Full Proposal for a new COST Action

Polymer Nanocomposites with novel functional and structural properties

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DRAFT
MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

Polymer Nanocomposites with novel functional and structural properties

The signatories to this "Memorandum of Understanding", declaring their common intention to participate in the concerted Action referred to above and described in the "technical Annex to the Memorandum", have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 299/06 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Signatories are fully aware of.

2. The main objective of the Action is ***to form a European-wide scientific and technology knowledge platform on the topic of nanocomposite materials in order to advance the R&D, the use and exploitation of these innovative materials in Europe with a special focus on SME.***

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at Euro ***25*** million in ***2007*** prices.

4. The Memorandum of Understanding will take effect on being signed by at least five Signatories.

5. The Memorandum of Understanding will remain in force for a period of ***4*** years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

COST ACTION

Polymer Nanocomposites with novel functional and structural properties
Acronym: PNCM (Polymer Nanocomposite Materials)

A. ABSTRACT AND KEYWORDS

Polymer materials reinforced with nanoscale components are adding new dimensions to composite materials and major improvements in functional and structural properties are within reach. Such polymer nanocomposites are of great importance for a multitude of industrial uses in automotive, health care, electronics, aerospace, mechanical engineering, construction and building and consumer products with great economical and ecological benefits. This new technology constitutes a driving force for new employment opportunities in Europe. In order to accelerate growth of this promising new field of technology, taking into account sustainability, safety and health, a COST activity is considered the most appropriate way of cooperation to facilitate further its commercial exploitation in Europe. Already 55 partners have shown interest in this Action of which are 19 companies (mainly SME). The interdisciplinary scientific technical COST network will create valuable links for the European research area, and will strengthen the approach to build scientific excellence in this field. It will stimulate European cooperation, technology transfer and will create valuable input from nationally funded projects for European industry with special focus on SME´s.

Keywords: nanoparticles, nanocomposites, polymer matrix, properties, processing

B. BACKGROUND

B.1. General Background

Polymer nanocomposites are blends of different polymer matrices with nanometre sized functional particles. The properties of such nanocomposites are remarkably different compared to conventionally filled polymers. These property improvements concern volume properties (modulus, strength), surface properties (hardness, abrasion resistance, and surface energy), dimensional stability, thermal stability, as well as e.g. photocatalytic, optical and electrical properties. These nanocomposites exhibit also reduced permeability and improved chemical stability (UV resistance). The incorporation of only a few percent of nanosized particles can make both dramatic property changes and formerly unachievable property combinations possible.
Despite such property improvements and despite a large amount of research being undertaken in industry, research laboratories and universities, nanocomposites is still a nascent field of materials science and technology which is in the development stage with tremendous potential growth prospects in the future.

To improve this situation in Europe, and making the best out of what is available requires top level research but also intensified networking and concentration in order to form a critical mass of expertise. This COST Action will be innovative in that sense that this critical mass of expertise can be formed targeting many different areas of application and facilitating the fast exchange of information between different areas of expertise and applications.

B.2. Current state of knowledge

The use of inorganic nanoparticles in polymers is a widely investigated area of research. The nanoparticles under consideration range from natural nanosized material, such as layered silicates, to synthetic nanoparticles such as aerosil or carbon nanotubes. Depending on which properties are to be altered, nanoparticles are chosen for their chemical composition, their size and their morphology. For example, platelet shaped layered silicates are widely used in the improvement of mechanical properties, in the decrease of gas permeability and as additives for flame retardency.

The surface of the particles is in most cases not compatible with the desired polymers. Therefore, most of the current research efforts are conducted into the modification of the particle surfaces. Different methods of surface modification are under consideration, such as plasma modification or, more widely used, the modification by wet chemical processing. The modification of the surfaces is needed to achieve a good wetting of the nanoparticles. Without this modification a good dispersion is not possible in most cases. Furthermore, for some polymeric systems, such as duromers, a reaction bonding to the surface is sometimes needed. This can be achieved by the respective surface modification.

The incorporation of the nanoparticles can be done by various methods. This includes the grafting of polymers on the surface of the nanoparticles during the synthesis of the polymers, the mixing of modified nanoparticles into the liquid polymer matrix during melt processing, and by dispersing the nanoparticles in polymer solutions. The solvents then are evaporated and a homogeneous dispersion evolves.

Sometimes also reactive solvents are used to avoid the evaporation process. The use of nanoparticles depends on the desired application. For flame retardency an addition of oxidising material, as the above mentioned layered silicates, is sensible. For health care applications, such as biozidic polymers, silver and titanium oxide nanoparticles are used. Electrical conductivity can be achieved by incorporating nano silver or carbon nanotubes. Due to the high number of combinations of nanoparticles and polymers, no universal solution is currently possible. Today much effort is put into the realization of specific solutions for single applications.

The commercialisation of polymeric nanocomposites has just recently begun. Some applications around nanocomposites center on the improvement of the flame retardency in electronics, building materials, automotive and aerospace applications. The addition of nanosized layered silicates leads to an improvement of the fire resistance due to synergistic effects with halogen-free flame retardants. Such materials are used e.g. for cables in automotive and aerospace applications. The use of nanoparticles leads to a reduction in costs due to savings in other flame retardant constituents. Furthermore, the use of nanoparticles reduces the health risk in the case of fire, as no halogen containing flame retardants are needed anymore. These improvements are providing new applications in indoor building materials, as isolation foams, paints or structural elements, where recent EU standards force materials producers to improve the fire reaction and resistance.

Also the use of silver nanoparticles is under commercialisation, for example in coatings for medical instruments or stents. Another application of silver nanoparticles is the incorporation into household goods, e.g. in refrigerators to prevent growth of hazardous micro organisms on the refrigerator walls. Products based on nanocomposites which have already entered the market are mainly in automotive (polymers for fuel lines and flame retardants) and packaging (gaseous barriers for food packaging). Many new products are presently being developed for electronics (capacitors, solid electrodes for batteries, nanoscale switches and sensors).

Other commercialisations of nanocomposites are slowly following, but are often hindered by the lack of understanding of the processing and the effects of the nanoparticles in polymeric matrices.

Nanoclays were the start of PNCM`s in the 1990`s when Toyota for the first time used Nylon 6 nanoclay nanocomposites to produce timing belt covers. Other automotive applications appeared quickly, e.g. by Mitsubishi (Nylon 6 nanoclay engine covers) and by General Motors in clay polyolefin PNCM`s for step assists in the GMC-Safari and Chevrolet Astro van. The most promising and already widely used applications are in packaging making use of the improved barrier properties of PNCM.

Globally the annual growth rates in the field of PNCM are around 20 % and have reached 200 million € in 2005. It is expected that the global market potential will already exceed 1 billion € in 2011. The US is presently the world leader in nanocomposites and nanotechnology research with over 3 billion € of funding (2006) and over 400 actors in this field (industry, spin offs, university labs, research centres). The effort of Europe in this promising field is approximately half that of the USA (funding of 1.5 billion € and 180 actors). Japan is also pursuing this field very strongly having approximately 100 actors.

Europe had a late start in this area of technology compared to Japan and the total efforts are still lagging behind those of the USA. It is therefore not surprising that the majority of composites making use of the superior properties of PNCM-technology are presently being produced and marketed by non European companies.

B.3. Reasons for the Action

Large established companies, e.g. Bayer Materials Science, BASF, Degussa, 3M, DuPont, Honeywell, Toyota, Mitsubishi, are acting as global players and are likely being able to form a critical mass of expertise, know-how and scientific networks by themselves. Nanocomposites and nanotechnologies are “disruptive technologies” that will open up new exciting opportunities of growth, for SME´s and spin offs. Accordingly more than 1200 spin offs have appeared globally in the new field of nanocomposites. Since small companies usually do not have the power and critical mass to form a sufficient knowledge base and create a scientific network themselves, a COST Action on this topic will be the most appropriate and efficient way to strengthen this emerging field. Such a COST network will support SME´s, ensuring that they have the highest level of scientific know-how available for fast and efficient product development in the global race to exploit this enormous market potential. The expertise from leading European scientists & engineers in combination with the experience of industrial companies will ensure a rapid and efficient transfer of knowledge and know-how to marketable innovations. This COST action will address therefore both economical/societal as well scientific/technical needs of the European society.

