, well-tolerated, highly efficient, specific and economically viable contrast agents for the detection and characterization of complex tumour and/or inflammatory lesions in Magnetic Resonance Imaging, in collaboration with our industrial partner.

Funding institution or country: European Union (FP6), Italy

Materials:

Budget: *Project Cost:* 4.21 million EURO; *Project Funding:* 2.91 million EURO

Industrial partners: 5

Research partners: 6

Participants:

- COMMISSARIAT A L'ENERGIE ATOMIQUE Country: FRANCE
- CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS Country: SPAIN
- UNIVERSIDAD COMPLUTENSE DE MADRID Country: SPAIN
- UNIVERSITA DEGLI STUDI DI PADOVA Country: ITALY
- MAX PLANCK GESELLSCHAFT Country: GERMANY
- UNIVERSITA' DI MILANO-BICOCCA Country: ITALY
- GUERBET Country: FRANCE

- RUSSIAN ACADEMY INSTITUTE OF GENERAL PHYSICS, RUSSIAN ACADEMY OF SCIENCE Country: RUSSIAN FEDERATION
- ALBERT-LUDWIGS-UNIVERSITAT FREIBURG Country: GERMANY
- NANOVECTOR SRL Country: ITALY
- TILL PHOTONICS GMBH Country: GERMANY

2.1.15 Electron Holography of magnetic and ferroelectric Nanoparticles arrays

Objective:

Electron Holography is attracting increasing interest as a method of material characterization by using Transmission Electron Microscopy (TEM), because it has various applications. These applications include: evaluation of magnetic and ferro-electric domains, imaging of the 3D shape of nano-structures, and dopant profiling in semiconductors.

The required attachment for electron holography was introduced into our TEM and our first steps were obtained with the cooperation of Prof. Lichte from Dresden University, a leader of the field. In this TOK (Transfer of Knowledge) program we intend to establish the method at Tel Aviv University by studying arrays of magnetic and ferroelectric nanoparticles. Such unique samples prepared by Dr. Gil Markovich from the School of Chemistry are of interest for both reasons:

- In the field of nanoscale ferromagnetic and ferroelectric materials there is a need for a technique that will be able to image the magnetization or electric polarization with nanoscale resolution. Electron holography has this capability and has many advantages over competitor techniques such as scanning probe microscopies. Together with temperature control of the sample, it would be an excellent tool to follow the dynamics of magnetization/electric polarization switching on the time scales of seconds or longer, and thus unprecedented information about the magnetic/electric dipole configurations in thin films of ferromagnetic/ferroelectric nanocrystalline arrays will be obtained.
- Due to the nanometer scale of the systems, they represent a challenge, as the electron holography method should be pushed to its limiting capability of detection. While the majority of the work will be carried out at Tel Aviv University, by European post doctorate fellowships with relevant background, the "state of the art" work will be obtained in collaboration with the group from Dresden.

Funding institution or country: European Union (FP6), Israel
Materials:
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 408184.00 EURO
Industrial partners: 0
Research partners: 1
Participant: TECHNISCHE UNIVERSITAET DRESDEN Country: GERMANY

2.1.16 Sensor nanoparticles for ions and bio-molecules (SNIB)

Objective:

The task of SNIB is to develop functional nanoparticles that allow the detection of ions (e.g. sodium, potassium, chloride), biomolecules (e.g. transmitter substances, amino acids, saccharides) or drugs and their metabolites in living cells and tissues. Analyte recognition is achieved via fluorescent indicator dyes that are embedded in the matrix of the nanoparticles. Specific binding of the analytes to the fluorophore causes changes in the fluorescence properties (e.g. fluorescence intensity and lifetime).

The polymer matrix of the nanoparticles does not only provide a selective scaffold for the fluorophore, it also provides a defined microenvironment, in which the binding of the analyte and the concomitant change in fluorescence cannot be compromised by interfering biomolecules (e.g. proteins). The size of the nanoparticles can be tailored to the specific task. Molecularly imprinted analyte-sensitive nanoparticles of larger diameter (300 - 600 nm) may be embedded in tissues whereas small nanoparticles (50 - 300 nm) can be injected directly into living cells. Unlike common indicator dyes, nanoparticles do not bind to proteins or accumulate in certain cell compartments.

This fact makes nanoparticles especially suited for the detection of ions whose detection via fluorescent indicator dyes is still limited. Furthermore, molecularly imprinted nanoparticles can open new ways for the detection of biomolecules that cannot be detected presently via fluorescent indicator dyes. Fluorescent nanoparticles will also be applied in process analysis, for the monitoring of food quality, and for the detection of toxic substances and warfare agents.

Funding institution or country: European Union (FP6), Germany

Materials:

Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 1.15 million EURO

Industrial partners: 0

Research partners: 2

Participant:

- UNIVERSITE DE TECHNOLOGIE DE COMPIEGNE Country: FRANCE
- UNIVERSITY OF EAST ANGLIA Country: UNITED KINGDOM

2.1.17 Multi-parameter sensing for high sensitivity diagnostics using fluorescent and magnetic nanoparticles (FLUOROMAG)

Objective:

The objective of FLUOROMAG will be to:

(a) produce noble metal nanoclusters or nanodots, (NDs), and core-shell (CSs) nanoparticles by a new method using controlled electrochemical techniques that ensure very uniform size distributions and transfer of this technology to a dedicated SME who will scale up the synthesis of these nanoparticles for commercial production as well as supply the consortium with NPs for

characterization of their extinction, fluorescent and magnetic properties and the further development of diagnostic tests.
(b) devise conjugation strategies to couple biomolecules to noble metal NDs and commercially available quantum dots, (QDs) to produce probes that can specifically target macromolecules such as proteins and DNA/RNA in vitro and in cells and tissues. We will take advantage of ND electrochemical synthesis to introduce specific molecules in the shells that permit efficient derivatization and coupling to biomolecules.
(c) develop multi-parametric diagnostic assays using combinations of bioconjugated QDs and noble metal NDs as novel, fluorescent probes, and bioconjugated noble metal nanoparticles as extinction probes. The goal is to achieve high sensitivity (down to single virus detection) in molecular and cellular recognition. New Hepatitis C, Dengue Fever and breast tumour assays are proposed that will monitor several antigens in multiplexed kinetic and end-point determinations.
(d) develop a commercial, low-cost programmable array microscope (PAM) module for wide field microscopes with SME partner which utilizes a spatial light modulator to achieve high-speed sectioning and simultaneous measurement of multiple fluorescence modalities as a detection system for single and multiplexed diagnostic assays using nanoparticles developed in a-c for the health-care market.

Funding institution or country: European Union (FP6), Germany
Materials:
Budget: *Project Cost:* 3.44 million EURO; *Project Funding:* 2.55 million EURO
Industrial partners: 3
Research partners: 2
Participant:

- UNIVERSITY OF TWENTE Country: NETHERLANDS
- UNIVERSIDAD DE SANTIAGO DE COMPOSTELA Country: SPAIN
- NOTTINGHAM TRENT UNIVERSITY Country: UNITED KINGDOM
- CAIRN RESEARCH LTD. Country: UNITED KINGDOM
- NANOGAP SUB-NM-POWDER S.A. Country: SPAIN

2.1.18 3-Dimensional Reconstruction of Catalysts by Scanning Transmission Electron Tomography ()

Objective:
The use of modern catalysts requires the fabrication and knowledge of nanometre-sized particles whose catalytic efficiency depends upon not only their chemistry but also their topology both in terms of the particle size and shape and also their distributio n within the support. In Cambridge, there has been enormous advances in the synthesis and characterisation of heterogeneous catalysts consisting of bimetallic nanoparticles distributed within a silica mesoporous framework. The development of such catalyst systems depends critically on a knowledge of how the particles are distributed in three

dimensions within the framework. Conventional electron microscopy whether in TEM or STEM mode will give only a projection of this structure and whilst this can give ext remely valuable information it does not reveal the full picture. Electron tomography has been developed to investigate (using only bright field images) the three-dimensional structure of viruses, macromolecules and so on. In this proposal, the aim is to us e the high angle annular dark field signal recorded under STEM illumination to investigate the 3-dimensional distribution of the nanoparticles. This kind of images are directly interpretably, are not plagued by phase contrast and be recorded quickly and ef ficiently in a modern analytical instrument. The installation of such a technique will be used to study a number of catalyst systems devoted mainly to nanoparticles of cobalt and of cobalt-iron and cobalt-gold on various light supports, such as mesoporous silica. The importance of cobalt as a powerful Fischer-Tropsch catalyst can hardly be over-emphasised. It is profoundly important if the cobalt co-exists (in a bimetallic entity) with either iron or ruthenium (or with certain noble metals).The development of this project would allow the researcher to acquire a unique experience in catalysts characterization using a novel technique available in just a few laboratories in the world.

Funding institution or country: European Union (FP6), United Kingdom
Materials:
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 159613.00 EURO
Industrial partners: 0
Research partners: 0

2.1.19 Time Resolved Single Molecule Spectroscopy Studies of Photoinduced Charge Separation and Charge Transfer in Model Photovoltaic Solar Energy Devices (FV-TR-SMS)

Objective:
"The development of renewable energy - particularly energy from wind, water, solar power and biomass - is a central aim of the European Commission's energy policy. Renewable energy sources are expected to be economically competitive with conventional energy sources in the medium to long term." Many of the most promising strategies for solar energy conversion involve charge separation of an exciton in a photovoltaic device comprised of a nanostructured composite of various types. We propose to use novel si ngle molecule (particle) modulation spectroscopy techniques to investigate photoinduced charge separation and charge transfer reactions in model photovoltaic solar energy devices based on nanoparticles. We believe that this general strategy will ultimatel y lead to new tools for photovoltaic device and materials research that will be single molecule spectroscopy (SMS) "functional equivalents" for photo-electro-chemistry and ultrafast spectroscopy. In particular, this proposal takes a new direction in solar energy conversion research by developing and applying a new technique, Fluorescence Voltage-Time Resolved-Single Molecule Spectroscopy (FV-TR-SMS). This method involves simultaneous and synchronized SMS E-Field modulation, and light intensity modulation and/or pulsed lasers. Preliminary FV-TR-SMS results demonstrate that these methods are

well suited to study the kinetics of photoinduced charge separation and transfer at the molecular level, and will allow us investigate in the proposed research critical unresolved issues regarding how charge separation and charge transfer processes depend upon chemical structure, morphology and the physical state (e.g. charging) of the layers and interfaces in the model photovoltaic solar energy devices."

Funding institution or country: European Union (FP6), Israel
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 271192.00 EURO
Industrial partners: 0
Research partners: 1
Participant: UNIVERSITY OF TEXAS AT AUSTIN Country: UNITED STATES

2.1.20 Arrangement of Nanoparticles in Phase Separated Systems (ANAPHASES)

Objective:
Controlled arrangement of inorganic nanoparticles in polymeric matrixes is a crucial key in the generation of advanced nanocomposites for new technological applications. The controlled combination of nanoparticles with a host polymer offer tremendous optio ns for the development of composites possessing novel catalytic, conductive, magnetic or optical properties. The extraordinary characteristics of these composites arise from the synergism between the properties of the components and from the interaction be tween nanoparticles and matrix. For this reason, the isolation of new routes for driving organic polymers and inorganic particles to assemble into nanocomposites is today considered a particularly important scientific challenge. Here, we propose a differen t and completely novel way to tackle the problem of “controlled dispersion” through the use of polymerization induced phase separation (PIPS). In this approach, nanoparticles coated with different organic or inorganic stabilizers will be initially dispersed in a reactive solvent. This solvent will be formed by a polymeric precursor (an epoxy monomer and an initiator) and a second component that phase separates during the polymerization reaction. By proper selection of the nanoparticle stabilizer, dispersion in the initial reactive solution and subsequent preferential migration of the particles to one of the separated phases would be achieved. The wide number of modifier/matrix combinations and the easy tuning of polymerization variables would make possible t he rational design of a high variety of morphologies, reinforcing the value of the proposed approach. Potential “short term” application areas for these composites include high density information storage, electro-luminescence-displays, electromagnetic shi elding, electronic devices, catalysis, sensing, etc.

