



**European Cooperation
in the field of Scientific
and Technical Research
- COST -**

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Secretariat

COST 232/09

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action MP0901: Designing Novel Materials for Nanodevices: From Theory to Practice

Delegations will find attached the Memorandum of Understanding for COST Action MP0901 as approved by the COST Committee of Senior Officials (CSO) at its 174th meeting on 26-27 May 2009.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action MP0901

DESIGNING NOVEL MATERIALS FOR NANODEVICES: FROM THEORY TO PRACTICE

The Parties 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 270/07 “Rules and Procedures for Implementing COST Actions”, or in any new document amending or replacing it, the contents of which the Parties are fully aware of.
2. The main objective of the Action is atomic-scale interface design and characterisation.
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 EUR 60 million in 2009 prices.
4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.
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.

A. ABSTRACT AND KEYWORDS

Engineering of surfaces and interfaces of nanostructures remains a central goal of modern solid state physics and chemistry, since atomically controlled interfaces play a key role in the performance of nanodevices. Limitations in characterisation and theoretical modelling tools have been a major obstacle to the development of controllable device interfaces. Technology is now entering a period of convergence between theory and characterisation tools: new electron microscopy tools can provide images and chemical mapping with atomic resolution; developments in near-field optical microscopy probes enable Raman spectroscopy of individual nano-objects. STXM-NEXAFS has been used to characterise individual nanoobjects. Concurrently, developments within the available computer codes (AIMPRO, siesta/transiesta ...) allow routine handling of systems with many 100s of atoms, and latest results show the promise of increasing this by a factor of 10-100, i.e. into the range of realistic nano-objects. These developments will allow theoretical modelling and experimental characterisation at the same nanometric scale. This Action combines development of these new tools with the expertise needed to exploit them for improved nano-interface control and novel device design. This approach will support the design and integration of novel materials of high technological relevance.

Keywords: Nanostructured Materials, Photoelectron Spectroscopy, Spectromicroscopy, Nanodevices and Theoretical Modelling

B. BACKGROUND**B.1 General background**

Manipulation, assembling and integration of low dimensional nanostructures (LDNs) in high performance devices are primary goals of nanotechnology - it is expected that LDNs will maintain their unique properties when they are assembled and integrated. These materials show properties and performances in applications that are different from their traditional bulk counterpart. A deep understanding of the electronic structure of LDNs and control of their integration would allow design of tailored functional systems. However, despite the current need, the processes of assembling and integration of individual LDNs, and the question of how their unique properties evolve, are still far from being developed and understood.

The key step of integration of LDNs into functional devices is the engineering of the electrical contact. Electronic devices based on LDNs such as carbon nanotubes (CNTs) have shown that their performance is influenced by a potential barrier existing at the metal-CNT contact, that governs the electron injection into the carbon nanotubes [J. Tersoff, Nature 2003, 424, 6949]. To achieve low-resistance Ohmic contacts with nanotubes and thus further advance their integration in new nanodevices, investigation of the metal-CNT interaction focused on detailed understanding of the physics and chemistry of this interface, is essential. In this context, metal nanoparticles supported on CNTs are important prototypes for understanding the nature of metal-CNT interaction. Furthermore, these hybrid systems formed by two interacting structures whose electronic properties are affected by their dimension, open a vast and very exciting field for basic research. It is well established that the electronic structure of CNTs is remarkably sensitive to the nanotube chirality and diameter. Moreover, the electronic properties of metal clusters are well known to be influenced by their dimension, i.e. by changes in their atomic coordination. The combination of these finite-size effects may have strong impact on metal cluster-CNT interaction, having outstanding influence for future nanoscale devices.

Recent experiments demonstrate that, similar to conventional semiconductor technology, the properties of nanostructures can be tailored by ion and electron irradiation. However, until now very little is known about the response of LDNs to ion and electron irradiation. New techniques for nanocontact deposition and post-deposition treatments to remove/burn functional groups are based on focused ion/electron beam irradiation. These applications indicate the high importance of obtaining fundamental knowledge about irradiation effects in nanoscale materials, aiming at minimization of irradiation damage when it is an unwanted phenomenon.

For applications such as quantum dot design for spintronics, or light absorption and emission devices, controlled doping of LDNs is required. However, conventional bulk doping techniques have not yet been successfully adapted to the nanoscale; in particular, problems such as surface segregation of dopant atoms pose a real limitation, given the high surface to volume ratio of nanoparticles. Once again, the detailed understanding and control of the surface physics and chemistry of LDNs are key issues. Nanoscale oxides have enormous potential in nanoelectronics, catalysis, light harvesting/storage applications; for example titanate nanoscrolls when used in new

technology for photobatteries are able to harvest and store energy simultaneously. In these materials a key limitation is the ability to withdraw the stored charge, and this requires advanced electrode design capable of effective penetration into the light harvesting material and of efficient electron transfer. The solar harvesting efficiency of these systems is therefore also crucially dependent on the precise nature of the interface between different LDNs.