B.4. Complementarity with other Research Programmes

This COST Action is complementary to a number of national and EU-wide research activities on nanocomposites. However, the topics in such nanocomposite research projects are focussed on distinct applications of PNCM or on special properties or special technology steps of PNCM`s.

This COST Action is unique in the sense that it will give the opportunity for a European wide networking and exchange of information regardless of applications and technologies of PNCM. Some of the identified R&D programmes on the topic of PNCM are listed in section

E3. The already available expertise created by nationally funded R&D projects on the topic of PNCM, or by R&D on a European level, will provide for this COST Action the right kind of geographically widespread know-how to be networked effectively.

C. OBJECTIVES AND BENEFITS

C.1. Main primary objectives

The main objective of this COST Action is to form a European-wide scientific and technology knowledge platform on the topic of nanocomposite materials in order to advance the R&D, the use, and the exploitation of these innovative materials in Europe with a special focus on SME´s. This covers the full spectrum from raw materials production, primary and further processing to semi-finished and final products, also covering health and environmental aspects.

C.2. Secondary objectives

Successful technical development of PNCM has to overcome the following various barriers in order that commercial products can benefit from the European market potential of PNCM. The identified current barriers are in technology, regulation, standardisation, trained workforce and technology transfer. In order to fulfil the above indicated main primary objectives of this COST Action the following secondary objectives for overcoming those barriers have been identified:

Secondary objective in technology

- Improve the presently inadequate characterisation and measurement tools for
  - Online monitoring
  - Process control of nanoscale features

- Improve the presently insufficient understanding of composition/ structure/processing/property relationships by
  - Modelling and simulation tools
  - Linking nanoscale structures to macroscopic functional properties

- Diminish the lack of stable industrial processes for uniform dispersion and exfoliation of nanoparticles in a polymer matrix
- Get better understanding and more information of the ultimate obtainable application properties

Secondary objective in regulation and standardisation measures

- Unify classification and standardization of PNCM
- Improve the management of health, safety and environmental risks of PNCM

Secondary objective in sufficiently trained workforce for PNCM

- Diminish the present lack of sufficiently trained workforce by education and training

Secondary objective in technology transfer

- Improve the presently not sufficiently effective communication between scientific and industrial interlocutors by
  - Exploration of industrial expectations and definition of possible nanotechnology applications.
  - Definition of research lines with oriented industrial objectives.

From a quantitative point of view the achievement of these specific objectives can be evaluated by the following parameters:

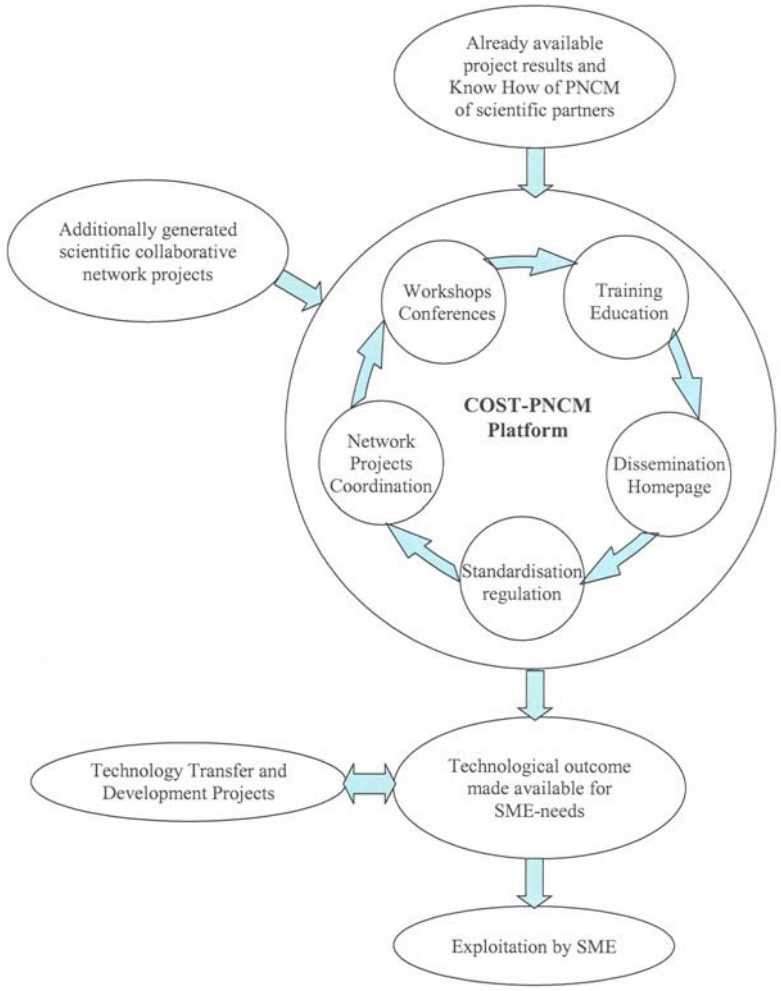
- number of transnational collaborative research proposals prepared
- number of groups and companies participating actively in the PNCM platform
- number of presentations and publications originating from collaborative research
- number of short scientific missions supported by the action
- number of training activities and number of people trained
- and most importantly the number of experimental achievements generated in this COST Action, which can be transferred to SME´s for further commercial exploitation.

In section C3 the suggested quantitative evaluation criteria are listed.

C.3. How will the objectives be achieved

The means to achieve these objectives is networking of existing expertise and knowledge of leading European experts in materials research and engineering within the proposed COST action constituting a PNCM technology platform (see Fig. 1). Specifically the exchange of the latest scientific results from RTD among the participating partners, both from institutes and industry, to use the benefits for industrial applications will be performed to achieve the objectives. The activities within this PNCM technology platform created by this COST action will result in a positive loop between industry and research community leading to highly efficient and fast commercialisation with a focus on SME´s. This will help to avoid duplication of effort to make most effective use of the actual European research budget.

Fig.1. COST PNCM-platform



The means to achieve these objectives are summarised below, giving quantitative figures for evaluation:

- Networking will reach at least 60 partners in 20 countries (55 partners in 18 countries have already signed up for this Action)
- Networking will be extended to at least 30 companies (19 companies, mainly SME, have already signed up for this Action)
- Minimum 9 collaborative, transnational projects on specific topics will be generated and coordinated
- Management Committee meetings will take place 2 times a year to facilitate better and more intense communication among members
- A standardisation meeting will be called 2 times
- 25 new experimental achievements (demonstrators, patents, new products) will be generated for further exploitation by SME´s
- A PNCM- website will be created and information material prepared and distributed
- A yearly PNCM-conference will be organized
- A total of 110 publications will be issued in peer reviewed journals as a result of the initiated scientific projects and of the yearly PNCM-conferences
- Organisation of 3 summer schools events for intensified training and education
- 20 short term scientific missions will be performed

C.4. Benefits of the Action

The benefits for European society will be:

•Increase the knowledge platform for nanocomposites, manufacturing, processing and application, make this available to many medium-sized and start up companies.

•Ensure that consortium partners (including participating SME´s) have a high level of up to date expertise of the latest science and technology achievements in polymer nanocomposites.

•Support consortium partners to bring products and services faster to a strongly competitive market.

•Enable technology transfer by intellectual property deals among the consortium partners.

•Stimulate start ups and spin offs from the participating research organisations.

•Contribute to the creation of new employment opportunities in Europe.

•Help to avoid disruption in technology by investigating in sustainability and communicating up to date safety information and recommendation of protective measures for the handling of nanoparticles.