Funding institution or country: European Union (FP6), Spainl
Materials:
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 146366.00 EURO
Industrial partners: 0
Research partners: 0

2.1.21 Advanced Electron Microscopy Study of Magnetic Nanocomposites (AMMAN)

Objective:

This proposal aims to apply advanced electron microscopy techniques to the study of magnetic nanocomposite materials, in particular sol-gel prepared FeCo oxide and alloy nanoparticles in silica and alumina matrices, which are promising for magnetic applica tions. These materials have previously been studied using detailed X-ray absorption spectroscopy measurements (in which the researcher was involved). However, there remain questions about variations in homogeneity of the nanoparticles, and the nature of surface oxide layers. Resolving these issues is central to understanding the material and apos;s behaviour, and advanced electron microscopy techniques are ideally suited for this. High resolution electron microscopy (HREM) of crystal grains will be used to observe differences between nanoparticles and to identify surface oxide layers. Electron energy loss spectroscopy (EELS) will be used to probe composition, oxidation state, and oxdie phases on the nm-scale. Finally energy filtered imaging will combin e spatial and spectroscopic information to map variations in homogeneity on nm-scale. These will be state of the art measurements, making use of the host and apos;s excellent microscopy facility, and providing extremely valuable augmentation of the resear cher and apos;s expertise in structural characterisation of novel materials.

Funding institution or country: European Union (FP6), Italy
Materials:
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 96067.00 EURO
Industrial partners: 0
Research partners: 0

2.1.22 Improving the detection sensitivity for protein micro-arrays: wave-guide SPR imaging and nano-particle enhanced imaging

Objective:

Surface plasmon resonance (SPR) spectroscopy has proven its utility and versatility in many studies, with a focal point in biochemical investigations. SPR is regarded as the most sensitive method in label-free analysis. Surface plasmon resonance imaging (S PRi) improves on the single spot interrogation of a sample by imaging an area of the sample, which can consist of a diverse sample matrix. Instead of monitoring the angular shift of the reflection minimum, a fixed angle measurement near the SPR angle is performed.

A very high detection sensitivity comparable to that of fluorescence spectroscopy is often demanded in various measurements to probe low concentration binding/interactions or weak affinities. Research efforts will focus on improvement of the detect ion sensitivity by developing wave-guide SPR imaging (WSPRi) and using nanoparticles for signal enhancement. The use of WSPRi allows for the excitation of plasmon resonance with both p and s polarized light. The resulting reflectivity spectra posses a much reduced half-width which translates to a higher sensitivity in imaging mode. Nanoparticles

functionalised antibodies in combination with silver staining will be applied and the protocol optimised, aiming at a signal improvement by two to three orders of magnitude compared to existing SPR imaging assays.

Funding institution or country: European Union (FP6), United Kingdom
Materials:
Budget: *Project Cost:* 0.00 EURO; *Project Funding:* 229327.00 EURO
Industrial partners: 0
Research partners: 0

2.1.23 Improving the understanding of the impact of nanoparticles on human health and the environment (IMPART)

Objective:
Nanotechnology is finding increased application in todays society and is being hailed as the next industrial revolution. Companies around the world are beginning to mass-produce nanoparticles (particles less than 100 nm in size) for use in everything from sunscreens to soil reclamation. The production of anthropogenically-derived nanoparticles will inevitably result in the introduction of these materials to the environment. However, despite rapid advances in nanotechnology, knowledge of the potential risks of nanoparticles to human health and the environment is limited. There is a concern that size matters with respect to toxicity, irrespective of the chemical composition. There are fears that materials that are biologically inert in bulk tend to become harmful in ultrafine particle form. Analogies have been drawn, for example, on the similarity of the structure of carbon nanotubes to asbestos fibres, whose detrimental effects on human health are well documented. There is a need to encourage greater understanding of the short and long term implications of nanotechnology for health and the environment. The primary aim of this CA is to prevent knowledge of the health and environmental implications of nanoparticles from lagging behind the technological advances. In order to do this, IMPART will foster communication links between a number of regional, national and international initiatives in order to reduce duplication of effort, pool expertise and facilitate co-operation between networks. This will re sult in an improvement in the understanding of the potential impact of nanoparticles on human health and the environment.

Funding institution or country: European Union (FP6), United Kingdom
Materials:
Budget: *Project Cost:* 741826.00 EURO; *Project Funding:* 699913.00 EURO
Industrial partners: 7
Research partners: 11
Participants:

- TECHNOLOGY CODES LTD. Country: IRELAND

- INSTITUTE OF PHYSICAL CHEMISTRY I.G.MURGULESCU OF THE ROMANIAN ACADEMY Country: ROMANIA
- NANO FUNCTIONAL MATERIALS CONSORTIUM Country: ISRAEL
- UNIVERSITATEA DIN CRAIOVA Country: ROMANIA
- CMP CIENTIFICA S.L. Country: SPAIN
- FORSCHUNGSZENTRUM KARLSRUHE GMBH Country: GERMANY
- UNIVERSITY OF CRETE Country: GREECE
- KAUNO TECHNOLOGIJOS UNIVERSITETAS Country: LITHUANIA
- JOZEF STEFAN INSTITUTE Country: SLOVENIA
- UNIVERSITY OF LEICESTER Country: UNITED KINGDOM
- TECHNISCHE UNIVERSITAT MUNCHEN Country: GERMANY
- VDI TECHNOLOGIEZENTRUM GMBH Country: GERMANY
- KATHOLIEKE UNIVERSITEIT LEUVEN Country: BELGIUM
- UNIVERSITY OF SURREY Country: UNITED KINGDOM
- TEMAS AG TECHNOLOGY AND MANAGEMENT SERVICES Country: SWITZERLAND
- NATIONAL INSTITUTE OF RESEARCH AND DEVELOPMENT FOR TECHNICAL PHYSICS Country: ROMANIA
- STICHTING BIOMADE TECHNOLOGY Country: NETHERLANDS
- LATVIJAS TOKSIKOLOGU BIEDRIBA Country: LATVIA
- DUBLIN INSTITUTE OF TECHNOLOGY Country: IRELAND

2.1.24 Multifunctional polymer materials and systems with tailored mechanical, electrical and optical properties (MULTIPOL)

Objective:

The increasing need of organic polymers for electronic applications is becoming critical since this market is growing rapidly and the current materials being limited in terms of multi-functionality, price and properties. The MULTIPOL project will propose the development of radically innovative organic materials, based on the SOLID technology recently discovered by HEARC. It was shown, that the polymer parylene can be deposited on a liquid substrate in a way that the liquid shapes of the overgrowing solid layer.

The resulting configuration is chemically stable and is the base of a huge variety of new micro-nano systems. The partners will concentrate their efforts on electronic applications, such as electronic papers, smart magneto-polymeric sensors and actuators, and solar cells. For this purpose, MULTIPOL project aims at "contaminating" the growing parylene layer in a controlled manner. Therefore, the objective of the projects will be achieved through the following steps: First of all, modelling and tools will be used to select the most promising liquids that should modify the properties of encapsulating parylene thin film. It is planned to prepare specific polymers, to use nanotubes/magnetic nanoparticles to add functionalities to the materials.

Fast screening tests will be carried out. After the selection, the enabling step consists in the understanding of the reactions at the substrate-liquid and liquid-parylene interfaces. This will be achieved through modelling. In parallel, the CVD technology used for parylene deposition will be optimised and adapted to the final products requirements. Scenarios as direct gas phase or plasma enhanced impact on the growing parylene layer should allow to further "tailor" the properties of the modified parylene layer and / o r foster reaction to obtain the modified parylene layers. The last step is dedicated to the assessment of the multi-functionality and the properties for the end-users applications.

Funding institution or country: European Union (FP6), Switzerland
Materials:
Budget: *Project Cost:* 3.3 million EURO; *Project Funding:* 2.2 million EURO
Industrial partners: 5
Research partners: 4
Participants:

- BAR ILAN UNIVERSITY Country: ISRAEL
- FUNDACION CIDETEC Country: SPAIN
- CEDRAT TECHNOLOGIES SA Country: FRANCE
- CONSIGLIO NAZIONALE DELLE RICERCHE Country: ITALY
- COMELEC SA Country: SWITZERLAND
- FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG E.V. Country: GERMANY
- INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM VZW Country: BELGIUM
- BRANDENBURGISCHE TECHNISCHE UNIVERSITAT COTTBUS Country: GERMANY
- POLITECHNIKA GDANSKA. Country: POLAND

2.1.25 Accurate Diagnosis of prostate cancer using Optoacoustic detection of biologically functionalized gold Nanoparticles - a new Integrated biosensor System (ADONIS)

Objective:
Prostate Cancer is the most common cancer disease for men. The choice of treatment and its efficiency relies strongly on the stage in which the cancer is when diagnosed. Screening procedures like digital rectal examination (DRE) and free prostate specific antigene (PSA) level testing are well established but lack accuracy, yielding only 80% of prostate cancers diagnosed in an early state.
The objective of ADONIS is the proof of concept of using optoacoustic imaging in combination with biologically functionalized nanoparticles as an integrated biosensor based system for accurate diagnosis of prostate cancer.
The idea behind ADONIS is to combine the superb biosensor selectivity of immunogold labelling with the peculiar optical properties of gold nanoparticles. It was recently shown that gold nanoparticles

have very strong surface plasmon absorption of light that is sensitive to their shape and dimensions. The absorption of light from these localized absorption centers generates pressure waves, which propagate through the tissue to be detected and analyzed with techniques similar to conventional ultrasonic imaging. Exploiting this effect in combination with the possibilities of biological targetting of nanoparticles using a tumour marker like prostate specific membrane antigen (PSMA), the expected result is a new concept for biosensor based diagnosis of prostate cancer which will allow the development of overall accessible, cost-efficient medical instruments for accurate diagnosis.

Funding institution or country: European Union (FP6), Germany
Materials:
Budget: *Project Cost:* 3.02 EURO; *Project Funding:* 2.23 million EURO
Industrial partners: 2
Research partners: 3
Participants:

- EL.EN. SPA Country: ITALY
- INSTITUTE OF CANCER RESEARCH: ROYAL CANCER HOSPITAL Country: UNITED KINGDOM
- UNIVERSITE DE LIEGE. Country: BELGIUM
- TP21 GMBH Country: GERMANY
- UNIVERSITAET BERN Country: SWITZERLAND

2.1.26 The development of a chairside diagnostic biomarker assay to assess metabolic activity with inflammatory diseases (CHAIRSIDE IMMUNOASSA)

Objective:
The project is concerned with the development of a chairside immunoassay for the detection and quantitation of biomarkers indicating inflammatory and jawbone destruction in dentistry. Specific bone matrix proteins have been identified in gingival crevicula r fluid (serum based fluid collected about teeth) in clinical conditions where active resorption of tooth supporting bone is highly probable and thus proposed as ideal biomarkers to determine the health status of deep unseen dental tissues. The assay consi dered in the project is the first prototype of a new line of diagnostic products to be developed jointly by the participants. The assay to be developed is noninvasive and aims at measuring the marker in crevicular fluid collected at tooth base on paper strips. The immunoassay will use coloured nanoparticles for its development so that it can be read by the dental surgeon at the patient's side. The test is expected to offer more relevant information on the pathological process than currently available diagno stic procedures, allowing for quicker therapeutic handling. The test will be developed jointly by the Dental School at the University of Wales College of Medicine which identified and purified the marker, and Englebienne and Associates, a Belgian SME spe cialised in developing rapid diagnostic tests. For the project purpose, a post-doctoral student from the academic partner (who has an understanding of teeth supporting tissues and biomarkers in health and disease) will be

hosted by the SME for training dur ing active product development. They will then assist in clinical validation co-ordinated by the academic partner. In the longer term, the collaboration established is intended to secure the shared development and commercialisation by the participants of a complete line of diagnostic immunoassay products for dentistry and stomatology. The project also intends to create the basis for a European centre of excellence in dental diagnostics benefiting society at large.

Funding institution or country: European Union (FP6), United Kingdom
Materials:
Budget: *Project Cost:* 161591.00 EURO; *Project Funding:* 161591.00 EURO
Industrial partners: 1
Research partners: 0
Participant: ENGLEBIENNE AND ASSOCIATES BVBA Country: BELGIUM

2.1.27 Single Particle Nanophotonic Switching - Bridging Electron MIcroscopy and Photonics (SPANS)

Objective:
This STREP project aims to study the underlying physical mechanisms of optical switching based on single-particle phase transitions triggered by light or electron-beam excitation and to demonstrate new types of nanophotonic switches based on this principle. The implementation of these ambitious research aims will require the development of new techniques to study active nanophotonic structures. We will for the first time combine nanophotonics with electron microscopy - employing sub-nanometre resolution diagnostic capabilities to achieve the deepest possible insight into the photonic switching process and to exercise electron-beam controlled switching.
This technique will be particularly suited to the study of optical switches and will employ the evanescent field of the electron beam to truly probe the near-field regime of these devices in a non-intrusive fashion. More specifically, a new all-optical switch will be developed using light-induced phase transitions in nanoparticles where two or more phases can co-exist in metastable form.
The reversibility of the phase transisions will be addressed, and the effect of the nano-environment will be investigated. Nanoparticles will be trapped by tips and analysed both by measuring:
(1) scattering and absorption of light driven to the nanoparticles down optical fibres,
(2) electron energy losses within transmission electron microscopes and
(3) light induced by those electrons.
Our ultimate goals are:
(1) to demonstrate the ability of some specific nanoparticles to act as single-photon switches based upon optically-driven phase transitions and
(2) to provide a general photonic nanostructures characterisation technique based upon electron microscopy that can have a significant impact in both the nanophotonics and the electron microscopy communities.