While the range of nanostructured materials and applications is extremely broad, the technological barriers to be overcome have a common basis: the lack of knowledge for detailed understanding and control of the interface physics and chemistry of LDNs, allowing for effective integration into larger scale devices.

A key factor which has blocked the scientific community in this area to date is a lack of appropriate characterization tools at this scale. Most materials characterization tools such as vibrational and electronic spectroscopy are typically macroscopic probes which sample over mm^2 or μm^2 at best and are therefore unsuitable for the observation of nanoscale interfaces. Direct observation techniques such as traditional high resolution transmission electron microscopy can often change the sample structure. The development of new experimental tools is therefore critical for the development and optimization of novel devices. At present the scientific community is witnessing a rapid upsurge of interest in synchrotron radiation-based techniques for the study of nanostructures, most importantly high-energy X-ray diffraction (HE-XRD) and near-edge X-ray absorption spectromicroscopy (NEXAFS-STXM and NEXAFS-TXM). Following recent developments in X-rays collimation optics, synchrotron X-ray microscopy has emerged as a powerful means for chemical analysis of isolated nanostructures that have strong advantages in studies of radiation-sensitive materials. Information recorded in NEXAFS with high spatial resolution, is equivalent to that delivered by electron energy loss spectroscopy in transmission electron microscope (TEM-EELS) [Hitchcock; Micron 39 (2008) 311-319]. NEXAFS microscopy has significant advantages for determining molecular orientation in "soft matter" samples and unique capabilities for fully wet samples allowing for the study of dispersed nanostructure in liquids - the latter representing a common step in deposition techniques.

Traditional XRD is a valuable research tool for macroscopic samples but becomes problematic when the reduction of dimensionality limits the degree of structural coherence and XRD patterns of nanostructures show both Bragg-like peaks and diffuse components. Nevertheless, the combination of high-energy XRD and atomic Pair Distribution Function (PDF) data analysis has been reported to tackle the problem [Petikov; Materials Today 11 (2008) 28-38].

Interpretation of experimental data at the nanoscale requires appropriate high level electronic structure simulations. Limitations in both computing power and theoretical methods mean that calculations are commonly performed on less realistic small test systems containing at most only a few hundred atoms. Quantum chemical calculations are typically order N^3 , i.e. doubling the number of atoms in a simulation increases the computing requirements by a factor of eight. This places a severe limit on the size of calculations, and one of the aims of this Action is to bring together groups working on new order 'N' quantum chemical methods (for instance within AIMPRO), and extend the order 'N' methodology to transport modeling (extending the transiesta code to order-N or adding transport functionality to AIMPRO).

The improved resolution of new experimental techniques such as NEXAFS-STXM ('top down' characterization) is now reaching convergence with the increase in attainable calculation size ('bottom up' theory), allowing the two communities to talk directly for the first time about the same systems.

The aims of this Action are threefold. Firstly to develop new theoretical and experimental tools capable of detailed analysis of LDNs' interface behaviour. Secondly to develop suitable experimental and theoretical test case LDNs in order to explore specific aspects of such interface behaviour. Finally, to transfer this new knowledge to experimental groups within this Action working directly on new designs and applications using LDNs.

B.2 Current state of knowledge

The search for materials which can meet future industrial demands for device integration is pushing the development of new LDNs. Nearly every class of traditional material has a LDN counterpart; successful synthesis includes graphene-based and metal-oxide-based nanostructures. Graphene-based materials such as carbon nanotubes (CNTs), nanohorns (CNHs) and graphene sheets (GSs) have been identified as promising candidate materials for future electronic devices provided that the challenges related to production of high quality raw materials with uniform structure and properties can be met. However, to date it is widely recognized that achieving optimal integration in actual devices is the single biggest challenge for realizing the much-anticipated breakthroughs associated with the use of electronic devices based on individual CNT and GS. Since the pioneering work by Heinze et al. [Phys. Rev. Lett. 89, 106801, 2002], it is common knowledge that charge transport in the CNT channel is controlled by a Schottky barrier that forms at the junction with the metal source, and that the nature and geometry of this contact can drastically affect electrical behaviour.

For CNTs the critical importance of electrical contacts is quite well documented, but contradictory results have been reported on the dependence of the contact resistance upon the length of the contact region, and on the nature of the metal-nanotube interaction. Recently, Vitale et al. [J. Am. Chem. Soc. 130, 5848, 2008] showed that in addition to the metal work function, the specific character of the chemical bond at the interface is an important factor determining the Schottky barrier height. Notably, neither of these studies involves actual nanoscale contacts to CNTs, which is a prerequisite for technologically significant integration densities.

Further control of CNT channels was reported to be possible by endohedral doping, however exploitation of such approaches is in its infancy. Compared to CNTs and GSs, CNHs remain relatively unstudied despite their lower production costs, ease of industrial synthesis scale-up and their potential applications in fuel cells and batteries, notably through addition of Pt nanoparticles. In these cases, the metal-CNH contact transparency can radically improve their catalytic and operational behaviour, but to date there have been no reports on the behaviour of impurities at such interfaces. In addition CNHs low symmetry makes computer modelling difficult and requires

extremely large calculations beyond the ability of most current DFT codes. Disparities and limitations in the literature highlight the critical need to understand in detail what physico-chemical interactions occur when nanoscale metal contacts are established with LDNs and how these contacts can be processed to produce reliable devices.