•Create and support standardisation measures for a faster penetration of the markets.

•Promote and develop up to date property measurements and data collection, as well as advanced characterisation techniques.

•Contribute to the creation of human resources, specialists with high knowledge in a topical, high performance domain.

•Diminishing the economic and knowledge discrepancies between the western and eastern European countries.

This COST Action will be an effective way to close the gap between European industry and academia, and the technology gap between the USA and Europe, by making faster and more efficient use of the scientific know-how in Europe through increased networking at the top level. Because of its enormous growth potential, this emerging technology of nanocomposites will be a major provider of new employment opportunities in Europe based upon growing

international commercial success combined with ecological advantages. Therefore, this COST Action will contribute to such a goal with high relevance for European society.

C.5. Target groups / end users

The target groups will be the University and Research laboratories in the field of PNCM within Europe and the end users of the generated Knowledge will be mainly SME´s, start ups and spin off companies.

D. SCIENTIFIC PROGRAMME

D.1. Scientific focus

The scientific programme is built around the objectives listed in section C. The proposed COST action is flexible enough to incorporate a variety of projects ranging from fundamental research on materials properties and innovative characterization methods up to processing and specific applications of PNCM. All the projects carried out by the participating scientists and laboratories will be driven by the need to fulfil the primary objective of this COST action to transfer the obtained scientific results into application and support their exploitation by European SME´s by overcoming the present technological barriers identified as secondary objectives in section C. This approach is securely based on the extensive knowledge already available at the participating laboratories which has been created by national and European wide projects of the past or by projects which are still underway. It will be the scientific focus of this COST action to concentrate the joint efforts on those scientific and technical items which are identified barriers for successful applications in industry preferentially in SME´s. Functionalising and dispersing the nanomaterials into the matrix is emphasized to be the key task of the proposed scientific programme in order to tailor the new nanocomposites.
The ceramic, metallic or other nanoparticles can enhance mechanical, electrical, optical and thermal properties of typical engineering plastics. The nanocomposites have these improved properties even when the dispersion of the nanoparticles is not perfect and when agglomerates are present. However, when high quality dispersion is achieved, a much smaller amount of the often precious nanoparticles will suffice to obtain the desired properties Also, with good dispersion interfacial phenomena between the nanoparticles and the matrix polymer offers new possibilities with smaller filler loading to tailor the material properties. Good nanodispersion should be done without time consuming wet processes where the solvent needs to be evaporated. New ground breaking processing methods therefore have to be developed. The elimination of solvents also has environmental benefits.
Basically anyone could buy the raw materials but only few can make the composite successfully.

A PNCM consists of three main constituents

- The matrix
- The reinforcing nanoparticle or nanofibre (=nanoelements)
- The interfacial region

The interfacial region is responsible for the interaction between the reinforcing elements and the matrix, and therefore to a large extent determines the difference in properties between the PNCM`s. The successful development of PNCM materials must take into account and achieve a proper balance between four areas:

- The selection of the matrix and nano-reinforcing elements
- The primary processing, i.e. the incorporation of nanoparticles into the matrix
- The further fabrication into components
- The achieved properties and the performance of the components

The primary processing has to take into account three important steps:

- Production of reinforcing nanoelements
- Surface functionalisation of nanoelements
- Integration of nanoelements into the polymer matrix

To obtain the desired properties, not only the kinds of particles and matrix are of great importance but also the uniform distribution of nanosized elements in the matrix.
The R&D areas which are of great importance for PNCM-processing are:

- Uniform dispersion and exfoliation at nanoscale; and/or the formation of controlled, patterned or hierarchical structures
- Tailoring of the enormously large interfaces between the nanosized filler and polymer matrix;
- The effective bonding of nanosized particles to the matrix, which is facilitated by chemical compounds and chemical treatments
- Setting up novel processing methods of nanocomposite materials
- Process control to ensure reproducible results
- Elaborating understanding and using the composition/process/property relationships
- Developing cost-effective processing methods
- Developing advanced modelling and simulation tools
- Drawing up adapted or new characterization methods for nanostructured polymer composites

The technological focus of this COST Action will be on the actual process of development of PNCM and the successful transfer from laboratory to industrial practice.

The process of transferring the results from R&D work on PNCM in the laboratories to industrial products follows the cycle in **fig.2.**

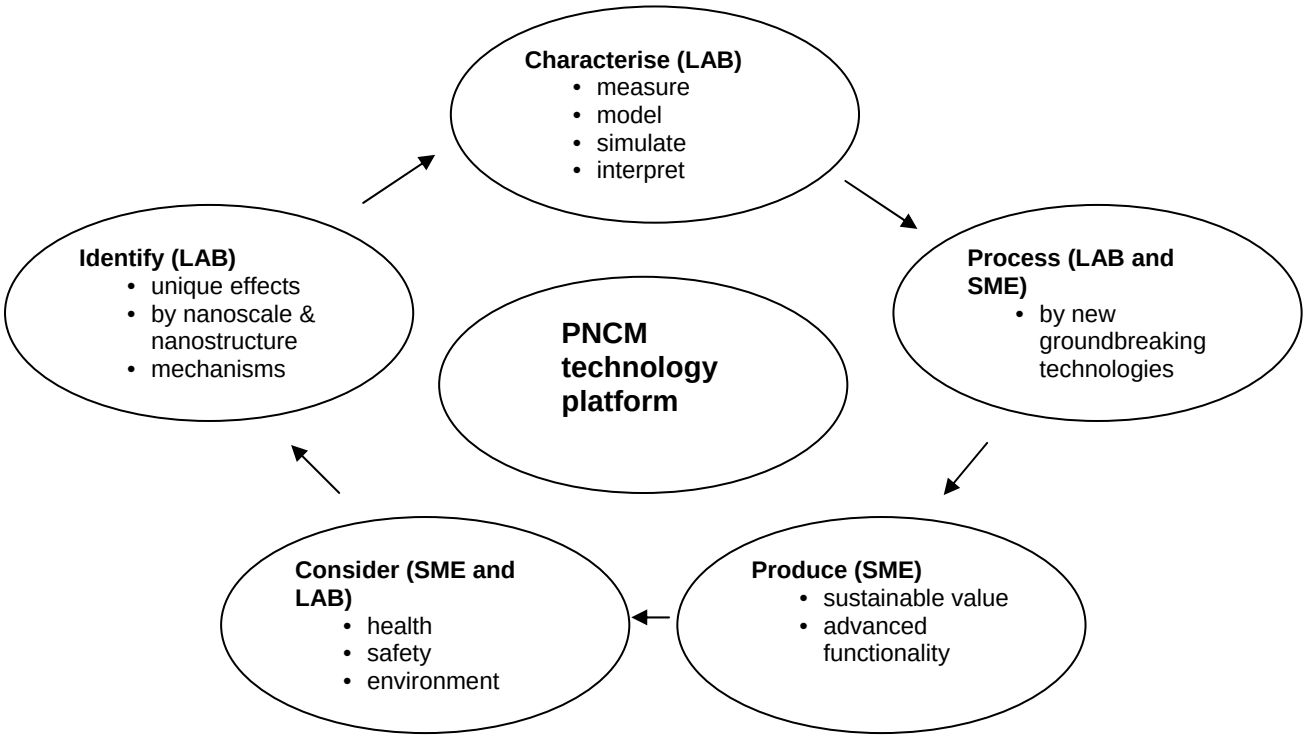


Fig.2. Cycle of technology transfer of PNCM-components from laboratory (LAB) into industrial practice (SME)

International competitive innovations with novel properties will cover technical progress as well as achieving the saving of raw materials and the protection of the environment..
Bio-based nanocomposites, as an environmentally sound solution for renewable materials, will also be included in the scientific programme.

D.2. Scientific work plan – methods and means

The COST action will help to concentrate the efforts of projects already underway at the different participating laboratories onto the primary and secondary objectives listed in section C.