Funding institution or country: European Union (FP6), Spain

Materials:

Budget: *Project Cost:* 1.48 million EURO; *Project Funding:* 755000.00 EURO

Industrial partners: 0

Research partners: 2

Participants:

- UNIVERSITY OF SOUTHAMPTON Country: UNITED KINGDOM
- UNIVERSITE PARIS-SUD Country: FRANCE

2.1.28 Metallic and semiconducting nanoparticle source for electronic and optoelectronic applications (NANOSOURCE)

Objective:

The proposal aims at mutual technology transfer between two academic research laboratories and an industrial partner. NTUA has experience on sensors and electronic/optoelectronic devices based on nanoparticles arrays, NCSRD has experience on the nanoscale characterization of materials and microelectronic device fabrication technologies and MANTIS Deposition Ltd has developed a nanoparticles source able to synthesize nanoparticles of extreme size uniformity. A main scientific goal of the project is the formation of 2-dimentional and 1-D configurations of nanoparticles with controlled size and density.

The accomplishment of this target will enable the fabrication of nanoparticles based sensors and electronic/optoelectronic devices beyond the state-of-the-art. The academic partners will have the opportunity to advance their research in the above fields by acquiring knowledge in the nanoparticle manufacturing technique of Mantis. From this exchange of knowledge the SME will benefit from the investigation of its product applicability in these new fields.

Funding institution or country: European Union (FP7), Greece

Materials:

Budget: *Project Cost:* 1.13 million EURO; *Project Funding:* 1.13 million EURO

Industrial partners: 0

Research partners: 1

Participants:

- NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS" Country: GREECE
- MANTIS DEPOSITION LIMITED Country: UNITED KINGDOM

2.1.29 Nanobiosensors for health monitoring (NANHEMO)

Objective:

The drive to understand biology and medicine at the molecular level with accurate quantitation demands much of current high-throughput analysis systems. Nanomaterials and nanotechnology combined with modern instrumentation have the potential to address this emerging challenge. Using a

variety of nanomaterials for multiplex diagnostics and imaging applications will offer sensitive, rapid and cost-effective solutions for the modern clinical laboratory. New nanomaterials, i.e., metallic nanoparticles labelled with plasmonically enhanced fluorescent metal complexes, will be developed to achieve optical-encoding capabilities for selective tagging of a wide range of medically important targets, including bacteria, cancer cells and individual molecules, such as proteins and DNA, in a single assay.

We envision further development in this field will provide numerous advanced tools with increased sensitivity and improved multiplexing capability, for unique applications in molecular biology, genomics and drug discovery. To achieve these ambitious goals will require the synthesis of a variety of luminescent and redox active metal complexes, nanoparticles and polyelectrolytes for encapsulation.

Funding institution or country: European Union (FP7), Ireland

Materials:

Budget: *Project Cost:* 30000.00 EURO; *Project Funding:* 30000.00 EURO

Industrial partners: 0

Research partners: 0

2.1.30 Study of coherent non-linear optical response of nanoparticles and application to multiphoton imaging in cell biology (FWMIMAGING)

Objective:

The objective of this research project is to develop a novel multiphoton microscopy technique and to investigate its application to selected problems in cell biology which require sensitive three-dimensional imaging, in-vivo and real time. This novel technique is based on the detection of the resonant coherent non-linear optical response (four-wave mixing) of colloidal quantum dots (CQDs) to explore their application as bio-labels beyond their fluorescence properties.

This method would retain many of the advantages of multiphoton fluorescence microscopy, such as intrinsic sectioning capability, and would offer additional advantages such as coherent detection free from fluorescence backgrounds. We expect the spatial resolution to be increased by a factor of two due to the optical non-linearity, resulting in a 130nm of lateral resolution at 550nm exciting wavelength and objectives with 1.3 NA.

Funding institution or country: European Union (FP7), United Kingdom

Materials:

Budget: *Project Cost:* 178874.00 EURO; *Project Funding:* 178874.00 EURO

Industrial partners: 0

Research partners: 0

2.1.31 Smart nondimensional biosensors for detection of tumor cells and cytotoxic amyloids intermediates (NANOSMARTS)

Objective:

This project integrates the development of (a) bioconjugated silicon nanoparticles (NPs) as new, < 3nm, fluorescent probes and (b) dual-emission band fluorescent biosensors for protein conformation investigations to be applied in diagnostic procedures related to tumor biology and neurodegenerative diseases. Epidermal growth factor receptor (EGFR) is an important therapeutic target in a variety of tumors, particularly malignant gliomas where mutation and/or amplification of EGFR is often observed. The laboratory has demonstrated in a pilot study the specific binding of biomolecules conjugated to Quantum Dots to patient-derived glioma spheroids. High wavelength emitting QDs are necessary to distinguish binding from tissue autofluorescence but such QDs are large (~40 nm) and do not penetrate deeply into tissues or access cellular junctions.

Funding institution or country: European Union (FP7), Germany

Materials:

Budget: *Project Cost:* 156993.00 EURO; *Project Funding:* 156993.00 EURO

Industrial partners: 0

Research partners: 0

2.1.32 Targeted Nanosystems for improving photodynamic therapy and diagnosis of cancer (NANOPHOTO)

Objective:

The overall objective of this proposal is the development of one or more nanosystems loaded with Foscan® and conjugated to cancer cell specific ligands for improving the efficacy and selectivity of photodynamic therapy (PDT) and optimise a fluorescence-based tumour imaging approach. At present, PDT with Foscan® can be very effective but is not selective because Foscan® accumulates in the tumour tissue as well as in healthy ones. A great improvement of the therapy can only come from the availability of a carrier able to seek cancer cells and deliver Foscan® selectively to them.

Three types of nanosystems, namely, liposomes, silica nanoparticles or poly (lactide-co-glycolide) copolymer nanoparticles, have been selected as potential nanocarriers for the selective delivery of Foscan®. The selection was mainly based on the different chemical nature of these systems, which can affect biocompatibility. During the first part of the project each type of nanosystem will be optimised through in vitro and in vivo tests and leader nanocarriers will be selected and conjugated to cancer cells specific ligands for increasing the selective delivery of Foscan®.

Funding institution or country: European Union (FP7), Italy

Materials:

Budget: *Project Cost:* 3.24 million EURO; *Project Funding:* 2.45 million EURO

Industrial partners: 1

Research partners: 3

Participants:

- UNIVERSITY COLLEGE LONDON Country: UNITED KINGDOM
- UNIVERZA V LJUBLJANI Country: SLOVENIA
- BIOLITEC AG Country: GERMANY
- ACADEMISCH ZIEKENHUIS GRONINGEN Country: NETHERLANDS

2.1.33 Metallic nanoparticles as nanomodifier for improving of solar cells

Objective:

No description available

Funding institution or country: Poland

Materials: metallic nanoparticles

Budget:

Industrial partners:

Research partners:

2.1.34 Polymeric composites with luminescent nanoparticles

Objective:

No description available

Funding institution or country: Poland

Materials:

Budget:

Industrial partners:

Research partners:

2.1.35 Optical investigations of Si nanoparticles and Si nanoparticles doped with rare-earth ions for emitter and light amplifier applications

Objective:

No description available

Funding institution or country: Poland

Materials:

Budget:

Industrial partners:

Research partners:

2.1.36 Spectroscopic investigations of electron states of colorant absorbed in TiO_2 nanoparticles

Objective:

Investigations of complex colorant – semiconductor for new type of solar cells

Funding institution or country: Poland

Materials:

Budget:

Industrial partners:

Research partners:

2.1.37 Bio-imaging with smart functional nanoparticles (BONSAI)

Objective:

The overall objective is the development of ultra-sensitive bio-imaging techniques based on novel multifunctional nanoparticles (NPs) with tailored optical and magnetic properties for visualizing complex cellular structures, receptors, tumour cells and tissues. True innovation rests on the capability to combine the preparation of 'ad-hoc¿ NPs, having different properties and functions, with the development of advanced bio-imaging techniques. The expected improvements of labelling cells and cellular structures with tailored NPs are sensitivity, speed and specificity in the visualization of biological systems. We plan the development of stable colloidal solutions containing non-cyto-toxic, colloidally stable Si-based NPs properly functionalised on the surface in order to improve and tune their optical properties and increase their selectivity in specific biological targets.

These NPs will be employed, in cooperation with two SMEs, for the development of optical bio-imaging techniques aiming at:

(i) understanding how the genome instructs and orchestrates the functions of cells, organs and organisms;

(ii) whole-cell labelling for cell or pathogen detection, cell tracking, cell sorting and cell lineage studies;

(iii) optical imaging of tumour cells for early cancer diagnostics.

A further task concerns the development of stable colloids of non-toxic, non-immunogenic NPs with:

(i) high magnetization, so that NP can be moved in the blood and accumulated in the target organ,

(ii) particle size small enough to remain in circulation after injection

(iii) narrow size distribution for differential uptake of various tissues.

The aim is the development of marketable, well-tolerated, highly efficient, specific and economically viable contrast agents for the detection and characterization of complex tumour and/or inflammatory lesions in Magnetic Resonance Imaging, in collaboration with our industrial partner.

Funding institution or country: EC, FP6

Materials:

Budget: 4.17 million euro

Industrial partners: 2

Research partners: 10

2.1.38 Single particle nanophotonic switching - bridging electron microscopy and photonics (SPANS)

Objective:

This STREP project aims to study the underlying physical mechanisms of optical switching based on single-particle phase transitions triggered by light or electron-beam excitation and to demonstrate new types of nanophotonic switches based on this principle. The implementation of these ambitious research aims will require the development of new techniques to study active nanophotonic structures. We will for the first time combine nanophotonics with electron microscopy - employing sub-nanometre resolution diagnostic capabilities to achieve the deepest possible insight into the photonic switching process and to exercise electron-beam controlled switching. This technique will be particularly suited to the study of optical switches and will employ the evanescent field of the electron beam to truly probe the near-field regime of these devices in a non-intrusive fashion. More specifically, a new all-optical switch will be developed using light-induced phase transitions in *nanoparticles* where two or more phases can co-exist in metastable form. The reversibility of the phase transisions will be addressed, and the effect of the nanoenvironment will be investigated.

Nanoparticles will be trapped by tips and analyzed both by measuring

- scattering and absorption of light driven to the *nanoparticles* down optical fibers,
- electron energy losses within transmission electron microscopes, and
- light induced by those electrons.

The ultimate goals are

- to demonstrate the ability of some specific *nanoparticles* to act as single-photon switches based upon optically-driven phase transitions and
- to provide a general photonic nanostructures characterisation technique based upon electron microscopy that can have a significant impact in both the nanophotonics and the electron microscopy communities.

Funding institution or country: EC, FP6

Materials:

Budget: 1.48 million euro

Industrial partners: 0

Research partners: 2

2.1.39 Arrangement of Nanoparticles in Phase Separated Systems (ANAPHASES)

Objective:

Controlled arrangement of inorganic nanoparticles in polymeric matrixes is a crucial key in the generation of advanced nanocomposites for new technological applications. The controlled combination of nanoparticles with a host polymer offer tremendous optio ns for the development of composites possessing novel catalytic, conductive, magnetic or optical properties. The extraordinary characteristics of these composites arise from the synergism between the properties of the components and from the interaction be tween nanoparticles and matrix. For this reason, the isolation of new routes for driving organic polymers and inorganic particles to assemble into nanocomposites is today considered a particularly important scientific challenge. Here, we propose a differen t and completely novel way to tackle the problem of ¿controlled dispersion¿ through the use of polymerization induced phase separation (PIPS). In this approach, nanoparticles coated with different organic or inorganic stabilizers will be initially disperse d in a reactive solvent. This solvent will be formed by a polymeric precursor (an epoxy monomer and an initiator) and a second component that phase separates during the polymerization reaction. By proper selection of the nanoparticle stabilizer, dispersion in the initial reactive solution and subsequent preferential migration of the particles to one of the separated phases would be achieved. The wide number of modifier/matrix combinations and the easy tuning of polymerization variables would make possible t he rational design of a high variety of morphologies, reinforcing the value of the proposed approach. Potential ¿short term¿ application areas for these composites include high density information storage, electro-luminescence-displays, electromagnetic shi elding, electronic devices, catalysis, sensing, etc.