Compared to carbon nanotubes, nanoscale tubular oxides are a relatively immature but rapidly developing field. Bulk oxides such as ZnO and TiO₂ are used for a wide range of applications including catalysis, fuel cells, light harvesting. Nanotubular and nanorod oxides offer the potential for massively increased active surface areas, and precise surface composition control through wet chemistry routes. However for this field to come of age requires a step-change in the knowledge of atomic surface structure and reactivity, and notably, interfacial behaviour between such oxides and supported material such as carbon nanotubes or metallic nanoparticles.

NanoTP focuses on the understanding and control of interfaces between nanostructures, to facilitate control of charge injection. The control of materials and their interfaces remains a central goal of modern materials physics and chemistry as atomically controlled interfaces become increasingly important in electronic nanodevices and their integration. Although Schottky, Mott and Bardeen by their pioneering work laid the foundation of our understanding of contacts at the macro- and mesoscopic scale, the nanosized objects require new insights because of the limited amounts of matter involved, the larger interface-to-volume ratio, the associated interface states, and the limited numbers of charge carriers available for screening. In essence, the contact region extends through the device with the result that contact formation chemistry dominates electrical performance. The well-recognized potential of LDN-based device applications provides impetus to understand contact formation in these systems.

Despite the significant literature, a long series of fundamental and unanswered questions remains: What concepts developed for bulk metal-semiconductor contacts can be applied to nanoscale systems? What role do defects and impurities play in metal-LDN interaction and how do their presence influence contact formation and electrical performance?

A key element of this Action will focus on developing suitable test systems such as metal nanoparticles supported on nanostructures, as important prototypes for understanding the nature of the metal-nanostructure interaction and interface formation. Several approaches will be developed to model, characterize, fabricate and control the physical-chemical properties of metal-LDN electrical contact.

B.3 Reasons for the Action

NanoTP will be built upon an integrated experimental and theoretical approach aimed at the understanding the physical and chemical properties of isolated LDNs. This will open the way to optimal integration and engineering of reliable nanodevices. The complexity of this effort requires a multi-technique effort: development of novel and integrated approaches for synthesis, manipulation, characterization and integration of LDNs that will further new perspectives for science and technology.

There is no other networking project that spans from synthesis of novel nanostructures and application to development of novel theoretical and experimental techniques. This network brings together pre-existing informal specialist networks, such as a network of nanoscale manipulation of graphene from Denmark, users and research scientists developing X-ray microscopes, the groups studying LDN surface functionalization, and the AIMPRO theoretical modelling network which extends across Europe. These networks are currently informal and receive no network funding. NanoTP gains significant added value from these groups since the networks are already in place, and NanoTP will serve to both support the links already existing within them and create synergies between them. Each of these informal networks focuses on one area of interest to NanoTP, which will provide an overarching framework within which they can work together towards development of new understanding and applications with controlled nanoscale interfaces.

Fragmentation and lack of resources for tackling major research issues in nanotechnology and application domains within the existing structure motivate this Action. The national and European research projects currently underway deal with the development of well defined topics. One major task of NanoTP is the coordination and further integration of the achievements of those R&D projects for the generation of a broad knowledge base for the entire field of nanotechnology. Without this collaboration European research in the subject will fall behind that in the USA and Asian countries where massive coordinated R&D programmes are being deployed.

B.4 Complementarity with other research programmes

There are several running national and European research projects that are directly related to the current proposal (examples of FP7: VIACARBON, CATHERINE, GRAND, FIBLYS, NANOIMPACTNET). Therefore, it will be possible to form links with these projects and organise joint workshops and seminars. The establishment of links and joint activities with directly related European projects and relevant COST Actions will be on the Management Committee agenda.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main scientific objective is atomic-scale interface design and characterisation.

C.2 Secondary objectives

From the scientific point of view, the new knowledge on hybrid systems comprising two interacting nanoscale materials whose electronic properties are affected by their dimension will open up a vast field for basic research – knowledge of the electronic properties of LDNs is the pillar for the development of new devices. The key motivation of this Action will be the sharing of expertise between groups working on new tools (experimental and theoretical) for characterization of isolated LDNs.

The Action goal will be achieved through objectives in the following areas:

Objective 1 - Synthesis of novel low dimensional Nanostructures (LDNs)

Objective 2 - Engineering of metal-LDN contacts

Objective 3 - Development of new tools for characterization and manipulation of LDNs

Objective 4 - Advanced characterization of LDNs and metal-LDN contacts

Objective 5 - Atomic-Scale quantum chemical modelling

Objective 6 - Integration in potential devices

The Action will provide resources for a pan-European effort, so that small laboratories with limited access to analytical facilities will be able to collaborate with other groups to synthesise, design, model, fabricate and characterise novel materials and devices. This action will therefore serve to spread know-how in the field to all participants' areas in Europe. This will lead to faster identification of and solution to problems and possibilities, thus increasing the competitiveness of European industries.