This COST Action will also generate and coordinate a number of additional research projects which will be carried out by the participants. The nine research areas which have to be covered by such projects are:

•New innovative nanosized filler particles and nanofibres: preparation and processing, basic properties and handling
•Development of polymer nanocomposite matrix systems based on thermoplastics, thermosets, elastomers, duromers and liquid crystalline polymers
•Preparation and processing of polymer nanoparticle blends with necessary surface modifying additives
•Study to understand the characteristics of the interphase region, its dependence on nano-element surface chemistry, the relative arrangement of constituents and its relationship to the PNCM properties
•Developing effective and reliable ways of nanoparticle dispersion and exfoliation
•Processing technologies and novel production processes for semi-finished or final products
•Modelling and simulation
•Characterisation, safety aspects, quality assurance, property database, standardization
•Scaling up, applications and commercialisation

The projects will be arranged vertically across the above mentioned research areas in order to obtain the necessary interactions and the required interdisciplinarity

It is the intention to further align the chosen projects on application areas along the value added chain e.g. on automotive components covering all aspects from raw materials up to finished products, including service properties and demands. Other fields of application of primary interest are medical products and electronics. The specific topics to be focussed on will be decided once the Action is underway and the first Management Committee Meeting has taken place

The research goals in the projects to be performed will aim at the improvement of the nanoparticle processing techniques, the development of new nanocomposites, polymer and polymer blend matrices with new property combinations and property profiles, and the generation of fundamental understanding of the structure/property relationship by advanced and improved modelling and simulation tools.

A number of cross-cutting activities are relevant and necessary for all projects:

•Safety, Ethics
•Sustainability, recycling
•Dissemination
•Intellectual property rights
•Technology transfer
•Outreach activities

The main innovation will be to obtain products with optimised properties and the industrial procedures for high quality nanocomposites which will be used in a large number of future innovative applications (Table1).

Table 1: Examples of innovative and intended applications of PNCM in various branches

Branches (examples)	Product	Property improvement
Automotive	Coatings, paint Windscreens Catalysts High performance nanocomposites Timing belt cover Engine cover Fuel lines	Scratch + corrosion resistance Scratch + optical transparency Catalytic activity Impact, strength, stiffness, weight reduction → safety, fuel saving, environmental protection
Electronics and Optoelectronics	Adhesives, glues Electrically conductive composites Signal wire shielding Electrostatic painting Interference shielding Photovoltaic sells	Electronically switchable, self healing Reduction of polymerisation Shrinkage, Wear resistance Increased conductivity
Medical	Membranes, tubing, stent delivery balloons Bioactive nanocomposites Dental fillings Artificial blood pumps, blood sacs, artificial hearts Orthopaedic applications High performance elastomeric membranes	Drug delivery, controlled release Brittleness reduction, flexibility + impact strength increase, Improvements of biological and mechanical properties Delivery of pharmacological agents Higher stiffness and elongation, Increased heat deflection temperature
Packaging (Food industry)	Conservation foil Membranes Bottles Containers	Diffusion barrier Filtration & separation capacity Monitoring conditions of the content, thermal history, …
Aviation	High performance nanocomposites	Impact, strength, stiffness, Weight reduction, morphing
Mechanical engineering	Controlled processing Adaptive systems	Controlled rheology, piezoelectric, magnetic effects
Construction	Coatings High performance nanocomposites Building preservation and restoration nanocomposites	Scratch + corrosion resistance Impact, strength, stiffness, weight reduction safety, Transparency Environmental protection Adherence to construction substrates Porous materials consolidation
Flame retardant applications	Wire and cable covers Battery char Electrical enclosures Home interior decoration materials Insulation Thermal/Acoustic Isolation foams	Delayed ignition Reduced smoke Stable chars
Sports equipment	Tennis rackets/squash	Stress resistant

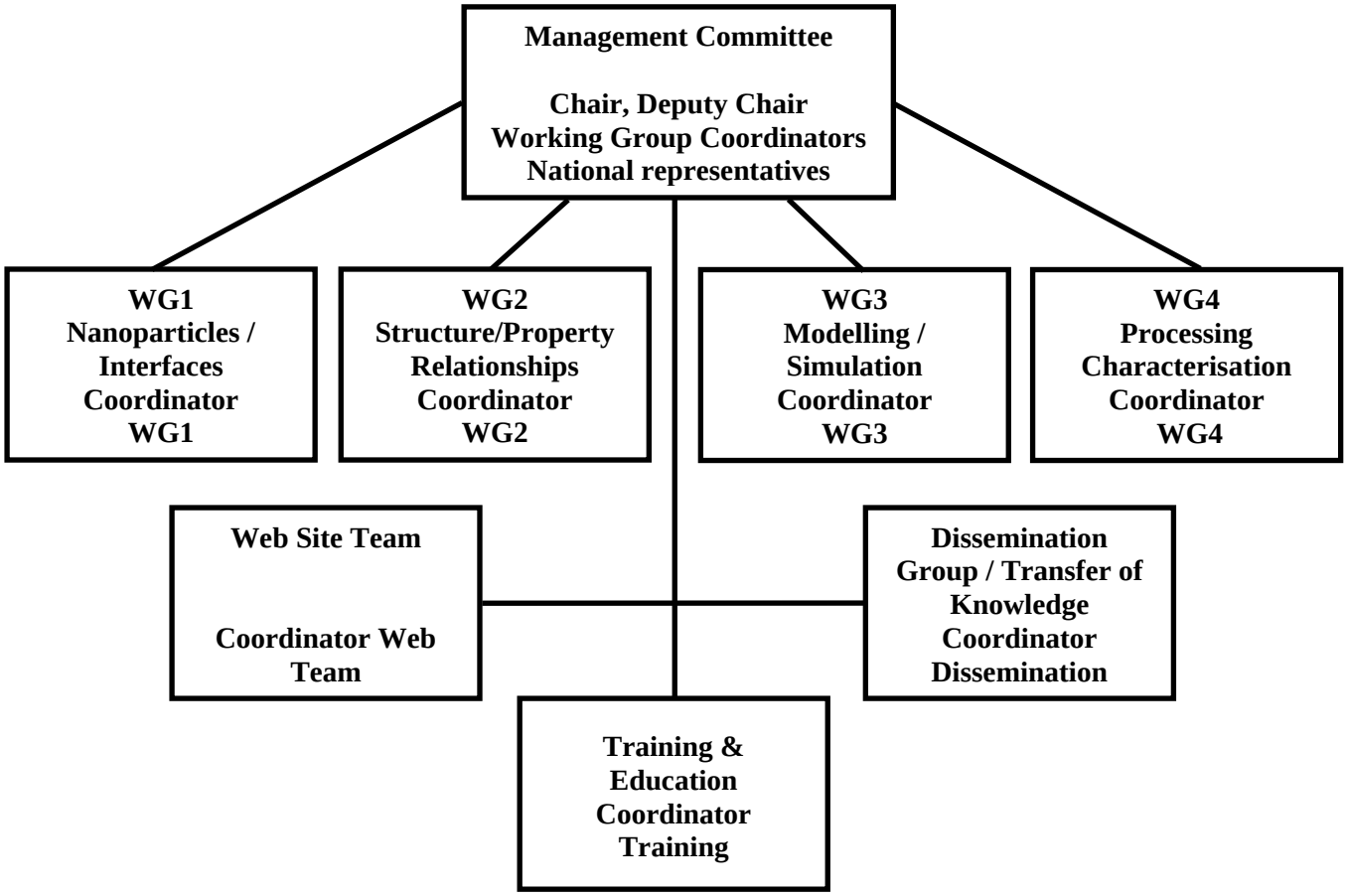
	rackets Fishing rods Hockey sticks Golf clubs High performance bicycles Skis & ski poles Training shoes	Shock absorption Stiffness Impact resistance Toughness Barrier properties
Surface Coating	Protective eyewear	Abrasion and chemical resistance Scratchproof/ resistance Impact resistance
Oil and Gas	Pipes for steam assisted gravity drainage Oil sand extraction equipment Plastic vessels	Higher strength Temperature resistance Erosion and corrosion resistance
Energy industry	Ultra capacitors Photovoltaic systems Plastic pipes Electrical insulation	Additional functionality Anti-corrosion properties Dielectric properties

The work within the projects will be guided by a detailed work plan.
This work plan will include meetings of the network members, short term scientific missions, workshops, conferences and outreach activities for technology transfer to industry.
This COST proposal will cover all costs for the activities within this network, e.g. management, coordination and meeting costs. The research programme itself will be carried out by the member laboratories and is funded by national and international research funds.