Funding institution or country: EC, FP6

Materials:

Budget:

Industrial partners:

Research partners:

2.1.40 Applications for semiconductor nanoparticles: from biomedicine to optics (NANBIOPTIC)

Objective:

Emphasis is put worldwide on the investigation of fluorescent semiconductor *nanoparticles* NPs (quantum dots). Some of the most profusely investigated materials are cadmium selenide CdSe and cadmium sulphide CdS. As a result, a great knowledge on synthesis methods, surface chemistry, crystallinity and high photoluminiscent properties yields are on stage. These materials are best suitable for high fluorescence quantum yields, photostability, and colour control by size quantisation. The research programme o f this proposal will concentrate on the synthesis CdSe/CdS core-shell *nanoparticles* in different configurations and the exploration of the photoluminescence properties in different environments for technological applications. In particular, CdSe/CdS core-shell NPs either in

spherical or rod-like shell will be synthesized. The former particles will be studied as fluorescence *labels* for biomedical applications and the effect of the latter will be explored in a 2D and 3D photonic environment out of microsphere arrangements. Further step will involve the use of these CdSe/CdS photonic structures as the active layer in a light emitting diode (LED). The purpose of the proposal is to explore the potential applications of high quality optimized semiconductor NPs from biomedicine to optics. The present project represents a multidisciplinary scheme gathering semiconductor *nanoparticles* in both biological and photonic environments with very promising applications. The objectives proposed on this project properly fit with the needs of the European Union to carry out world-class research by the availability of skilled researchers and their capacity to produce, transfer and utilize knowledge.

Funding institution or country: EC, FP6
Materials:
Budget:
Industrial partners:
Research partners:

2.1.41 Optimization of Si solar cells, plastic materials and technologies for the development of more efficient concentration photovoltaic systems (ORION)

Objective:
The development of renewable energy is a central aim of the EU Commission's energy policy. Concentration PhotoVoltaics (CPV) has been demonstrated to be a good solution in PV industry and in the last years has become more attractive and several companies have been founded with the main goal of decreasing the cost of PV-generated electricity. The main objective of this project is the optimization of materials and technologies involved in CPV System production to reduce system cost/watt and increase system efficiency. The reduction of system cost/watt, that reflects in reduction of PV-generated electricity, will be achieved by:
- developing an all-plastic system by using recycled plastic compounds;
- developing Si solar cells for automatic assembling technology;
- implementing and industrializing automated high-rate technologies for cell assembly and optics production.
The increase of system efficiency will be achieved by;
- increasing Si concentration cell efficiency by using surface plasmonic crystal structures;
- developing plastic materials doped with down-converting nanoparticles for modification of the solar spectrum to enhance the cell efficiency.
The scientific objectives concern optimization of Si solar cell and the development of new application-addressed nanocomposite thermoplastic material. Technological objectives concern the implementation and industrialization of automated low-cost technologies for CPV components

fabrications. The scientific and technological objectives of the project will be exploited by the realization of a low CPV system with a projection 2-3 /Watt . The new system, ready to be produced at the end of the project, will be based on Si concentration solar cell technology coupled to hybrid mirror-lens concentrator optical system. The project also includes the design and development of an innovative one-axis tracker integrated with optics for the realization of a compact and modular CPV system for domestic rooftop applications.

Funding institution or country: EC, FP6
Materials:
Budget: 2,920,000 Euro
Industrial partners: 2
Research partners: 3

2.1.42 Hybrid solar cells (Hybrid Solarzellen)

Objective:
description available in German
Funding institution or country: FWF Austria
Keywords: core/ shell, nanoparticle, hybrid materials, CuInS2, photovoltaic, semiconducting polymers

2.1.43 Optical properties of metallic nano gratings (Optische Eigenschaften metallischer Nanogitter)

Objective:
description available in German
Funding institution or country: FWF Austria
Keywords: surface plasmon, grating, optical near-field, nanooptics, nanoparticles, nanotechnology

2.1.44 Surface Plasmon Polariton Nano-Optics

Objective:
description available in German
Funding institution or country: FWF Austria
Keywords: nanotechnology, near-field optical microscopy, surface plasmon polaritions, nanoparticles, nano-optics, electron beam lithography

2.1.45 Gold-functionalized magnetic nanoparticles for biological applications

Objective:
Self-assembly based synthesis of nanoparticles is a highly versatile route towards state-of-the-art nanoengineering of functional materials. One of the most promising areas of nanoparticle research, both in terms of academic interest and possibilities for high-value applications, is nanoparticle-based

systems for targeted delivery of biologically active agents. This is connected to the possibility of introducing multiple functions into one set of particles, which for example enables imaging (magnetic or optical activity), drug/gene incorporation, and introduction of targeting ligands (antibodies, proteins, etc.) into the same particles. The current proposal is a joint proposal between the department of physical chemistry, Abo Akademi University, Turku, Finland, and Shanghai Jiao Ting University, Shanghai, China connected to the synthesis of magnetic particles surrounded by a silica core onto which gold nanoparticles are immobilized.

Funding institution or country: Finland
Contact person: Mika Lindén, mlinden@abo.fi

2.1.46 Visible Light Induced Photo-degradation of Organic Matter Using Semiconductor Nanoparticles for Hygi

Objective:
This proposal aims to fabricate visible light activated antibacterial materials composed of sol gel TiO2, sol gel with TiO2 additives, doped TiO2 and new materials. These materials will be coated onto hospital surfaces - walls, floors, doors, benchtops and wardrobe. Two strands will be investigated; the first is the modification of TiO2 to narrow the band gap and hence enhance the material's visible light absorption capabilities. The second strand will be the development of novel photocatalysts. Properties such as self-cleaning, antibacterial and photocatalytic properties will be incorporated to coatings in conjunction with enhanced scratch, abrasion, wear and oxidation resistance and chemical resistance. Coating formulations arising from pilot plant scale operations will be applied in Irish and Finnish hospitals in the final stage of the programme. The project will be done together with VTT, Millidyne Oy, Oy Soft Protector Ltd, Department of Public Health/HUT, CREST - the Centre for Research in Engineering Surface Technology, SCPS - School of Chemical and Pharmaceutical Sciences and General Paints Ltd. and Mergon International.Funding institution or country: Finland

Contact person: Mika Lindén, mlinden@abo.fi

2.1.47 Optical Memory in Nanoscale Materials, OMENA

Objective:
Optical memory devices with high information density are nowadays most important for information storage, and various photonic approaches have been discussed to improve the parameters. In optical memories, information is written as changes of optical properties, and it is read by optical means. The studies in this field are promising to lay the basis for forthcoming revolution in optical communications and optical computing with important advantages as miniaturization and increased reliability. Photonics within conventional Si technology forms the main research topic. Integration of all photonic functions into silicon is a strong challenge, and Si nanocrystals open a promising perspective here. Based on our recent results, optical memories can be constructed from Si nanocrystals in oxide host,

providing storage of information with high density, very high temperature stability and extremely long retention time. Other approaches suggested to study here are based on metal nanoparticles, and they can increase substantially the achievable information density. The highest carrier density can be obtained within the concept of information storage on molecular level, and this approach will also be studied. In order to read the optical information, transmission, Raman, infrared absorption, and photoluminescence spectroscopic methods will be used. We will promote the following specific objectives: (1) Development of solid materials containing various nanoparticles and molecular conformers suitable for optical memories; (2) Optical memories based on laser-induced crystallization and stress of nanoparticles in solid hosts. (3) Optical memories based on structural transformations and agglomerations of metal nanoparticles such as gold, gallium, etc. (4) Optical memory on molecular level based on conformational changes in solid materials by electric field and laser light. (5) Theoretical simulations of structural transformations of nanoscale materials suitable for optical memories. The proposed plan is interdisciplinary comprising physics, chemistry, materials science, nanoscience, and theoretical simulations. The present team is constituted of scientists from various disciplines having very different equipment and experimentaland theoretical skills. There is practically no overlap in scientific expertise between the teams, meaning that it is built in an economic way and evidencing the added value from the cooperation. The suggested team consist of six Finnish and four foreign groups (from US, Russia, and Australia); hence it will facilitate the creation of new multidisciplinary research teams and national and international research networks. The participating teams are internationally recognized in the field of Photonics. The proposed plan corresponds to the research scheme Optical materials and interaction process of the Research Program.

Funding institution or country: Finland
Contact person: Mika Lindén, mlinden@abo.fi

2.1.48 Multifunctional Superparamagnetic Iron Oxide Nanoparticles for Targeted Magnetic Resonance Imaging

Objective:

We will exploit novel approaches of immobilizing functional molecules through bioinspired (cyanobacterial iron chelator, mussel adhesive proteins) anchorage chemistry to iron oxide nanoparticles. Biotinylated, adhesive PEG constructs will be assembled on Superparamagnetic Iron Oxide Nanoparticles (SPION) and assembly protocols optimized. Further functionalization includes sequential immobilization of streptavidin (or neutravidin) and biotinylated targeting ligands or alternatively direct coupling of such ligands. As a model application, the novel multifunctional SPIO particles - presenting specific targeting ligands - will be used for the non-invasive detection of early stages of vulnerable plaque in blood vessels by Magnetic Resonance Imaging (MRI) using suitable animal models.

Funding institution or country: Switzerland

Keywords: Superparamagnetic iron oxide nanoparticles (SPION); surface functionalization; biomimetic surfaces; biological targeting; magnetic resonance imaging (MRI)

2.1.49 Multifunctional Peptide Nanoparticles for Drug Targeting, Drug Delivery and Imaging Applications

Objective:

We have recently invented and developed a novel type of nanoparticles based on peptides as building blocks. By attaching a targeting unit, one or several different drugs, and/or biomarkers, multifunctional peptide nanoparticles can be designed for a wide range of in vivo and ex vivo biomedical applications. Here we propose to functionalize these peptide nanoparticles as 1. multifunctional drug targeting and delivery devices and 2. as imaging tools for multiplexed screening applications.

Funding institution or country: Switzerland

Keywords: NA

2.1.50 Synthesis and assessment of mixed metal-oxide nanoparticles andfilms for solar photo-electrochemical hydrogen fuel prod

Objective:

The objective of this project is to develop mixed metal-oxide narrow band-gap semiconductor nanoparticles with optimized redox potentials to produce hydrogen efficiently via photocatalysis using visible light. Acetylene flame spray synthesis is a new method for nanoparticle and nanocomposite production from affordable inorganic precursor solutions with high crystallinity. Such particles are of high relevance for photoelectrochemical and photocatalytical (PEC, PC) applications..

Funding institution or country: Switzerland

Keywords: NA

2.1.51 Biochemically modified nanoparticles for the development of novel fluorescence assays

Objective:

NA

Funding institution or country: Switzerland

Keywords: NA

2.1.52 Development of Nanoparticles With Tunable UV Absorption Characteristics NANUVA

Objective:

NA

Funding institution or country: Switzerland

Keywords: NA

2.1.53 Doped and dye-sensitized TiO2 nanoparticles in polyester fibers with advanced deodorizing properties using the visible wavelength range (Nanodor-Vis)

Objective:

NA

Funding institution or country: Switzerland

Keywords: NA

2.1.54 Sensing and Manipulation of Nanoparticles on Photonic Crystals by an opical tweezer

Objective:

In this proposal we want to exploit the potential of an optical tweezer as a tool for nano-manipulation of active particles coupled to photonic crystal structures. An optical tweezer is created in a homemade beam-scan confocal microscope. As active particles we use colloidal particles coated with semiconductor nanocrystals which emit in the near-infrared. The particles are trapped in solution close to the surface of photonic crystal structures which will be provided by our collaborators. Coupling to resonant defects and modifications of the luminescence properties are studied in detail. A second more fundamental research topic of this proposal generalizes the investigation of periodic dielectric structures, such as photonic crystals, to arbitrary, but still controlled dielectric structures. We plan to use multiple optical tweezers to trap and manipulate dielectric particles. In this way an arbitrary strutured dielectric environment which consists of few well controllable constituents can be created. We. plan to study the optical properties of such structures, as well as their effect on the local density of states of the electromagnetic field. Similar as in the first research topic the latter can be explored with the help of nanoscopic active probe-particles placed inside these structures.