The main expected deliverables arising from the networking are:

- [1] Increased number of European scientific workshops and conferences led by ERA scientists in the field;
- [2] Intensification of collaborative work between the partners of the Action
- [3] Increased dissemination of information and documentation of scientific data
- [4] Increased sharing of scientific facilities
- [5] Increased number of joint publications within the Action
- [6] Decreased overlap of research in the ERA

NanoTP will seek to access the fundamental advantages offered by LDNs over traditional materials.

The main expected scientific, technological and industrial deliverables are:

- [1] New strategies to synthesize LDNs and tailor their properties.
- [2] New non-destructive experimental tools and strategies to study isolated LDNs,
- [3] New theoretical modelling tools to enable simulation of realistic nanoscale objects,
- [4] New knowledge on surface treatments of LDNs,

- [5] New protocols for creating robust, low-resistance contacts between LDNs and metal electrodes enabling the integration of LDNs in actual devices,
- [6] Theory and advanced modelling of LDNs, contacts and interfaces and for novel LDN design.
- [7] Development of new experimental tools and approaches to manipulate LDNs
- [8] Development of new experimental tools to characterize nanostructures and nanodevices under work condition
- [9] Improvements in reliability of nanodevices

C.3 How will the objectives be achieved?

The Action objectives will be achieved through networking between internationally recognized researchers; transfer of knowledge from Academia to industry will be stimulated by including specialists from industry for task-oriented discussions and investigations.

NanoTP brings together 25 groups that have made key experimental and theoretical scientific contributions. They will be the Action backbone; by sharing codes for theoretical models, synthesis strategies and characterization results, they will ensure high scientific quality from the outset:

- Theoretical models aiming to explore the structure, functionality and reactivity of atomic-scale interfaces between nanoobjects (carbon nanotubes, metallic nanoparticles and nanostructure oxides) will be generated by a team of scientists from different areas of expertise (objective 4, WG4)
- New advanced theoretical tools appropriate for the large-scale atomic modelling in objective 4 will be developed
- Scientists from different areas of expertises will focus on the development of new tools and strategies for LDN manipulation, assembly and characterization (objective 3, WG2)
- Several LDN synthesis routes will be developed and compared (objective 1, WG 1)
- Striving to develop reliable devices, WG3 will focus on several routes for LDNs integration through interface design.
- The knowledge acquired will be employed for the fabrication of demonstrator devices. (objective 6, WG3).

Highest benefit from existing complementarities can be drawn through exploitation of the Short Term Scientific Missions (STSM) offered by the COST framework. Workshops and scientific-retreats will be crucial to promote a cooperative and effective collaboration.

Exploitation and IPR: Intellectual Property issues arising as a result of the network's research will be explored in consultation with the partners' IP development offices, patents will be submitted where appropriate. Each partner has the responsibility to protect confidential data. At the outset, a Consortium Agreement (CA) will be established to deal with joint discoveries between partners at different institutions. The legal framework that defines knowledge and IPR ownership, use, maintenance, prosecution and licensing will be integrated into the CA. The network is strongly aware of the importance of IP protection and non-disclosure, since several of the members have substantial patent portfolios.

C.4 Benefits of the Action

The Benefits of the Action can be summarised under four groupings:

1 - Benefits for early starting researchers (ESR):

NanoTP will open the opportunity to work on issues embracing very different frameworks of ideas and technologies. ESRs will learn to understand how complementary knowledge is put together to develop new concepts.

The Action will ensure that ESR will be adequately trained in important subjects to meet the current and future challenges and competition in the nanotechnology field - they will:

- (i) be masters in state of the art concepts and techniques specific to their research,
- (ii) be familiar with the strengths and weakness of a number of techniques applied in the respective fields,
- (iii) be well placed to appreciate the implications of their own research results for other disciplines

- (iv) be able to understand the importance of the link between academic and industrial research and the challenges of the industrial implementation of basic research results
- (v) be prepared to assume team leadership in either academic or industrial work environments
- (vi) have skills in scientific communication.

ESRs will develop a critical appreciation of the whole intellectual process, from basic questions to highly specific technical investigations, and spacing out to the wider interpretation of results applied to actual devices.

2 - Scientific Benefits and Academic benefits for the networking partners:

Presently there is no single national or local group in Europe that is capable of carrying out all aspects of a complete project in nanotechnology by itself. The Action will enable the maximum level of integration and spread the excellence across the ERA.

Members will benefit from NanoTP's interdisciplinary nature which will enhance the research quality, the scientific reputation of the members and provide the launching pad for future collaborative ventures. Additional benefits for the members in terms of collaboration within the ERA will be:

- Development of longer term collaborations: NanoTP will both establish new collaborations and strengthen existing ones;
- Broadening of the instrumentation pool and expertise base, significantly enhancing the research and training opportunities available to each member;
- Integrating experimental and theoretical, academic and industrial research via inter-host mobility.
- Sharing of expertise and experience

NanoTP will generate new knowledge on the properties of interfaces between two interacting nanoscale materials, far beyond present state-of-the-art. This is justified by the fact that it will not only study already existing interfaces, but also apply specifically designed surface treatments with capability for controlled and site-selective chemical and electrochemical reactions, structural modification and diffusion control.