E. ORGANISATION

E.1. Coordination and Organisation

The COST Action will be coordinated by a Management Committee (MC) as described in the "Rules and Procedures" (COST 299/06). The Chair and the deputy-Chair will be elected at the "kick-off" meeting to be held early at the start of the Action. Each signatory country will send two representatives. In addition, scientific coordinators for the working groups and a web site and Transfer of Knowledge Coordinator will be appointed. Finally, a secretary supporting the Chair in administrational matters will be appointed.
At the "kick-off" meeting, the intended research projects in section D will be discussed and updated, if necessary.



Meetings of the Management Committee will be embedded in the annual PNCM conferences. These meetings will deal with all strategic issues such as suggesting and approving of new Working Groups, as well as changing directions of or closing down existing Working Groups. A major issue will be the organization of the next PNCM conference, based on the budgetary allowances. Organizational details of approved Short Term Scientific Missions (STSMs) should be fixed. Ways to improve the tools for internal communication (e.g. an intranet-facility) and external contacts will continuously be discussed. The MC will decide on urgent matters by electronic communication (e-mail).

Travel allowances will be distributed for Short Term Scientific Missions (STSMs) for exchange of students, as well as senior scientists, between the participating research groups. A motivation and a simple plan should be submitted to the Training & Transfer of Knowledge Coordinator, who will present the current applications of highest quality to the MC. Depending on the budget available, the MC will decide which applications should be granted. The MC is responsible for gender- and geographical balance in the distribution of travel reimbursements. Young researchers must be included to a percentage agreed upon at the "kick-off" meeting.
Depending on the vote of the MC, a separate seminar series (summer school) on the fundamentals of PNCM will be arranged with the purpose to introduce new graduate students, post-doctoral fellows and non-specialists into the field. This will be widely announced in order to reach scientists from different disciplines. The aim is to help the audience to overcome the barriers of advanced chemistry, physics and technology associated with PNCM. It will provide a valuable and thorough introduction to the field for young researchers.

The Chair will compile the PNCM Progress Report from the Scientific and Outreach Reports, and present some of the highlights to the MC during its annual meeting. This report will form the basis for the evaluation of achieved objectives and possible re-evaluation of future targets proposed at the Committee meeting. The website will be utilized to inform about the progress of the COST Action internally and externally.

The annual PNCM-conference

An annual two-day conference will be organized, gathering the European nanocomposite community in order to summarize current status and future trends of the research field. It will include all aspects of nanocomposites: theory, chemistry, physics, technology and applications. The fundamentals of nanocomposites will also be covered with the purpose to introduce new graduate students, post-doctoral fellows and non-specialists into the field. Scientific highlights obtained during the past year will be communicated. Industrial associates will present their most recent technological innovations and scientific results for further exploitation. Participants and invited speakers from non-European countries, such as Japan and the USA, will keep the members of the COST-Action up-dated on the most recent results, as well as on general trends within the global nanocomposites research community. Round-table discussions on topics of mutual interest will be arranged in a positive atmosphere, encouraging the exchange of knowledge, experience and innovative ideas.

As there has been limited contact between the network partners for the exchange of scientific knowledge and experience previously, there is a strong wish to arrange the first conference as soon as possible. Hence, it will be held in early 2009 provided the Action can be started in 2008. The Chair and the Deputy-chair will be responsible for the organization of this kick-off event. The conference will be repeated in the 2nd quarter of each of the following years. The organizers are responsible for the planning of an attractive programme and widely announcing it, and for arranging appropriate conference facilities.

The COST initiative is the most suitable instrument for supporting this kind of open, flexible and growing networking in a nascent research and engineering area including the generation of new projects.

E.2 Working Groups

At the start of the COST Action four working groups (WG) will be formed, being responsible for the fulfilment of the scientific goals of the corresponding Research Projects. Working Group coordinators will be elected in order to lead the scientific discussions, coordinate the activities of the sub-projects and provide the Chair with a brief yearly written report. All scientists participating in the PNCM COST Action will be invited to join one or several Working Groups, depending on their research activities. In the course of the COST Action new (additional) Working Groups can be established depending on the needs/wishes of the consortium.

The four working groups chosen at the moment cover the following subjects:

WG1 Nanoparticles / Interfaces
- Selection of matrix and nanoparticles, production of nanoparticles
- Surface functionalisation / chemical treatments of nanoparticles

WG2 Structure/Property Relationships
- Linking nanosized structures to macroscopic functional properties

WG3 Characterisation – Modelling – Simulation
- Characterisation and measurement tools
- Simulation and modelling tools

WG4 Processing
- Primary processing
- Dispersion - exfoliation
- Characterisation, properties and performance of components
- Process Control (inline)
- Cost effective methods of processing
- Standardisation
- Manufacturing into components
- Management of health, safety & environmental risks

E.3. Liaison and Interaction with other research programmes

Table 2: Liaison and Inter Action with other research programmes

FP5	5 FP: Transnanopowder (ISP-2000-00098), Nenamat (SSA)
FP6	Nanotube Composite Materials for Aerospace, CNT reinforced hybrid composite materials with sensing and actuating capabilities – NOESIS- (STREP), ExActResoMat - External Activation of Resorbable Materials (IP for SME), NanoRoad SME (SSA), TOK-NANOTEC-EST - "Intensive Program for Transfer of Knowledge to Eastern European Reference Pole for Micro- and Nanotechnologies - MINATEC-EST", (Marie Curie Host Fellowships for Transfer of Knowledge funded by EC), 6 FP: CarCIM (STREP)
FP6 CRAFT	Nanopowder, Nanoceram,
FP7	Nanocomposites will be a strongly emphasised topic in FP7
ESF	Nanotribology
COST	High pressure tuning of chemical and biochemical reactions - High Pressure Synthesis and Processing of Nanopowders (COST D30), Nanostructured Materials, Triboscience and Tribotechnology: Superior

	Friction and Wear Control in Engines and Transmissions (COST 532)
ESA	NACO - "Non-Conventional Matrix/Carbon Nanotubes Reinforced Composite for Applications in Space"
EUREKA	Bionanocomposite
ERA-NET	BIONANOCORE - Bioactive Nanocomposite Constructs for Regeneration of Articular Cartilage (Era Net Materials)
NATIONAL PROJECTS	These are numerous on this topic. Therefore, just a few selected from a few specific countries are given : e.g. in vivo bone engineering via combining a novel composite scaffold technology with a growth factor (Bilateral grant Poland-Singapore), Polymers modified by nanoparticles: technology - properties – application (national Polish grant), Fabrication of ceramic-polymer composites intended for dental fillings (national Polish grant), Technology and processing of composites materials modified by CNTs (national Polish grant), functionalisation of CNTs – technology and mass production (national Polish grant), Air jet milling method and equipment for size reduction of metallic and mineral materials up to micro- and nano-size (national Polish grant), Nanomobil (WING), In Portugal, NM-RTM – "Modeling and Control of the RTM process using Magnetic Nanofluids) (National Portuguese Foundation for Science and Technology). In Romania, the National Plan for research-development and innovation (PN II), as well as other research programmes and projects provide funds to sustain the nanoscience, nanomaterials and applications in nanotechnologies field development, in particular the nanocomposites. Joint National project of Latvian Council of Science "Innovative structurally integrated composite materials: design, technology of production and processing, longevity". National Research programme in Material science in Latvia "Development of advanced functional materials for microelectronics, nanoelectronics, photonics, biomedicine and special composites and corresponding technologies elaboration" (2005-2008). Ligth-Structural-Thermoresistant Nanocomposites for construction materials applications, Nanolet (national Spanish grant), intumescing paints based on organoclays for steel coatings, Protefoc (national Spanish grant, Hybrid nanocomposite coatings for tribological properties in ceramic/construction applications, (national Spanish grant).