Funding institution or country: DFG Germany

2.1.55 Toolbox for building photonic/plasmonic crystals in a glass matrix containing metallic nanoparticles

Objective:

This project will investigate a new approach to generate photonic (plasmonic) crystals, based on nanocomposite materials consisting of a dielectric (usually glass) and embedded metallic nanoparticles. The optical properties of this base material can be varied within a wide range of parameters by using different components (metal/matrix), and by varying size, concentration and shape of the nanoparticles. A two-step procedure will be applied to produce photonic crystals from such materials with well-defined defects: in a first step, a method developed very recently will be

utilized to transfer local lateral structures from a structured electrode (e.g. a 2D Si photonic crystal) to the base material by help of an electric field; in the contact regions, the dielectric becomes transparent again by dissolving the nanoparticles in the matrix, while in non-contact regions nanoparticle clumps remain. As long as the length scale of the electrodes is much larger than the particle size, the optical properties in these regions are very close to that of the base material. Treatment with ultrashort laser pulses allows further local modification of the optical properties, e.g. creation of special defect structures by introducing local dichroism. The high flexibility of the propesed materials system in preparing different structures with large variety of optical properties can only be effectively explored if the predictive power of simulations of the photonic strucutres is combined wit the proposed experiments.

Funding institution or country: DFG Germany

2.1.56 Nanotronics – Photovoltaics and Optoelectronics from Nanoparticles (Nanotronics - Photovoltaik und Optoeletronik aus Nanopartikeln)

Objective:

description available in German

Funding institution or country: DFG Germany

2.1.57 Nonlinear Photonics with Metallic Nanostructures on Top of Dielectrics and Waveguides

Objective:

In this project we are going to investigate the optical properties of nanoscale mesoscopic metallic nanostructures and of strongly correlated materials. We want to study both isolated and strongly coupled nanoparticles. The optical properties are being investigated by continuous wave and by ultrafast (femtosecond and picosecond) spectroscopy. Metallic nanoparticles are becoming an important building block in nano-optics. However, in order to be able to localize light on a mesoscopic scale, it will be necessary to understand the exact mechanism how light couples to such nanostructures and how its energy is being transferred into electronic excitations (particle plasmons). Furthermore, it is necessary to unterstand how these excitations can transfer to neighboring particles and reradiate back into space. When arranging the particles into a regular metallic nano-structure, it will be necessary to understand the linear and nonlinear optical properties of such metamaterials. Our project aims to clarify the temporal dynamics and the control of light-matter coupling in metallic nanostructures. Strongly correlated materials are believed to have the potential for the fastest optical switches available. However, only a few experiments have so far proven the existence of theoretically calculated quasiparticles in these systems, such as magnons and spinons. Nearly nothing is known about the ultrafast temporal dynamics (lifetime and dephasing) of these quasiparticles. Our project aims to investigate these elementary processes, using state-of-the art and novel ultrafast methods.

Funding institution or country: DFG Germany

2.1.58 Linear and nonlinear optical properties of metallic photonic crystals and pseudo/negative index materials

Objective:

Metallic photonic crystals can be composed of regular arrays of metallic nanoparticles on a waveguide. Strong coupling by light, especially through this underlying waveguide, leads to collective states. These states consist of localized particle plasmons and extended polaritonic excitations, similar to cavity polaritons in a semiconductor microcavity. We have two goals in our project: (a) We would like to understand and describe the linear optical properties of the coupled light-particle-plasmon system, especially the optical transmission and reflection properties that differ substantially from the spectra of individual metal nanoparticles. For example, we found strong Fano resonances as a sign of interference between a narrow resonance and a continuum. What exactly is the nature of these interfering states, and how are they coupled? What determines the coupling strength? Do these coupled systems form a complete photonic bandgap? What determines the size of the normal-mode coupling? (b) The coupled system exhibits a new type of excitations, so-called particle-plasmon-waveguide-polaritons. What is the lifetime of these excitations, what is their dephasing time? We want to study these coherent properties using nonlinear femtosecond spectroscopy, e.g., autocorrelation spectroscopy. Is it possible to tailor the dephasing times of the coupled system? Can we quantify the radiative and nonradiative contributions to the dephasing rate? Meeting these challenges will yield a fundamental and more complete understanding of the linear and nonlinear optical properties of collective excitations in metallic photonic crystals.

Funding institution or country: DFG Germany

2.1.59 Laser-Induced Phase Transitions in Gas-Phase Suspended Molecular Nanoparticles

Objective:

Experimental and computer-chemical investigation of melting and vaporisation of gas-phase suspended H20 and D2O nanoparticles is proposed. The heating of the particles being initially in thermal equilibrium will be realized by use of infrared-emitting laser sources. HDO will act as an indicator for presence of the liquid phase in the particles. A new technique for generation of mantle-core particles and layered particles composed of different isotopomers, combined with laser heating and sensitive FTIR detection, will allow to get site-dependent structure information for water nanoparticles for the first time. Special efforts will be directed on the investigation of thickness, structure and temperature dependence of the quasi-liquid-layer (QLL) on the particles. The QLL determines the vapour pressure of the particles; the role of quantum effects will be on focus. Other efforts are addressed to study processes of the particles as molecular self-diffusion. Smaller sizes of water clusters in thermal equilibrium with 2 to 100 molecules per particle are aimed for by use of laser-

induced explosive particle vaporisation. A bank of computer codes for simulating structure and dynamics of water clusters will be applied for sizes up to n = 1000 molecules and developed for bigger particles parallel to the experimental program. The codes apply Molecular Dynamics, Path Integral Monte Carlo and other methods. The expected results should have major importance to basic water research, to atmospheric and astro-chemical applications as well as to nanoengineering of molecular nanoparticles.

Funding institution or country: DFG Germany

2.1.60 Investigations on development of phosphorescent nanoparticles as label for bio-analytics and medical diagnosis (Untersuchungen zur Entwicklung von phosphoreszierenden Nanopartikeln als Marker für die Bioanalytik und medizinische Diagnostik)

Objective:

description available in German

Funding institution or country: DFG Germany

2.1.61 Synthesizing, functionalizing and exploring metal nanoparticles for biophysical single molecule studies, and new materials

Objective:

We will explore the use of metal nanoparticles for medical sensing devices, new photonic materials and single molecule biophysical studies. Using metal nanoparticles as labels in biophysical studies has advantages over commonly used fluorescence markers because they neither blink nor bleach and can provide both distance and orientation information. For materials science and device applications, the large field enhancement under optical illumination, the changes in color upon changes in the environment, and the directed scattering will prove useful for applications ranging from fundamental research, new biosensors to decorative coloring. This interdisciplinary research program will follow four parallel but connected work-streams: The controlled systhesis of metal nanoparticles of different shape and composition, especially gold nanorods. These particles will be used in the following projects. The functionaliszation of nanoparticles with biomolecules by understanding and controlling surface properties in order to assemble the particles into artifical nanostructures. The study of the mechano-chemistry of large biomolecules during their functional task on a single molecule level using plasmon based labes, and Engineering new materials for nonlinear optical devices by exploring the optical field enhancement of the tip of metal rods.

Funding institution or country: DFG Germany

2.1.62 Selective therapy of the eye by laser-active nanoparticles (Selektive Therapie des Augenhintergrundes durch laseraktivierte Nanopartikel)

Objective:

no description available

Funding institution or country: BMBF Germany

2.1.63 Preparation, Evaluation and Application of randomized Lase-systems (Präparation, Evaluation und Anwendung Randomisierter Laser-Systeme)

Objective:

no description available

Funding institution or country: BMBF Germany

2.1.64 Functionalisation of nanoparticles for multi-photon bio-imaging of tumor cells (Nanoparticules fonctionnalisées pour la bio-imagerie multiphotonique de cellules tumorales)

Objective:

no description available

Funding institution or country: France

2.1.65 Nanoparticles with regular porosity for imaging using functionalized xenon (Nanoparticules à porosité ordonnée pour l'imagerie par xénon fonctionnalisé)

Objective:

no description available

Funding institution or country: France

2.1.66 SONS EUROCORES: Proposal 05-SONS-FP-014 Liquid Crystal Nanoparticles - LC-NANOP

Objective:

Liquid crystals (LCs) are the quintessential, self-organising, molecular materials of the modern era. The ease with which they can be reoriented in electrical, magnetic and mechanical fields has led to a plethora of applications, resulting, for example, in the dominance of the electro-optic displays market. Most LCs have been designed as either low molar-weight materials for displays (eg 4-alkyl-4'-cyanobiphenyls) or high molecular-weight materials for high yield-strength polymers (eg KevlarTM, and VectraTM). In contrast to existing materials, nano-structured LCs can combine self-organisation with the ability to form secondary and tertiary structures, in a structural hierarchy similar to that found for proteins. Furthermore, super- and supra-molecular LCs can exhibit a variety of physical properties

which make them attractive for applications in the fields of nano-science, materials and biology. We predict that future materials research and applications of LCs will be focused on a variety of exciting topics, which reflect our ability to control self-organising, self-assembling and micro-segregating processes of complex/giant molecular systems to yield addressable, self-organised nano-structures. The materials themselves will be "property designed" and synthesised with smart and often multifunctional characteristics. Their applications will spread across the boundaries from advanced technological devices through to smart bio-materials/sensors, even to the discovery of new "states of matter". Anticipating such exciting developments, we intend to utilise the unique self-organising abilities of LCs in a bottom-up approach to the creation of ordered arrays of nano-particles, rather than the currently used, but self-limiting, top-down methodologies (eg nanolithography). In taking this approach, we will be able to prepare liquid-crystalline nano-particles with hierarchical hybrid structures with specific built-in functionality. The primary challenges in this programme are the rational design, synthesis (pure and/or with up-scaling) and characterization of super- and supra-molecular materials with in-built functionalities, which will self-organise and/or self-assemble in order to yield novel materials or states of matter of practical importance. Thus, the liquid-crystalline nano-particles will be designed, with the aid of simulations, in the form of a nano-particle (eg, silsesquioxanes, carbosilanes gold, silver, titania, viruses and spores etc) as the central scaffold, and where the scaffold may be multilayered. Surrounding the scaffold is a "liquid-crystalline coat", which may be derived from spherical, disc- or rod-like mesogenic units. The external coat may consist of one or more mesogenic layers, which in turn can accommodate further functional units (eg photochromic). The mesogenic coat, however, has the specific purpose of providing the self-organising, and ultimately self-assembling, vehicle for the core nano-particles. As noted although shown as spherical, the scaffolds do not necessary have to be spherical. Furthermore, they can be designed to have holes and cavities within their structures, thereby allowing formation of ion channels and binding sites.

Funding institution or country: EPSRC UK

2.1.67 Study of interactions induced by light and electron scattering in mesoscopic systems of interest in electronics and optics (tudio de las interacciones inducidas por el scattering de luz y electrones en sistemas mesoscópicos de interés en electrónica y óptica)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 30.12.1999

End date: 30.12.2002

2.1.68 Influence of exchange and dipolar interactions on the magnetization process of multiphase systems (Influencia de las interacciones de canje y dipolar en el proceso de imanación de sistemas multifásicos)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 01.01.1994

End date: 01.01.1997

2.1.69 Development of expression vectors for gram-positive bacteria of biotechnological interest (Desarrollo de vectores de expresión para bacterias gram-positivas de interés biotecnológico)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 01.01.2000

End date: 31.12.2000

2.1.70 Synthesis of iron nanoparticles doped with Co, Y and Pt by laser pyrolysis with application as diagnostic contrast agents in magnetic resonance imaging (Síntesis de nanopartículas de hierro dopadas con Co, Y y Pt por pirólisis láser con aplicación como agentes de contraste en diagnóstico por imagen de resonancia magnética)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 28.12.2000

End date: 27.12.2003

2.1.71 Preparation and characterization of magnetic nanoparticles for application as biosensors (Preparación y caracterización de nanopartículas magnéticas para su aplicación como biosensores)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 01.01.2000

End date: 31.12.2000

2.1.72 Development of magnetic particles suitable for use in immunoassays (Desarrollo de partículas magnéticas adecuadas para su utilización en inmunoensayos)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 19.07.1999

End date: 19.01.2001

2.1.73 Analysis of genes involved in forebrain development (Análisis de genes implicados en el desarrollo del cerebro anterior)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 01.01.2000

End date: 31.12.2000

2.1.74 New building materials and ceramic glassy residue from the manufacture of vitreous fibers (Nuevos materiales de construcción vítreos y vitrocerámicos a partir de residuos de la fabricación de fibras vítreas)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 28.12.2000

End date: 27.12.2003

2.1.75 Magnetoresistive sensors, magnetic oxides and metals: improving its properties by their composition and configuration (Sensores magnetorresistivos de óxidos y metales magnéticos: mejora de sus propiedades mediante su composición y configuración)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 28.12.2000

End date: 27.12.2003

2.1.76 Study of interactions induced by light and electron scattering in mesoscopic systems of interest in electronics and optics (Estudio de las interacciones inducidas por el scattering de luz y electrones en sistemas mesoscópicos de interés en electrónica y óptica)

Objective:

description available in Spanish

Funding institution or country: Spain

Start date: 30.12.1999

End date: 30.12.2002

3. Literature survey

This part of the review is mainly based on two novel handbooks: “Handbook of Nanotechnology”, 2nd edition, Bhushan editor, Springer, 2007; “Nanoparticle Technology Handbook”, edited by Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama, Elsevier, 2007, as mentioned before. Also some more useful handbook wrote in last 6 years taked into account, such as: “Handbook of nanoscience engineering and technology”, edited by William A. Goddard III, Donald W. Brenner, Sergey E. Lyshevski, Gerald J. Iafrate, 2002, CRC Press, 2002; “Introduction to Nanotechnology” Charles P., Jr. Poole, Frank J. Owens, Wiley, 2003;

Based on these literature and differents review papers published in last 3 – 5 yaers should be emphasize following areas in which nanoparticles are intensively studing, using and have strong applications perspectives, such as:

1	Photonic	21	Solar cell
2	Photonics	22	Solar cells
3	Light	23	Photovoltaic
4	emit	24	Opto
5	Emitter	25	Optoelectronic
6	Phosphor	39	Photo
7	Phosphore	26	Optoelectronics
8	Phosphors	27	OLED
9	Luminescence	28	Marker
10	Luminescent	29	Markers
11	Luminophore	30	Laser
12	Luminophor	31	Fiber
13	Luminophors	32	Waveguide
14	Display	33	Waveguides
15	Displays	34	Health
16	Matrix	35	Environment
17	Matrices	36	Safety
18	Label	37	Security
19	Labels	38	Communication
20	Solar		

Table 3: Keywords

Most of review articles which were used for this review focuse on properties of nanoparticles which can be used for different application areas mentioned above.