This Action aims at producing high profile research results which, when disseminated, will play a substantial role in contributing to international recognition of the COST networking scheme.

3 - Technological and industrial benefits:

- NanoTP's results should not only outline the most promising routes for defect-mediated engineering of various nano-materials, but also shed light on the behaviour of these materials under extremely demanding conditions such as irradiation-hostile environment in space applications and in fusion reactors.
- Since NanoTP will afford a sound, in-depth understanding of the underlying basic principles that govern interface formation, technological benefits concern principally the development of routes to fabricate reliable nanodevices.
- Development of new experimental and theoretical tools that will allow the European industry to hold technologies that will set the bases for the development of the post-nanotechnology era.

4 - Long term benefits to quality of life and environment

This Action will contribute to development of novel technologies which are indispensable for improvements in quality of life and the environment. The expected impacts on electronic components are extremely valuable for medical applications, chemistry and environmental applications, energy applications and information as well as in communication applications.

In addition, NanoTP will promote awareness among the public, regulation bodies and administrations on the safe use, recycling and disposal of nanostructured materials and nanodevices.

C.5 Target groups/end users

NanoTP will enable the ESR members to further their research careers and employment opportunities in generic and novel technologies. It will have a significant impact on individual members, all of which have a strong interest and/or have invested significantly in the nanotechnology field. The academic sector will enhance its research profile and will find new routes for research activities. The industrial partners in this Action will see the technology transfer from research to laboratory production line.

Another important target group will be the general public. The Action will be directed at the general public by providing access to its dedicated web site displaying its activities as well as the long term implications and consequences of its research concerning biological, security and environmental issues will be envisaged. In addition, it will include a strong two-way communication to evaluate the public concerns about nanotechnology and active methods such as open public days will be used to raise awareness of nanoscience to both inform and allay fears. NanoTP will promote a link with the EU funded network NANOIMPACNET (European network on the health and environmental impact of nanomaterials) to tackle issues related to risk and environmental impact assessment.

End users will be different industries as well as society (consumers). Knowledge built up by NanoTP will serve to improve the efficiency of nanobatteries, solar cells, fuel cells, LEDs, force sensors, bio-detectors, gas sensors, Micro/Nano-reactors, Micro-TAS (for micro total analysis systems), industrial chemical catalysis, water-treatment devices, internal combustion engine, FEDs

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

NanoTP initially focuses on the control of charge injection into nanostructures. This is of strategic importance for the development of European industrial capability in nanoelectronics.

The Action will coordinate different tasks to achieve the objectives described in section C. The work plan is organized in four complementary working groups, each devoted to a progressive development of synthesis, characterization, integration and modelling aspects.

Initially, this Action will focus on the study of carbon-based LDNs. In the short/medium term, the use of novel LDNs capable of carrying high currents, exhibiting unique properties in terms of chemical and thermal stability, as interconnects in integrated circuits is expected to reshape the development of functional devices. Looking further ahead, there are far-reaching and potentially extremely important applications for LDNs in many other fields, for example, chemical and biosensors, energy conversion and storage devices, field-emission displays, active and passive electronic components and electro-optical devices.

Description of the NanoTP tasks:

Task 1: Synthesis of Novel Low Dimensional Structures

This task focuses on developing a better understanding of synthesis routes for functional LDNs.

Task 2: Engineering of metal-LDN contacts

Through this task NanoTP will investigate different strategies to control the interface formation at the nanoscale for optimizing metal-nanostructure interactions.

New methods for assembling LDNs on suitable substrates will be studied.

Task 3: Characterization of LDNs and metal-LDN contacts

Reliability in characterization of nanostructures is a key issue for the development of novel devices. The exchange of experiences in similar technological fields avoids the multiplication of errors and fosters an effective task oriented development. This task combines the need for development of reliable measurement protocols and the evaluation of new non-destructive tools for characterization of LDNs.

Task 4: Theoretical Modelling

This task will consist in the development of new algorithms and modelling approaches allowing for the simulation of large scale systems, in collaboration with application oriented modelling groups, to interpret the results of Task 3 and to provide direction for Task 1. The key innovation step is a realistic model of LDNs and LDN interface.

Task 5: Integration of LDNSs in Potential Devices

This task will evaluate the knowledge developed in tasks 1-4. Fabrication of demonstrator devices comprised CNTs, novel low dimensional metal-oxide structures, such as nanotubes and nanoribbons (referred hereafter as MO_x -NN, where NN indicates nanotubes and nanoribbons and $M=Ti, Nb, Ce, Mo, W, Mn \dots$), CNT/ MO_x -NN and graphene channel materials will be performed. Gated devices will be investigated and optimized. Initially NanoTP aims at the development of new technology for optimisation and improvement of current sensing technologies for electromechanical sensors, chemical sensors and biosensors. In a later stage, NanoTP will study the impact of interface formation on the performances of particular transistor geometries and other devices.