E.4. Gender balance and involvement of early stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will put this as a standard item on all its MC-agendas.
The Action will also be committed to considerably involve early stage researchers. This item will also be placed as a standard item on all MC-agendas. An effort will be made to maintain a good gender balance in the elected leading team members of the COST Action (Chair, Deputy-Chair and MC members, WG coordinators).
Further Action will be made by the Management Committee to build and maintain diversity in all teams by nationality and races.

The research to be carried out within the WGs will provide ample MS and PhD training opportunities. The different groups involved will provide significant scope for Short Term Scientific Missions, with priority given to early stage researchers (MS, PhD students and young postdoctoral scientists). Another positive approach to involve early stage researchers

will be the offer of an annual thesis prize. PhD supervisors will be asked to nominate candidates. The winner, decided by the MC, will give a presentation of her/his work at the next PNCM conference.

In order to provide equal opportunities for all eligible participants in the Action to attend the MC, WG meetings, and the summer schools and the PNCM conference, provision will be made for any child minding beyond that needed to carry out everyday duties. The COST Action is committed to the goals of the Helsinki Group on Women and Science and will encourage a strong participation of young women researchers, by promotion and publicity of the Action's aims among young researchers during their early training when a higher percentage of women are active in the field. The participation of women early in their careers is seen as a way to fortify their involvement in the field, increasing the possibility of achieving a better gender balance in the future. This will strengthen the presently insufficient involvement of women in the physical sciences.

F. TIMETABLE

The COST Action will run for a total of four years. The timetable and milestones of the Action are given in Table 3.
The Action will be initiated at the "kick-off" meeting in the beginning of year 1. The Working Groups will be formed and Working Group Leaders elected. The first PNCM conference will be organised together with the second MC meeting. The PNCM conferences will then be repeated every year. The first scientific activities will primarily be devoted to fundamental research and the refinement of the technology, as this will benefit all other Working Groups.

Table 3: Timetable and milestones (M) for the PNCM Action

	YEAR 1	YEAR 2	YEAR 3	YEAR 4
1st Qu	MC-Meeting			
2nd Qu	PNCM Website operative (M)	MC-Meeting	MC-Meeting	MC-Meeting
		PNCM (M)ilestone Conference	PNCM (M) Conference	PNCM (M) Conference
3rd Qu				
	WG-Meetings	WG-Meetings	WG-Meetings	WG-Meetings
4th Qu	MC-Meeting	MC-Meeting	MC-Meeting	MC-Meeting
	PNCM Conference (M)	Standardisation Meeting (M)		Standardisation Meeting (M)

G. ECONOMIC DIMENSION

The following 18 COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Austria, Belgium, Switzerland, Czech Republic, Germany, Spain, Greece, Finland, France, Italy, Latvia, the Netherlands, Poland, Norway, Portugal, Romania, Sweden and Great Britain.
On the basis of national estimates, the economic dimension of the activities to be carried out under the COST Action has been estimated at 25 million € for the total duration of the Action.

This estimate is valid under the assumption that all the countries mentioned above, but no additional countries and partners, will participate in the Action. Any departure from this will change the total cost accordingly to a higher sum.
A major part of this number is made up by the total manpower supported by Academic Institutions and (inter-)national grants devoted to the activities of the Action, which is shown in Table 4.

Table 4: Manpower of academic institutions devoted to the COST Action

Country	Initial No. of Members	WG1	WG2	WG3	WG4	Other Activities*	Total
		Person Years					
AT	**2**	**3**	**2**	**3**	**4**	**2**	**14**
BE	**3**	**6,5**	**9,5**	**6,2**	**13**	**2,8**	**38**
CH	**2**	**2**	**5**	**2**	**5**	**1**	**15**
CZ	**2**		**5**			**1**	**6**
DE	**5**	**12**	**14**	**9**	**18**	**2**	**55**
ES	**3**	**3**	**2**	**2**	**4**	**3**	**14**
GR	**1****	**5**	**8**	**6**	**5**	**2**	**26**
FI	**1**	**2**	**1**	**2**	**3**	**1**	**9**
FR	**2**	**3**	**2**	**3**	**4**	**2**	**14**
IT	**3**	**2**	**3**	**2**	**1**	**1**	**9**
LV	**2**	**3**	**2**	**-**	**3**	**2**	**10**
NL	**1**	**1**	**2**	**2**	**3**	**1**	**9**
NOR	**1****	**1**	**-**	**-**	**1**	**-**	**2**
PL	**1**	**2**	**3**	**1**	**2**		**8**
PT	**2**	**-**	**1.5**	**1**	**1.5**	**3**	**7**
RO	**2**	**2**	**2**	**-**	**-**	**1**	**5**
SE	**1**	**0.5**	**1**	**1**	**1**	**0.5**	**4**
UK	**3**	**1**	**1**	**1,5**	**1**	**0.5**	**5**
TOTAL	**37**						**250**

*** Training, Summer school, Website, Standardisation, Technology Transfer, Dissemination**

**** Company partner**

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H. DISSEMINATION PLAN

H.1. Who?

The main target audience for dissemination will be

- The network partners
- Other researchers in the field (outside the COST Action)
- Research institutes and academic units (in nearly related fields)
- Standardisation bodies
- Industry (with a strong focus on SME´s)
- The general public

H.2. What?

A **website** dedicated to the PNCM Action will become the pivot for the distribution of information from and to the network partners. For the exchange of scientific information (*internally* as well as *externally*), communication resources will be offered, facilitating the distribution of preliminary results between groups. Information on, and material required for, the PNCM conferences will be available and possible to be downloaded. In addition, the website will host a discussion forum for interactive support of the PhD-students, post-doctoral fellows and researchers interested in following the activities of the PNCM network. The website will be set up and maintained by the web site group. A public section of the website will also be open to other researchers, who are interested in this field but not network partners. They will be invited to join the network. The organisation of **conferences and summer schools** will constitute an important element for the dissemination plan as well.

Distribution to the general **public** in terms of popular science articles, seminars and sound or television broadcasts will also be highly encouraged.
The **standardisation bodies** will be invited to take part in the scheduled standardisation meetings.

Open research positions related to the concerted Action will be announced in the **academic press** and at scientific conferences. This is also an efficient way of widely distributing the information that the PNCM network has been established in Europe. For recruiting new collaborators (and indirectly new network partners) the Action will also make use of the services of the website ERACAREERS, the Pan-European ResearchERs Mobility Portal. Further ways to reach people will be on the agenda of (especially the first) organisational meetings.
Industry (with a focus on SME´s) will mainly be reached via personal contacts of the network partners.

H.3. How?

At the "kick-off" meeting the outline of a website**,** dedicated to the new PNCM COST Action, will be presented to all partners. The tasks of a webmaster will be performed by the appointed Secretary, with the help of graduate students of the Member Departments on a rotational basis.
As indicated, the deputy Chair acting as a Scientific Coordinator and the Training & Transfer of Knowledge Coordinators will be appointed at the “kick-off” meeting. The former will act as an *internal* coordinator, as well as a mediator between the MC and the various WGs. This person will assemble a yearly scientific report of the WG reports, forming the scientific part of the progress report, in turn compiled by the Chair. The Training & Transfer of Knowledge Coordinators, on the other hand, will act as contact persons to the *external* scientific

environment, looking for new Action partners, supporting young researchers (post-doctoral fellows and graduate students) wanting to employ PNCM Science and Technology for their research, and keeping contact with representatives from the industry. These important efforts to reach external people and activities will assure the integration of PNCM Science and Technology within a broader European research/industry community, and will increase the awareness among the general public. A yearly report on these outreach activities will be written and included in the overall progress report.