The following table gives an overview of the number of papers in the ScienceDirect database (http://www.sciencedirect.com/) concerning certain topics. Three different colors were used for indication of areas which have: blue color – above 20 publications from 2002 year to nowadays, yellow color – above 50 publications from 2002 year to nowadays, orange color – above 100 publications from 2002 year to nowadays. It gives possibility to determine most perspectives directions and application areas.

Keywords	Overall	2008	2007	2006	2005	2004	2003	2002
Nanoparticles	**15273**	3984	3347	2621	1965	1508	1077	772
Nanoparticles and photonic	**54**	12	15	13	5	3	5	1
Nanoparticles and photonics	14	5	2	1	3	3	-	-
Nanoparticles and light	**1154**	330	243	180	130	128	87	56
Nanoparticles and emit	**26**	9	3	4	5	3	1	2
Nanoparticles and emitter	18	1	1	10	3	1	1	1
Nanoparticles and phosphor	**102**	35	22	17	8	10	7	3
Nanoparticles and luminescence	**402**	115	69	81	49	35	32	21
Nanoparticles and luminescent	**169**	42	31	37	25	17	13	4
Nanoparticles and display	**227**	52	58	44	36	14	10	13
Nanoparticles and markers	**84**	19	25	14	13	7	3	3
Nanoparticles and solar cells	**120**	36	20	32	12	14	6	-
Nanoparticles and photovoltaic	**42**	16	7	9	2	7	1	-
Nanoparticles and opto	7	2	-	1	3	-	1	-
Nanoparticles and optoelectronic	**44**	13	6	11	4	5	4	1
Nanoparticles and optoelectronics	13	5	4	2	1	-	1	-
Nanoparticles and fibers	**222**	66	59	39	30	12	12	5
Nanoparticles and laser	**804**	171	178	148	92	92	58	65
Nanoparticles and LED	**295**	87	55	56	37	25	25	10
Nanoparticles and waveguide	19	4	2	6	3	2	-	2
Nanoparticles and health	**65**	27	14	11	4	4	3	2
Nanoparticles and environment	**350**	102	78	56	42	35	20	17
Nanoparticles and safety	**64**	27	17	7	5	3	3	2
Nanoparticles and security	3	1	2	-	-	-	-	-
Nanoparticles and communication	**27**	5	7	9	3	1	3	1

3.1. Literature background

3.1.1 Selected topic - phosphors

There are many famous working hypotheses as legends in various research fields. If famous one is chosen in the phosphor research field, it is that “luminescence efficiency of fine (nano)particle phosphor is low”. When the particle size of phosphor material was reduced, the luminescence efficiency decreased remarkably. The nanophosphors (phosphors based on nanoparticles) have large surface area with many defects than that of bulk phosphor [4]. This phenomenon appears especially in submicron-size phosphor. Therefore, bulk phosphor with several microns diameter has been usually used in many applications such as displays and lamps.

The synthesis method of a nanophosphor is classified into chemical synthesis methods such as a solution method and physical synthesis methods such as mechanical grinding. In the chemical synthesis method, the nanophosphor obtained at low temperature has a low crystallinity and high temperature annealing leads to the grain growth. In the physical method, the luminescence efficiency decreases by the formation of the surface defects with the mechanical contact. On the other hand,

many attempts to obtain a high-luminance nanophosphor were carried out by new synthesis method and the surface modification. In 1994, Bhargava et al. reported that the luminescence efficiency of surface-modified ZnS:Mn^{2+} nanophosphor increased with decrease of particle size [5]. The high-efficiency ZnS:Mn^{2+} nanophosphor has the following two characteristics. One is new surface modification by methacrylic acid. As indicated above, the surface of the nanophosphor has many defects and non-radiative relaxation is dominant at the phosphor surface. The other is new hypothesis that there is strong coupling between ZnS s–p electron and Mn^{2+} d electron in the nanophosphor by quantum effect. Bhargava claimed that the hypothesis was supported by observation of shorter luminescence lifetime (3.7 ns and 20.5 ns) of nanophosphor than the bulk one (1.8 ms). However, it is considered that the short lifetimes of the ZnS:Mn^{2+} nanophosphor are due to the structural defects at present [6–9].

Some interesting results about nanoparticles ZnS and CdS doped with Mn were obtained in [90] and related papers:

Several questions concerning the properties of the Mn^{2+} in *ZnS* and *CdS nano*crystals and role of the interactions between *Mn* ions and spin subsystems of *Mn* ions and free carriers were formulated. The results presented in these papers bring detailed answers to these questions:

- It was shown by structural investigations that the studied *nano*crystals are real quantum confinement objects with grains of the size about 10 *nm*.
- It was shown that two types of the *Mn* centers are observed in the *nano*crystals. It was concluded by ESR experiments:
- Well–defined the hyperfine structure was observed in ESR signal related to the isolated *Mn* ions located close to the surface of *nano*crystals;
- The broad ESR signal was observed which was related to the *Mn* ions with nearby other *Mn* ions located in a volume of nanocrystals.
- Then we demonstrated that the fast component of the photoluminescence decay is related to the $^4T_1$–$^6A_1$ Mn^{2+} intra–shell transition. It was confirmed by the results obtained from time–resolved photoluminescence investigations for all studied samples with different dimensionality and with different *Mn* fractions.
- Next we showed that the fast component of the photoluminescence decay is present in all studied samples with different dimensionality and with different *Mn* fractions, but only under the band–to–band excitation. This result we obtained from optical investigations, comparing photoluminescence, time–resolved photoluminescence and photoluminescence kinetics measured at different excitation conditions.
- Finally, we found that the fast component of the photoluminescence decay is not a feature of a low–dimensionality of the studied samples and is present in the samples with different dimensionality from 0D to 3D.
- There are two important mechanisms in *Mn* doped A_2B_6 semiconductor compounds which allow to relax the selection rules for Mn^{2+} intra–shell, namely:

- The *Mn–Mn* spin cross–relaxation mechanism. But only ~ 100 –150 μs component of the photoluminescence decay is related to recombination transitions at adjacent *Mn* ions coupled by an exchange interaction. As the consequence this mechanism cannot account for the fast component of the Mn^{2+} photoluminescence decay;
- The strong *Mn* ion–free carrier interaction is demonstrated. The ~ 100 –800 *ns* component of the photoluminescence decay in *ZnS: Mn nano*crystals is related to this interaction.
- The spin–flip interactions between *Mn* ions and free carriers are responsible for the fast component of the photoluminescence kinetics in *Mn* doped A_2B_6 semiconductor compounds.

Concluding, were found that:

- The theory proposed by Bhargava and coworkers is wrong.
- The statement by the Meijerink that the fast component is not related to the Mn^{2+} photoluminescence is wrong.
- Efficiency of the Mn^{2+} intra–shell emission is strongly enhanced in *nano*crystals of small size by the mechanism explained above.

The most important conclusion of this thesis is that doped nanocrystals can be efficient light emitters and thus can find applications in optoelectronics as a new class of phosphors and in biology and medicine as fluorescence labels.

Apart from the quantum effect, the former surface modification technique by the organic materials became a useful processing method for the nanophosphors. Isobe et al. reported that emission intensity of ZnS:Mn^{2+} nanophosphor increased with the surface modification of carboxylic acid [10–12]. This is not only a capping effect of surface defects but also efficient energy transfer process from the carboxylic acid to the Mn^{2+} ion.

However, these nanophosphors have a semiconducting character even if they contain the localized emission ions such as Mn^{2+}. The mainstreams of current phosphor are the oxide phosphors including the rare earth (RE) ions as the emission center because of high luminous efficiency. When rare earth phosphor is activated by small-energy blue and near-UV light, light absorption and emission occur around the emission ions. The semiconducting character of oxide host lattice was not reflected at all by the photoluminescence. There was the 4f orbital of rare earths located near an atomic nucleus and comparatively covered by an outside 5s orbital. Therefore, the electron of 4f orbital is hard to take a quantum effect for the nanoparticles. Recent results of rare earths doped nanophosphors are reviewed below.

In 2000, Park et al. reported synthesis of $Y_3Al_5O_{12}$:Tb nanosize phosphor (25–45 nm) from nitric acid solution by sol–gel method [13]. This sample with heat treatment until 800^{o}C was amorphous and the excitation spectrum was different from that of the sample with high-temperature heating. From decay time and excitation spectrum, they claimed that the nanophosphor sample was useful for plasma display. Hasse et al. synthesized nanosize YVO_4 and $LaPO_4$ by the hydrothermal technique. The sample was colloidal solution and separated by centrifugation. The YVO_4 nanophosphor has the same crystal structure as its bulk sample. On the other hand, monazite structure is observed for the nano

$LaPO_4$. The particle size depends on pH value of the solution and other reaction parameters. In alkaline solution, the sample was fine particles from 10 to 50 nm. In acid solution, morphology of the sample was nanofiber [14, 15].

In 2001, Konrad synthesized 10 nm sized cubic yttria phosphor by chemical vapor technique [16]. The crystallite size increased to 20 and 50 nm upon heating at 900 and 1100^{o}C, respectively, in air for 5 h. Depending on the particle size, a broadening of absorption edge and blue shift of photoluminescence spectra were found. The change of spectra was explained by the change of a configurational coordinate diagram.

In 2002, Lu et al. reported synthesis of small-size LED phosphor $Y_3Al_5O_{12}:Ce^{3+}$ by sol–gel method [17]. Raw material aqueous solution reacts with urea in the presence of polyvinyl alcohol at 150^{o}C. Gelling was achieved at 250^{o}C. Although the heat treatment at 800–1100^{o}C yielded the nanosize phosphor, the emission intensity was remarkably low compared with the conventional bulk sample synthesized at 1450^{o}C.

In 2003, Pan et al. reported the synthesis of a red $CaTiO_3:Pr^{3+}$ nanophosphor from polymer precursor [18]. The nanophosphor powder (10 nm) was obtained by heating at 600^{o}C for 5 h. Higher temperature and longer heating time increased particle size of the phosphors and photoluminescence intensity. The emission spectrum is comparable with the conventional phosphor synthesized by the solid-state reaction. Wang et al. synthesized Y_2O_3:Tb nanophosphor by the combustion synthesis [19]. The particle size estimated by XRD pattern was 35–70 nm. It is an interesting feature that the emission intensity is increased by irradiating the 250 nm UV light. It is considered by ESR measurement that the behavior is due to the passivation of the dangling bond on the surface. Tissue et al. reported on the vapor-phase synthesis of Y_2O_3:Eu nanophosphor [20]. By CO_2 laser heating under 10 and 400 Torrnitrogen, 5 and 12 nm nanophosphor samples were obtained, respectively. The particle size grew up to about twice by annealing for a long time at 800^{o}C. The crystal structure of 5 nm particle changed from mixed phase to cubic single phase and 13 nm particle did not change the monoclinic structure. He et al. reported synthesis of Y_2O_3:Eu nanophosphor by wet chemical synthesis [21]. Chloride solution of yttrium and europium was mixed with butanol, which acted as a surfactant. The nanophosphor was obtained by adding sodium carbonate to the solution and heat treatment at 800^{o}C. When butanol was added, the sample of a particle size was smaller than that of the non-surfactant sample.