Provisions for the inclusion of new participants and unforeseen activities: The tasks listed above are flexible and liable to alterations should new participants and unforeseen activities become available during the implementation.

Although several European groups are independent leaders with their efforts concerning the investigation of isolated nanostructures with distinct characterization techniques and with their specific strongly complementary competences, Europe has not yet established a clear leadership in this context. The possibility to complement these efforts financed on a national basis with a well-organized networking structure of European dimension is a unique opportunity of cross-fertilization between different partners. The open character of COST Actions is considered as particularly appropriate for the rapidly evolving field addressed here.

D.2 Scientific work plan: methods and means

NanoTP will achieve its scientific objectives through 4 inter-related work packages identified in the workgroups (WGs). These groups are responsible for carrying out the scientific tasks listed in section D1.

Synthesis of carbon-based LDNs, silicon nanowires (SiNWs), novel MO_x-NNs will be performed by WG1. The integration of these structures in reliable devices will be evaluated by WG3. WG1 will address different synthesis methods for LDNs such as chemical, electrochemical (anodizing, electroplating) and physical methods such as hydrothermal synthesis; thermal evaporation as well as plasma enhanced chemical vapour deposition (PE-CVD). The successful fabrication and integration of nanostructured materials will be supported by a range of novel and established advanced morphological and physico-chemical characterisation techniques like high-resolution electron transmission (HRTEM) and field-emission scanning electron microscopy (FESEM), TXM-NEXAFS, ToF-SIMS, STM as well as X-ray photoelectron and vibrational spectroscopies (addressed by WG2) which will be combined with advanced theoretical modelling (WG4).

WG1: Engineering of Novel Nanostructures

This WG will concentrate in the synthesis of metal-oxide (MO_x-NN) and graphene-based low dimensional nanostructures. Aiming at interface engineering, the key innovation will be the development of surface modification strategies that will not impact (damage) in the LDNs structure. Furthermore, nanostructuring approaches to engineer the basic electronic and mechanical properties through surface treatment and nanostructuring will be developed.

The scientific workplan for WG1 activities will include:

1. Catalytic protocols for the oxidation and exfoliation of pristine graphite material using innovative soft chemistry routes.
2. Electrolytic oxidation (anodizing) of superimposed or multilayered thin-film valve metals will be considered for generating self-organized nanocomposites or metal-oxide wide/narrow band gap semiconductors or interchanged metal/oxide structures with 2-D and 3-D periodicity and regular and controllable depth and concentration profiles at the nanoscale. Among suitable materials for these LDNs are amorphous or crystalline oxides of tungsten, niobium, titanium, molybdenum, tantalum etc. formed by anodizing under/through nanoporous anodic alumina matrix films. These anodically grown LDNs will have tailored shape and morphology (nanowires, columns, tubes, hillocks, dots or meshes) and population density (up to 10^{12} cm²); they can remain anchored to, or be released from, a metal, semiconductor or dielectric substrate, which opens numerous alternatives for their analysis and potential applications, particularly by making compatible their growth with Microsystems Technology.
3. Determination of synthesis conditions where the morphology and organisation of MO_x-NN can be specified with a yield of nearly 100%. Different transition metal ions can be intercalated into the structure, as an important step for the tuning of electric and magnetic properties.

4. Synthesis of nanotubes and nanowires directly on silicon devices. A part of this work concerns development of effective routes to fast, local CVD synthesis, where the heat is generated by an electrical current in a conducting silicon loop, the so called m-CVD approach. This allows convenient in-situ electron microscopy of the growing structures, fast optimisation, and is CMOS compatible - since only part of the chip is heated to high temperatures.

5. Nanostructuring of suspended and supported graphene and characterisation of the electronic and mechanical properties. The electronic properties of graphene can be tuned by periodic patterning of nanoscale holes, or by shaping the graphene flakes into narrow strips. The mechanical properties are extraordinary in several aspects: very high stability even for single suspended graphene sheets, and unusually low friction between individual graphene sheets. Different lithography methods will be used (Focused Ion Beam Lithography, Electron Beam Lithography, TEM - Lithography) to fabricate demonstrators. In-situ (TEM) and ex-situ electrical and mechanical characterisation will be carried out on these structures, with respect to the effects of nanostructuring and surface customisation.

Main Deliverable: Protocols for synthesis of novel LDNs and for control their surface and intrinsic properties.

WG2: Characterization of nanostructures and nanoscale junctions

This will be devoted to characterize physical and chemical properties of LDNs, the impact of post-synthesis treatment on the nanostructure electronic states and morphology and nanoscale junctions. A combination of traditional and innovative analytical spectroscopic techniques will be applied. The scientific workplan for WG2 activities will include the study of the chemical and physical properties of LDNs with complementary physicochemical techniques such as Raman, absorption and fluorescence spectroscopy, electrochemistry, thermogravimetric analysis, differential scanning calorimetry etc. Furthermore, state-of-the-art high-resolution electron microscopy (TEM and SEM), and dynamic light scattering (DLS) will offer insight into the morphology and structure of the LDNs will be used.