Part II Additional information

A. LIST OF EXPERTS

A1. List of 35 Expert Institutions who have been consulted during the drafting of this proposal and have expressed definite interest to participate in this COST Action

Country	Name	Institution	Department	Type	E-Mail
AT	**Erich Kny** Nils Stelzer	**ARC**	**Tech Transfer**	**RO**	**erich.kny@arcs.ac.at** nils.stelzer@arcs.ac.at
AT	Wolfgang Stadlbauer	Upper Austrian Research	Surface Engineering	RO	wolfgang.Stadlbauer@uar.at
BE	**Paul Kiekens** Serge Hoste Joris Degrieck	**Ghent University**	**Centre for Materials Science and Engineering (CMSE)**	**UNIV**	**paul.kiekens@UGent.be**
BE	Put Stijn	Umicore Research		RO	stijn.put@umicore.com
BE	Ignaas Verpoest Stepan Lomov Paula Moldenaers	K.U. Leuven	Leuven-Materials Research Centre (Leuven-MRC)	UNIV	Ignaas.verpoest@mtm.kuleuven.be
CH	Thomas Graule	EMPA	Dept. Advanced Ceramics	RO	Thomas.graule@empa.ch
CH	Christopher Plummer Véronique Michaud	EPFL	Laboratory of Composite and Polymer Technology	UNIV	Christopher.plummer@epfl.ch Veronique.michaud@epfl.ch
CZ	Jiri Svejcar	Brno Univ. of Technology	CRDMT	UNIV	svejcar@fme.vutbr.cz
CZ	Jiri Krejcik	SVUM Prague	Research and Testing Centre	RO	krejcik@svum.cz
DE	Bernd Rothe	RWTH Aachen	IKV	UNIV	rothe@ikv.rwth-aachen.de
DE	Karl Schulte Malte Wichmann	Techn. Univ. Hamburg-Harburg	Inst. Polymers and Nanocomposites	UNIV	schulte@tuhh.de wichmann@tuhh.de
DE	Martin Schehl	Institut für Verbundwerkstoffe GmbH	Zentrale Services	RO	martin.schehl@ivw.uni-kl.de

DE	Tassilo Moritz	Fraunhofer	Inst. Keramische Techn. Systeme	RO	Tassilo.Moritz@ikts.fraunhofer.de
DE	**Wolfgang Faul**	**Kompetenz-zentrum Neue Materialien**		**RO**	**wolfgang.faul@nmngmbh.de**
ES	John Gutiérrez Jose Luis Vilas	University of the Vasc Country in Leioa(UPV /EHU)	Magnetism and Magnetic Materials Department	UNIV	jon@we.lc.ehu.es joseluis@ehu.es
ES	Maríajose López-Tendero	AIDICO	R&D Dep. - Nanomaterials Division	RO	mlopezt@aidico.es
ES	Pilar Bilbao	Area de Plásticos y Nanocomposites	GAIKER Centro Tecnológico	RO	bilbao@gaiker.es
FR	Philippe Miele	Univ. Lyon	Lab. des Multimat. Interfaces	UNIV	Philippe.Miele@univ-lyon1.fr
FR	Thierry Massard	CEA		RO	thierry.massard@cea.fr
FI	Jari Koskinen	Technical Research Centre of Finland (VTT)		RO	Jari.Koskinen@vtt.fi
IT	Claudio Nicolini	Univ. Genova	Nanoworld Inst.	UNIV	cattedra@ibf.unige.it; secretary@nwi.unige.it
IT	Enrico Stura	Fondazzione EL.B.A.	Nanoelectronics Lab	RO	fondazione@fondazione-elba.org
IT	Francesco Branda	Naples University	Dep. of Mat. and Prod. Eng.	UNIV	branda@unina.it
LV	Ilmars Zalite	Riga Technical University / RTU	Inst. of Inorganic Chemistry	UNIV	ilmars@nki.lv
LV	Jānis Zicans	Riga Technical University / RTU	Institute of Polymer Materials	UNIV	zicans@ktf.rtu.lv
NL	Alexander Schmets	Delft Univ. Techn.	Delft Centre Mat.	UNIV	a.j.m.schmets@LR.tudelft.nl
PL	Malgorzata Lewandowska Jakub Michalski	Warsaw University of Technology	Faculty of Materials Science and Engineering	UNIV	malew@inmat.pw.edu.pl jmichalski@

					inmat.pw.edu.pl
PT	António Torres Marques	Faculdade de Engenharia da Universidade do Porto	Dep. of Mechanical Engineering and Industrial Management	UNIV	marques@fe.up.pt
PT	Celeste Pereira Paulo Nóvoa	INEGI	Inst. de Engenharia Mecânica e Gestão Industrial	RO	cpereira@inegi.up.pt prnovoa@inegi.up.pt
RO	Geta David	Technical University	Department of Natural and Synthetic Polymers	UNIV	geta_david2000@yahoo.com
RO	Mihaela Olaru	"Petru Poni"	Institute for Macromolecu-lar Chemistry	RO	olaruma@icmpp.ro
SE	Ignacy Jakubowicz	SP Technical Research	Polymer Technology Institute of Sweden	RO	ignacy.jakubowicz@sp.se
UK	Anthony Kinloch	Imperial College London	Dep. Mech. Eng.	UNIV	a.kinloch@imperial.ac.uk
UK	Hanshan Dong	Birmingham Univ.	Dep. Metall. and Mat.	UNIV	h.dong.20@bham.ac.uk
UK	Alasdair Wilson Hailiang Du	Northumbria University	AMRI	UNIV	alasdair.wilson@unn.ac.uk hailiang.du@unn.ac.uk

The names of the experts which are highlighted will be possible members of the management committee (Chair, Deputy Chair)

A2. List of 19 Companies (mainly SME) who have been contacted during the drafting of this proposal and have expressed interest to participate in this COST Action

Country	Name	Institution	Department	Type	E-Mail
DE	Helmut Schmidt	EPG		SME	schmidt@e-p-g.de
DE	Manfred Schäfer	Cabot GmbH	Entwicklungs leiter		manfred_schaefer@cabot-corp.com
DE	H. Langguth	Cetelon Nanotechnik GmbH & Co. KG			cetelon@gmx.net
DE	Robert Theobald	Cleancorp Nanocoatings	Manager		info@cleancorp.de
DE	Florian Michl	Future Carbon GmbH			florian.michl@future-carbon.de
DE	Lars Wahlen	Lehmann & Voss & Co. Produktentwicklung			
DE	Patrick Sonntag	NanoCompound GmbH	Manager Marketing		Sonntag@nanocompound.de
DE	Manfred Pyrlik	nanoresins AG			info@nanoresins.com
DE	Jens Helbig	Neue Materialien Würzburg GmbH			helbig@nmwgmbh.de
DE	Jürgen Stebani	PolyMaterials AG	Vorstand		j.stebani@polymaterials.de
DE	Raimund Brotsack	rent a scientist GmbH	Geschäftsführer		raimund.brotsack@rent-a-scientist.com
DE	Matthias Schweinsberg	SusTech GmbH & Co. KG Darmstadt	Geschäftsführer		matthias.schweinsberg@sustech.de
GR	Dimitri Karagiannis	INASCO	RTD	SME	d.karagiannis@inasco.com
IT	Antonella Cavallo	Alenia Aeronautica		Company	acavallo@nospam_aeronautica.alenia.it