In 2004, Chander et al. synthesized the nanocrystal of a long-persistence phosphor $SrAl_2O_4$:Eu, Dy by modified combustion method [22]. The nitrate solution of starting materials was mixed with urea and boric acid heated from 400 to 600^{o}C. The nanophosphor sample of 50 nm or less was obtained after combustion reaction. However, the decay time is shorter than that of the sample synthesized by a conventional solid-phase reaction. Although Peng et al. also have synthesized the 25 nm phosphor by the combustion synthesis method [23], the afterglow time was still shorter that of the conventional ones.

Summarizing these, it has been observed that “luminescence efficiency of fine(nano)particle phosphor is low”. Does the nanophosphor have practical use? White LED application is one of the promising candidates. Rayleigh scattering decreases in proportion to the sixth power of particle size. Therefore,

the nanoparticles dispersed in resins scatter light less vigorously and become transparent. Rare earth complex phosphors are dispersed in the plastics [24]. Fukui et al. reported nanocluster phosphors containing the rare earth ions [25]. Isobe et al. reported the transparent phosphor sheet of nano ZnS:Mn and $Y_3Al_5O_{12}$:Ce [26].

On the other hand, there are some trials to improve the luminescence efficiency of the nanophosphors by precise process control. Nishisu et al. reported the synthesis of 300–400 nm Y_2O_3:Eu spherical phosphor by uniform coprecipitation method [24]. The luminance of the nanophosphor under 147 nm excitation is comparable to that of the conventional sample synthesized at high temperature. The spherical phosphor could maintain almost a monodispersed state. Kakihana et al. reported synthesis of high-luminance 200–300 nm Y_2O_2S:Eu phosphor by complex homogeneous precipitation method [25]. Masui et al. synthesized new layered $Gd_2O_2CO_3$:xTb^{3+} green phosphor in 0.476 Li_2CO_3–0.270 Na_2CO_3–0.254 K_2CO_3 flux. This nanophosphor shows higher luminance than that of commercial lamp phosphor [26].

3.1.2 Selected topic - luminophors

The rapidly increasing price of energy sources is a strong motivation for introduction of more efficient generation of light sources for an overhead illumination. This is because, the most widely used incandescent lamps (their amount is estimated to be about 9 billion items in the world) have extremely low efficiency of only about 3-4 percent.

If replaced by new generations of more efficient lamps huge financial savings (80 billion USD per year or even more) will result. Moreover, reduced energy consumption will also result in reduced emission of CO_2 gas to the atmosphere. The latter is crucial factor considering correlation between emission of CO_2 gas and effects of a global warming.

At present there are two alternative replacements of incandescent lamps – compact fluorescent lamps (CFLs) and GaN-based white light emitting diodes (w-LEDs). These modern light sources require luminophors to convert UV (in CFLs) or violet/blue emission (in w-LEDs) to a visible emission.

Luminophors are very well developed for the use in fluorescence lamps. Thus, the currently available phosphors are optimized for down-conversion of the two main UV emission lines of mercury vapors (55 % at 254 nm and 9 % at 185 nm).

Unfortunately, light conversion efficiency is very high only if we count number of absorbed and emitted photons, i.e., it is 100 % if absorption of one UV photon results in emission of one visible photon. If we consider energy conversion efficiency, the present phosphors are far from being highly efficient. The energy conversion efficiency is usually below 50 %.

Also for w-LEDs it is important to develop more efficient phosphors. This is because the first generation of commercialized w-LEDs is based on the concept of hybrid LEDs. In this case the 400 nm blue/violet emission from InGaN quantum wells is mixed with a yellow emission of YAG:Ce phosphor (excited by a primary emission of the LED) to achieve an impression of a white light.

Presently used phosphors in CFLs and w-LEDs are activated with RE and/or TM ions. Such doping enables to achieve light emission in a given spectral region, which has some advantages (for example temperature insensitivity), but also imposes some limitations.

Especially RE ions show very attractive properties for applications as emission activators. Their 4f-4f transitions result in sharp, atomic-like photoluminescence (PL) bands, which are temperature and host insensitive.

As mentioned above use of intra-shell transitions of TM or RE ions imposes also some limitations. In particular, the intra-shell 4f-4f transitions of RE ions are difficult to excite under the host excitation, which is due to the screening of electrons from the 4f shell by electrons in the external and filled 5s and 5p shells. In the consequence, host excitation is inefficient and 4f-4f transitions are excited only upon 4f-5d or charge transfer (CT) excitation (see [4] and references given there). Moreover, the 4f-4f transitions are parity forbidden and thus show rather low rates of radiative decay [4].

The above imposes serious limitations on host materials for RE ions. Their band gap must be large enough to allow for either 4f-5d or CT excitation. Moreover, we must select materials in which one of these excitation processes exactly fits to the energy of emission of mercury vapors or LED emission.

These limitations could be avoided if RE, TM emission could be excited by band-to-band excitation of the host material [5].

3.1.3 Selected topic - solar cells

Today, due to the increasing global demands on energy, it is imperative that a renewable energy source be determined, that is cost effective and reliable. Solar cell technology has shown much promise over the years to replace the use of fossil fuels. However, with the current technology, the cost per watt is rather high due to the high cost of manufacturing silicon-based solar cells. The cost per watt can be lowered two ways. Lower the manufacturing cost, or increase the amount of power output for the same cost. The latter is related to efficiency of the device. In other words, the efficiency is the amount of energy output vs. the amount of energy coming in. In Figure 1, we can see the chronology of the efficiencies for different types of solar cell technology.

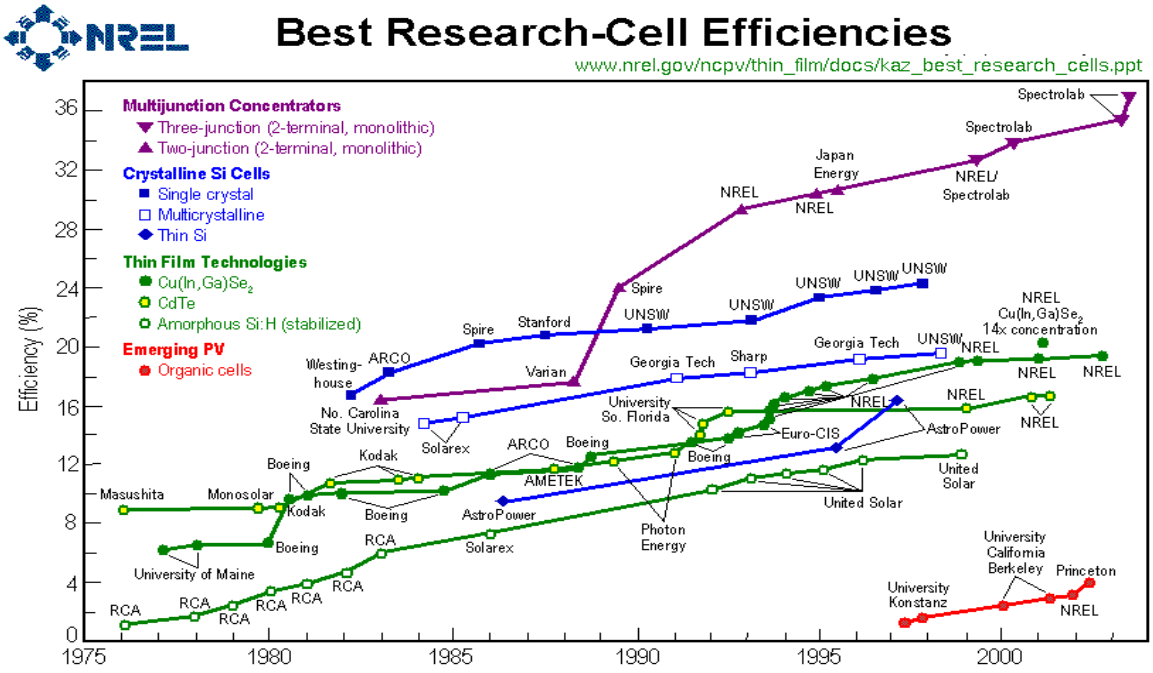

Figure 2: Chronology of solar cell efficiency according to different methodology [1]

The current best is around thirty-six percent. Clearly, a more efficient way of converting sunlight into energy needs to be researched in order to make solar cell technology economically viable. Most traditional solar cells rely on a semiconductor (typically silicon) for both light absorption, and charge transport. A fairly new, promising method separates these functions. Organic dyes (dye sensitizers), which are sensitive to light, can absorb a broader range of the sun's spectrum. When a photon hits the dye, an electron in the dye becomes excited and is injected into the conduction band of a nanoparticles semiconductor oxide, where charge transport takes place. Electrons lost from the dye, are regenerated by a redox electrolyte, usually an inorganic solvent. These components are sandwiched between substrates of transparent conducting oxide. This configuration has shown promise in the laboratory [2]. It appears that the enormous surface area per unit volume of nanoparticles can increase the photon to current ratio. Future studies are focusing on controlling the order and shape of the particles to increase the photon to current ratio even further. Although the mechanisms and processes of the dye sensitizer, electrolyte, and conducting substrate are worthy of further study, the focus of this paper will be to review the material properties of TiO_2 nanoparticles, and explore the mechanisms that make it a promising material in improving the efficiency of dye sensitized solar cells (DSC).A brief review of the operational theory will be followed by a discussion of the nanoparticles oxide layer.

3.1.4 Selected topic - optic gas sensors

Zirconium oxide as the host material has a direct wide band gap of about 5.8 eV (near 212 nm) and low phonon frequencies, which make this material a suitable host for RE ions, what leads to several other than optoelectronic applications. For example, it is used in jet engines to determine oxygen content in exhaust gases, to measure pH in high-temperature water, as membranes for high temperature solid oxide fuel cells, as a component of waveguides, laser mirrors and optical filters, as well as for electrolytes or insulators in microelectronic devices.

For zirconia optical gas sensors, a recently discovered phenomenon of dependence of luminescence intensity on oxygen partial pressure creates an opportunity for new applications [91, 92].

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4. Actual applications

A search of the European Patent Database (http://ep.espacenet.com) was conducted. As for papers, there was no distinction made between patents filed in the European Union or elsewhere in the world. The search was performed for patents filed up to 2008 (nowadays). Several search terms were applied for more detailed analysis in the database. All used terms strongly correlated with the nanoparticles application areas.

The search terms and results are listed in the following table.

Three different colors were used for indication of areas which have: blue color – above 20 patents to nowadays, yellow color – above 50 patents to nowadays, orange color – above 100 patents to nowadays. It gives possibility to confirm right choice of most intensively developing directions and application areas.

Keywords	# of hits (Worldwide)
Nanoparticles	**4061**
Nanoparticles and photonic	4
Nanoparticles and light	**115**
Nanoparticles and emit	**22**
Nanoparticles and emitter	3
Nanoparticles and phosphor	3
Nanoparticles and luminescence	13
Nanoparticles and luminescent	**31**
Nanoparticles and display	**20**
Nanoparticles and markers	4
Nanoparticles and solar cell	3
Nanoparticles and solar cells	3
Nanoparticles and photovoltaic	10
Nanoparticles and opto	1
Nanoparticles and optoelectronic	4
Nanoparticles and optoelectronics	0
Nanoparticles and fibers	**22**
Nanoparticles and laser	**48**
Nanoparticles and LED	1
Nanoparticles and health	7
Nanoparticles and biomedical applications	0
Nanoparticles and environment	25
Nanoparticles and safety	3
Nanoparticles and security	8
Nanoparticles and communication	3

Using the results of the patent search, a few patents were selected to be presented to exemplify possible uses of nanotubes for the different sectors that were investigated.

4.1. Information and Communications Technology

4.1.1 Method of using nanoparticles to fabricate an emitting layer of an optical communication light source on a substrate

Abstract of US2007161134

A method of using nanoparticles to fabricate an emitting layer of an optical communication light source on a substrate is proposed, in which a host capable of reacting with unstable ions on the surface of a rare earth ions nanomaterial is used as a carrier of nanoparticles to make the rare earth ions nanomaterial release rare earth ions, thereby forming an emitting layer that can be excited by an external current or light source to emit light.