Strategies for identification of key parameters to tune the metal-nanostructure interaction a large-scale of spectroscopic and crystallographic analysis of metal-nanostructure contacts will be performed in addition to local measurements of the atomic scale structure and the local density of states (LDOS) by scanning tunnelling microscopy (STM).

New advances in traditional techniques are being also decisive for development of the novel nanotechnology era.

- High Resolution TEM (HRTEM) has always been an important means to study the atomic arrangements in nanostructures. The advent of aberration correctors has taken the capabilities of HRTEM to a new level at which the atomic arrangement and even single atoms can directly be imaged with a resolution approaching 50 pm. Beam-sensitive samples can now be imaged at low electron energies with reduced/without radiation damage, achieving resolutions which are still in the 1 Ångström range. In addition, scanning TEM in combination with high resolution spectroscopy makes it possible to probe the electronic structure of nanomaterials at the position of individual atomic columns. Electron microscopy (EM) uniquely allows the internal structure and composition of materials to be investigated at scales ranging from the nanometer to the sub-Angstrom. This has resulted in TEM becoming a primary tool for characterization in material science and nanotechnology. With appropriate experimental design it is possible to do more than simply obtain a static image, diffraction pattern, or chemical signature from a sample: the structure and the chemistry under applied bias (chemical, electrical, magnetic, etc.) can be observed in real time ("in situ") allowing evaluation of structure-processing-property interrelationships [Stach E.A., Materials Today 50 2008].
- Scanning transmission X-ray microscopy (STXM) provides excellent electronic and geometric structure characterization at a nanoscale resolution without impacting on the structure and allowing the analysis of samples at thickness of several microns - what reduces the impact of the sample preparation. STXM will be used to characterize metal-nanostructure interactions, and methods to retain desirable properties during assembly. Its analytical capabilities are an ideal complement to the higher spatial resolution imaging of STM and TEM.

- The new generation of full-field transmission x-ray microscope (TXM) for automated cryo-tomography and nano-spectroscopy overcome several limitations of conventional TXM setups. The separation of monochromatization and object illumination is the key to the new optical concept. A conventional grating monochromator provides the high energy resolution while a single-bounce ellipsoidal glass capillary employed as achromatic condenser illuminates the object. This optical concept works ideally in combination with an undulator source providing the required collimated x-ray beam and high photon flux. The TXM provides an energy resolution up to $E/\Delta E = 10^4$ which is well suited for spectromicroscopy. The sample stage of the TXM is an adaption of a state-of-the-art TEM stage allowing the usage of the same sample holder for TXM and TEM. With its unique energy resolution, the TXM also supports imaging in high orders of diffraction of the zone plate objective. Using this approach, a spatial resolution below 15 nm lines and spaces could be demonstrated and paves the way towards sub-10 nm real space x-ray imaging.

- Evaluation of the metal-nanostructure contacts
Electrical characteristics of metal-nanostructure will be investigated. Ballistic/non ballistic conduction will be probed. Mechanisms involved in metal/contact charge injection and transport will be examined both by low noise I-V measurements and by noise comparison (voltage and current fluctuations measured between the couple of amperometric and the couple of voltmetric contacts).

- Inelastic electron tunneling spectroscopy (IETS) has evolved into an essential tool in the understanding of nanoscale junctions. Its advantage over conventional optical vibrational spectroscopy such as infrared (IR) and Raman is its sensitivity. Since the interaction of an electron with molecular vibrations is much stronger than that of a photon, as little as one monolayer of molecules is enough to produce good IET spectra.

Main Deliverable: New techniques and protocols for the characterization of LDNs in a non destructive way, i.e. without impacting their structure.

WG3: Integration of Nanostructures in demonstrator devices

This work group will devote its efforts to the fabrication of metal-LDN contacts and their integration in actual devices in order to evaluate the protocols developed by workgroups 1 and 2.

The scientific workplan for WG3 activities will include:

1. Tuning of nanostructure interface properties by combining different surface functionalization methods (*i.e.* wet chemistry functionalization, plasma functionalization and/or spatially resolved active site creation via ion/electron beam modification).
2. Ion and electron irradiation experiments for tailoring the LDN properties.
3. Tool-based methods to manipulate nanostructures will be optimized. Methods for nanostructure positioning and manipulation based on the nanostructure's physico-chemical properties will be developed, as well as fabrication of special grippers and end-effectors to handle LDN's using mechanical force.
4. Metal - contact deposition: metal-inking with the aid of an STM tip, electron beam lithography (EBL), FIB-CVD, electron beam induced deposition (EBID), thermally deposited metal layers as well as chemically directed functionalized metal nanoparticles will be used to build up metal-nanostructure contacts. Contact characteristics will be explored: metal type, contact configuration, shape and interface chemistry. Post-deposition activation treatments will be performed to remove/burn off functional groups.
5. Based on the knowledge acquired on traditional LDNs, protocols to integration of novel nanostructures such as CNHs and GSs will be developed. NanoTP aims at the development of demonstrator devices such as electromechanical sensors, chemical sensors and biosensors, based on LDN transistor configurations, which will significantly benefit from the synthesis efforts of WG1.
6. The realization of electronic devices such as field-effect transistors requires controlling and even switching off the electrical conductivity with a gate electrode which is made difficult by the absence of a band gap in the intrinsic material - engineering of LDN band gap combined with advanced gate designs will be evaluated.