IT		CRF Centro Ricerche Fiat Company		Company	
IT		Elasis Company		SME	elasisweb@elasis.it
LV	Eriks Palcevskis	PCT Ltd.	Plasma & Ceramic Technologies	SME	pct@nki.lv
NOR		EURO Composite Plastic AS		SME	post@ecpnett.com
PL	Jan Mazur	PZL-Swidnik S.A.		Company	Jan.mazur@pzl.swidnik.pl
SE	Lars Liljenfeldt Patrik Fernberg	SICOMP	Swerea Group	Company	lars.liljenfeldt@sicomp.se

B. History of the Proposal

The initiating partners are members of the European Network of Materials Research Centres (ENMat, website: http://www.enmat.eu). ENMat's goals are: the creation of knowledge, the dissemination of results and their beneficial use in materials science and technology. ENMat provides a qualified project management structure, including secretary, coordinator, and steering committee. The first idea for this COST Action arose at the ENMat spring meeting in Faenza, Italy in May 2006. Immediately after this meeting a short proposal for the open COST call in 2006 was prepared. The topic of this proposal covered the aspect of nanocomposites but did not focus only on polymers, but included also ceramics and metals. The proposal passed the evaluation threshold but was not selected. For the COST open call in 2007 a new short proposal was prepared focussing on polymer nanocomposites. This has been selected for the submission of a full COST proposal (This proposal!)

C. Recent Publications

Technology review: Nanocomposites, Amir Bahrami – TWI ltd. http://www.twi.co.uk

Plastics Nanocomposites Technology and Trends Feb. 6, 2007, Don Rosaldo provided by Omnexus.com, http://www.omnexus.com

The Royal Society report 2004. Nanoscience and nanotechnologies: opportunities and uncertainties. RS policy document 19/04. www.royalsoc.ac.uk

NRM report. EU funded project of Road Maps for Nanomaterials, NRM, published by Willems & van den Wildenberg.

Krätschmer W., Lamb L.D., Fostiropoulus K. & Huftman D. R. Solid C60: A new form of carbon. Nature, 1990 347 - 354.

Emilie J. Siochi, Peter T. Lillehei, Kristopher E. Wise, Cheol Park and Jason H. Rouse

Design and characterization of carbon nanotube NCs, NASA Langley Research Center
http://techreports.larc.nasa.gov/ltrs/PDF12003/mtg/NASA-2003-4ismn-ejs.pdf

Lee. R., HKSAR Innovation Expo'05 Hong Kong Convention and Exhibition Centre 2005. Emerging Trends of Advanced Materials and Their Potential Impacts
http://www.itc.gov.hklinnotech/Ricky-Lee.pdf

V. Abdelsayed, Y. Ibrahim, M.S. EI-Shall and S. Deevi. Polymerisation of butadiene on nanoparticles' surfaces and formation of metal I polymer NCs. Applied Surface Science, Volume 252, Issue 10, 15 March 2006, Pages 3774-3782. V.

J. W. Cho and D. R. Paul. Nylon 6 NCs by melt compounding. Polymer, Volume 42, Issue 3, February 2001, Pages 1083-1094.

You-Ping Wu, Yi-Qing Wang, Hui-Feng Zhang, Yi-Zhong Wang, Ding-Sheng Yu, Li-Qun Zhang and Jun Yang. Rubber-pristine clay NCs prepared by co-coagulating rubber latexand clay aqueous suspension. Composites Science and Technology, Volume 65, Issues 7-8, June 2005, Pages 1195-1202

Nicolini C., Adami M., Paternolli C., Nanostructured organic matrices and intelligent sensors in Smart Biosensor Technology (G. Knopf & Bassi A.S. eds), CRC Press, 231-244, 2006.

Stura E., Nicolini C., New nanomaterials for light weight lithium batteries, Analytica Chimica Acta 568, 57-64, 2006.

Carrara S., Bavastrello V., Ram M.K., Nicolini C., Nanometer sized polymer based Schottky junctions Thin Solid Films 510, 229-234, 2006

Bertoncello P., Notargiacomo A., Erokhin V., Nicolini C., Functionalization and photoelectrochemical characterization of poly [3-3'(vinylcarbazole)] multi-walled carbon nanotube (PVK-MWNT) Langmuir–Schaefer films, Nanotechnology 17, 699-705, 2006

Grasso V., Lambertini V., Ghisellini P., Valerio F., Stura E., Perlo P., Nicolini C., Nanostructuring of a porous alumina matrix for a biomolecular microarray, Nanotechnology 17, 795-798, 2006.

Tao Jiang, Yu-hua Wang, Jen-taot Yeh and Zhi-qiang Fan. Study on solvent permeation resistance properties of nylon6/clay NC. European Polymer Journal, Volume 41, Issue 3, March 2005, Pages 459-466.

M. J. Biercuk, M. C. Llaguno, M. Radosavljevic, J. K. Hyun, and A T. Johnson. Applied Physics Letters -- April 15, 2002 -- Volume 80, Issue 15, pp. 2767-2769

Tony McNally, Petra Pötschke, Peter Halley, Michael Murphy, Darren Martin, Steven E.J. Bell, Gerard P. Brennan, Daniel Bein, Patrick Lemoine and John Paul Quinn. Polyethylene multi-walled carbon nanotube composites. Polymer, Volume 46, Issue 19, 8 September 2005, Pages 8222-8232..

CA. Martin, J.K.W. Sandler, A.H. Windle, M. -K. Schwarz, W. Bauhofer, K. Schulte and M.S.P. Shafter. Electric field-induced aligned multi-wall carbon nanotube networks in epoxy composites. Polymer, Volume 46, Issue 3, 26 January 2005, pages 877-886

Cheol Park, Zoubeida Ounaies, Kent A. Watson, Roy E. Crooks, Joseph Smith, Jr., Sharon E. Lowther, John W. Connell, Emilie J. Siochi, Joycelyn S. Harrison and Terry L. St. Clair. Dispersion of single wall CNTs by in situ polymerisation under sonication. Chemical Physics Letters, Volume 364, Issues 3-4, 4 October 2002, Pages 303-308

Gary Loblick, Marc Godin. Plastics market opportunity study prepared for Alberta economic Development, March 2002 by: http://www.thecis.ca/working%20papers/Plastic%20Market%20Opportunity%20Study%20Final.pdf

Freedonia Group (03-01-2006), Market report on NCs to 2010.

I. Zalite, J. Grabis, Nanosize powders of refractory compounds for obtaining of fine-grained ceramic materials, Mat.Sci.Forum, 2007, vol. 555, pp. 267-272.

Р.Д. Максимов, С. Гайдуков, М. Калнинь, Я. Зицанс, Э. Плуме. Механические свойства и влагопроницаемость полимерного нанокоммозита на основе немодифицированной глины. Пластические массы, 2007, № 2, с. 39-44.**????**

R.D.Maksimov, S.Gaidukovs, M.Kalnins, J.Zicans, E.Plume, A nanocomposite based on a styrene-acrlate copolymer and native clay 1. Preparation, testing, properties, *Mechanics of composite materials, 2006, Vol.42, No.1., p.45-54.*

R.D.Maksimov, S.Gaidukovs, M.Kalnins, J.Zicans, E.Plume, A nanocomposite based on a styrene-acrlate copolymer and native clay 2. Modeling the elastic properties, *Mechanics of composite materials, 2006, Vol.42, No.2., p.163-172.*

Kalkis, R. Maksimov, J. Zicans. Thermomechanical Properties of Radiation - Modified Blends of With Liquid Crystalline Copolyester, POLYMER ENGINEERING AND SCIENCE, August 1999, Vol. 39, No.8, p. 1375-1382

J. Zicans, R. Maksimov, M. Kalnins, S. Gaidukov, E. Plume. Polypropylene / layered silicate nanocomposite: preparation, testing, and properties. Book of Abstracts of the International Baltic Sea Region conference „Functional materials and nanotechnologies, 2007, Riga: 2007, 145 p. – p. 92.