4.1.2 Method for the manufacture of patterned micro-and nanoparticles and use of such particles in the assembly of nanoscale architectures in solution

Abstract of US2005242035

A method for the manufacture of patterned microparticles comprises immobilizing microparticles, including nanoparticles, to be patterned on a surface of a porous membrane, causing an inorganic or organic coating material which can bind to exposed surfaces of said microparticles, and which can permeate through the pores of said membrane, to flow relative to said immobilized microparticles, and removing the microparticles from the membrane following binding of said coating material. The method enables one to prepare a wide range of anisotropically-modified patterned microparticles, including microparticles patterned with nanoparticles or a biomolecular material such as DNA and protein. The patterned microparticles produced can be used in wide range of applications in health, information and communication, and sustainable environment such as shelter, clothing, energy, food, transport and security.

4.2. Environment

4.2.1 Use of derivatized nanoparticles to minimize growth of micro-organisms in hot filled drinks

Abstract of US2005224417

A method and article for removing a selected metal-ion from a solution. The method included providing a container for holding a liquid, the container having an internal surface having a metal-ion sequestering agent and antimicrobial agent for inhibiting growth of microbes in the liquid, filling the container with the liquid in an open environment, closing the container with the liquid contained therein, and shipping the container for use of the liquid without any or reduced further processing of the container containing the liquid.

4.2.2 Reactive nanoparticles as destructive adsorbents for biological and chemical contamination

Abstract of US6417423

Compositions and methods for destroying biological agents and toxins such as Aflatoxins, Botulinum toxins, and Clostridium perfrigens toxins are provided wherein the substance to be destroyed is contacted with a finely divided metal oxide nanocrystals. In various embodiments, the metal oxide nanocrystals have reactive atoms stabilized on their surfaces, species adsorbed on their surfaces, or are coated with a second metal oxide. The desired metal oxide nanocrystals can be pressed into pellets for use when a powder is not feasible. The methods of the invention are safe for humans, equipment, and the environment, and provide for decontamination of warfare sites, of equipment exposed to the contaminant, and of soil, water and air having been exposed to the contaminant. Preferred metal oxides for the methods include MgO, CaO, TiO_2, ZrO_2, FeO, V_2O_5, Mn_2O_3, Fe_2O_3, NiO, CuO, Al_2O_3, ZnO and mixtures thereof. Preferred reactive atoms stabilized on the surfaces of the metal oxide nanocrystals include halogens and Group I metals, and preferred species stabilized on the surfaces of the metal oxide nanocrystals include SO_2, NO_2 and ozone.

4.3. Health and well-being (human)

4.3.1 Nanoparticles for Imaging Atherosclerotic Plaque

Abstract of US2008206150

Atherosclerosis is an inflammatory disease of the arterial walls and represents a significant health problem in developed nations. Described is a targeted Magnetic Resonance Imaging (MRI) contrast agent for in vivo imaging of early stage atherosclerosis. Early plaque development is characterized by the influx of macrophages, which express a class of surface receptors known collectively as the scavenger receptors (SR). The macrophage scavenger receptor class A (SRA) is highly expressed during early atherosclerosis. The macrophage SRA therefore presents itself as an ideal target for labeling of lesion formation. By coupling a known ligand for the scavenger receptor, dextran sulfate, to a MRI contrast agent, early plaque formation can be detected in vivo. Targeted MR contrast agents offer a unique opportunity to visualize early plaque development in vivo with high sensitivity and resolution, allowing or early diagnosis and treatment of atherosclerosis.

4.3.2 Nanoparticles Comprising an Intracellular Targeting Element and Preparation and Use Thereof

Abstract of US2007292353

The present invention relates to novel activatable particles which can be used in the health field. More specifically, the invention relates to composite particles comprising an intracellular targeting element, which can generate a response when excited, and to the uses thereof in the health field, particularly in relation to human health. The inventive particles comprise a nucleus comprising at least one inorganic

and optionally one or more other organic compound(s) and which can be activated in vivo, in order to label or alter cells, tissues or organs. The invention also relates to methods for producing such particles, as well as pharmaceutical and diagnostic compositions containing same.

4.4. Safety and security

4.4.1 Catalytically active unit, useful e.g. in the production of safety materials, comprises a substrate comprising polymer particles, preferably nanoparticles

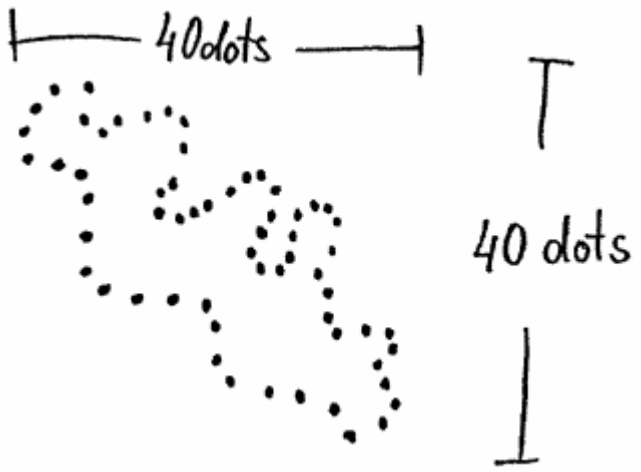
Abstract of DE202005013330U

Catalytically active unit (I) comprises a substrate, where the catalytically active unit and/or the substrate comprising polymer particle, preferably polymeric nanoparticles, and/or that the substrate is exposed to the polymer particles, which contains at least one catalytically active component. Independent claims are included for: (1) safety materials of all kinds, manufactured by using a catalytically active unit and/or exhibiting a catalytic unit; and (2) filters and filter materials of all kinds, manufactured by using catalytically active unit and/or exhibiting a catalytic unit.

4.4.2 Security printing liquid and method using nanoparticles

Abstract of US2005068395

The invention relates to a printing method according to which, during the printing process, one or more narrow nozzles eject a printing liquid, and to a printing liquid suitable for such a method. The invention is particularly suitable for forgery-proof printing on papers or articles. According to the invention, the printing liquid contains nanoparticles that can be induced to fluoresce or phosphoresce. Said nanoparticles are small crystalline particles that can be induced to fluoresce or phosphoresce on their own or when mixed with dopants. Individual dots (10, 12) can be printed by means of a printing liquid that contains said nanoparticles. Due to their small size of from 1 to 1000 nanometers, preferably in the range of 300 nanometers or even much smaller depending on nozzle diameter, there is no risk of very narrow ink jet nozzles getting plugged. The induction and fluorescence emission frequency ranges are narrow-band so that for a security control of the print the respective wavelength-specific induction or detection is required, thereby increasing protection against forgery.



5. Barriers

5.1. Summary

A principal technical barrier in many applications is accurate control of size and morphology of particles. In some cases adequate functionalization will also represent a barrier. In both cases scaling these capabilities, once achieved, to reliably, quality controlled, industrial production represents a challenge, and one that Europe has traditionally often had difficulty meeting. Along with this concern about lack of process industry thinking, several concerns about environmental impact of the processes they are working with are expressed by experts. Huge amounts of waste can be foreseen, which would contain nanoparticles in a free state that can interfere with human and animal life. This aspect is not addressed sufficiently, as many others have pointed out before. Expanding this concern to include the increasing application of nanoparticles directly to the skin, we can recognize a barrier that may arise in future - public hostility based on the discovery, too late, of ill effects on health. This argues for early research and openness. In terms of costs, the barrier cannot be generalized. Most applications outside of bulk structural composites are relatively price insensitive. On the other hand, it is clear that the lack of industrialisation of processes not only results in variations in quality, but still also in excessive costs (e.g. polymeric nanocomposites). Improving the production yield of nanoparticles would assist with barriers such as cost. Since size and size distribution is important for the activity of nanoparticles, understanding the optimum ranges of these characteristics is an essential first step. Production yield of specific active sizes and control of the size distribution would reduce waste and costs. An effective and cheap way to achieve this would be post-selection using specialist filter systems. Technologies exist to achieve this. Materials that are not within specification could be recycled. Development of on-line instrumentation capable of measuring size and size distribution would be beneficial in overcoming this barrier. Again technologies exist. On-line instrumentation would improve product consistency and performance. Yields can be increased by preventing agglomeration and preventing unwanted chemical reactions on highly reactive particles during the production

process. What is remarkable is the view of experts on the availability of infrastructure to perform their typical nanotechnology-related activities. Most of them seem content with what they have access to, with only one third stating that they encounter limitations in this area. The lack of pilot-plant-like facilities does present a limitation to the speed with which science could reach the markets in applications already validated on a small scale.

5.2. Specific barriers

Reportedly, it is difficult to see great potential for the extensive mass production of any form of nanoparticle on a scale comparable to, say, carbon black for use in car tyres, though widespread structural nanoclay use cannot be ruled out if sufficient price reductions can be achieved (the main barrier). A wide variety of niche applications could generate significant demand but the greatest value will be in the stage of incorporation of the nanoparticles into final materials. Many of these final materials will make quite specific demands on the nature of the nanoparticle, which suggests that the most profitable scenarios for nanoparticles based products involve relatively low-volume, specialist materials. It follows that refinement of production processes with an eye to increased control over size, structure etc. represent a promising avenue to pursue, probably more promising than simple scalability of production, i.e. mastery rather than economy. This fact makes the landscape open for smaller operators such as start-ups and SMEs and identifies the chief technical barrier in nanoparticle production as control of size and morphology.

Fabrication related barriers:

- Manufacturing of small nanoparticles with extremely (even atomically) precise size and crystal orientation.
- Reproducible manufacturing and control of size distribution of small nanoparticles with precise size and crystal orientation.

No particular barriers in the area of nanoparticles' functionalisation have been identified - it is more a case that functionalisation of nanoparticles is a fairly young field with much learning still to be done.

Regarding usage of nanoparticles in biomedical applications, e.g. cellular imaging, the critical value in these applications is the capability that is achieved, which is often novel. Nanoparticles are thus simply a component in a system that is dependent on many factors for success - barriers, beyond those of obtaining fine control of size and structure, are often not connected with the nanoparticles themselves.

Health related barriers:

- toxicity aspects of applications with free nanoparticles for the human, organisms and the environment due to
  - size
  - used chemical elements

6. Trends and future applications

After analyzing information presented above could be conclude that, the ***main applications*** of nanoparticles are new types of ***optic, phosphores and similar nano-electro-optic devices, also new type flexible displays and visualization devices***. In all of those cases, papers on the topic are increasingly published (confer section II), and also, a significant number of patents has been filed in these areas. Devices based on nanoparticles are on market entry level (for example, last news shown that flexible displays based on doped nanoparticles were presented). It means that in near future (1 year) this material will be widely used for production of electronic devices for industrials and end users applications.

The ***ICT sector*** should especially profit from smaller feature sizes, optic, electronic and electric properties of nanoparticles. Analysing of research, articles and patents shown that optical and display devices beased on the first to hit the market. Also should be emphasize that light emitter devices also white phosphores will be widely used for production of electronic devices for industrials and end users applications in near future (during 1 year).

The ***environmental sector*** currently doesn't benefit much. The only application suggested is in the improvement of solar cells and photovoltaic devices, for which also a patent has been filed. However, there is still much development to be performed at this stage to reach the point of application.

The ***health and medical sector*** is the one that will largely profit from new types of enhanced markers for diagnosis and treatment, generally visualization applications are expected from nanoparticles in this sector, due to properties of this material it will have typical medical applications, such as cell tracking, cell labelling, sensing cellular behaviour, and drug and biomolecule delivery.

The ***safety and security sector*** might also profit from new types of sensors and labeling systems. The impact on the industry for the next few years seems rather large.

Conclusion: Information presented above shows that nanoparticles will be used in all sectors: ICT, health and medical sectors, safety and security sectors for industry and end user applications. In near future (1–2 years), materials and devices based on nanoparticles will putting down into mass ICT production.

7. 7. Information sheets on relevant photonic materials

Based on the results obtained in parts 2, 3 and 4, about 20 to 30 relevant photonic materials will be identified in each category, which have a high potential for future industrial applications. In this part it is crucial to explain the advantages of these photonic materials and why these photonic materials have a high potential for future applications or what is the scientific / technological breakthrough achieved. E.g. it is necessary to explain which property of the material results from nanosize / is of interest / has been improved (in regard to state-of-the-art) and also it is important to mention the problems, which are still to be overcome.

These materials will be incorporated into the database.

- For each material identified with a high potential, an information sheet/table has to be filled in (cf. template which is developed by the roadmap experts), with :
- its relevant properties (optical, electrical, …) which are of interest / have been improved,
- industrial applications (actual and future),
- production process,
- phase of development.

8. Imprint

This report has the objective to give an overview on the recent scientific research and development undertaken in the field of optical fibres and has not the goal to be exhaustive.

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