Main Deliverable: Optimized protocols for LDN integration in nanodevices.

WG4: Theoretical modelling

Modelling of structure and properties of complex surfaces and interfaces

Nanomaterial interface design requires detailed atomic understanding of the structure of the nanomaterials, their surface structures and reactivity, and key defect species. This information can then be fed into interface models of different combinations of nanomaterials in order to understand interface specific behaviour such as charge transfer, structural variation and impurity pinning. The combinations of nanomaterials to be considered here are diverse and led by experimental availability, including but not limited to carbon nanotubes, nanohorns (nanocones), nanoslabs and scrolls, graphene, metal oxide nanorods and nanoribbons, and metallic nanoparticles. Particular emphasis will be placed on "real-world" surface defects (such as "oxidised" vacancies in graphene based nanostructures) since the latter are often decisive for the material's response.

Modelling transport phenomena through molecular junctions and nanostructures

Results of structural studies can be used to simulate the transport properties associated with different nanoscale interfaces, for example allowing prediction of Schottky barrier effects, spin-injection, and defect-induced charge scattering at interfaces and within the nanomaterial 'bulk'. This provides the key bridging step between the atomic structural calculations and experimental transport measurements.

Modelling of irradiation-induced phenomena in nanostructured materials

By combining multi-scale simulations and experiments NanoTP will study irradiation-induced phenomena in nano-structured materials. The expected knowledge will help to develop new irradiation-based methods for processing these nano-materials. The multi-scale simulations will be done at different levels of sophistication, ranging from time-dependent density-functional-theory models to kinetic Monte-Carlo approaches. NanoTP aims to obtain fundamental understanding of irradiation effects in nanoscale materials and to use this knowledge to optimize the irradiation process and minimize the irradiation damage, when it is an unwanted phenomenon.

Modelling of point and line defects

NanoTP will address the role of defects and active sites, for example in controlling mechanical properties of carbon nano-materials due to cross-linking and functionalization. The role of defect-defect interaction, for example dopant atom or functional group self-organisation, will be explored, along with the impact this has on device behaviour. Particular attention will be paid to graphene, as essentially nothing is known about its response to ion and electron irradiation, or dopant behaviour. NanoTP's results should not only outline the most promising routes for defect-mediated engineering of various nano-materials but also shed light on the behaviour of these materials under extremely demanding conditions such as irradiation-hostile environment in space applications. These results can be compared with heteroatom defects induced through growth doping and heteroatom implantation, allowing construction of detailed pictures of defect formation, aggregation and response in these nanomaterials. This can feed into understanding of defect surface segregation and thus their importance in controlling interface behaviour.

Development of new modelling tools

New approaches in implementing localised basis set DFT using novel basis set contraction approaches, alternative functionals, as well as cross-over with multi-scale modelling approaches such as DFTB and embedding will be explored with the aim of producing a rapid code whose speed scales linearly with the number of atoms. New functionality will be added to the existing code (e.g. incorporation of dispersion forces) making it better adapted to the modelling of nanoscale interfaces. In parallel with this, improved transport codes based on nonequilibrium Green's functions (NEGF) will be developed, both for effective modelling of transport properties in realistic nanomaterials (e.g. with defects, substrates, gates and/or contacts), as well as for complete STS simulations of nanointerfaces. Given the range of theoretical experience represented within NanoTP (partners are active developers for a range of DFT, DFTB, TDDFT, NEGF and empirical potential codes), there is scope for exchange of best practise, shared development of new functionality that may be useable in different codes, as well as benchmarking and 'round robin' testing of new methods using real-world test systems from the more applications-oriented theoretical groups.

Main Deliverables:

- Development of new versions of DFT and DFTB codes (AIMPRO, DFTB+, transiesta ...) capable of simulating extremely large scale systems (Order 'N'). Development and integration of large-scale transport simulation techniques, allowing development of new knowledge of nanomaterial interfaces at the atomic scale.
- Fundamental understanding of defect formation and behaviour in LDNs (e.g. through growth or irradiation) and use of this knowledge to optimize doping, irradiation and post-growth treatment processes such as functionalisation to control interfacial defect behaviour (such as minimizing irradiation damage, when it is an unwanted phenomenon).

E. ORGANISATION

E.1 Coordination and organisation

Chaired by the Action Chairperson, NanoTP will be coordinated by a Management Committee (MC) following the "Rules and procedures for implementing COST Actions".

In line with the COST mission, i.e., to strengthen Europe in scientific and technical research through the support of European cooperation and interaction between European Researchers.

NanoTP will have 4 coordination aspects to achieve its objectives: management, dissemination of the Action, networking and activities:

- (i) **Management:** the MC, chaired by the NanoTP Chairperson, will steer and oversee the activities, and ensure that the milestones are accomplished. The MC will meet twice a year and convene for additional meetings if any special need arises. One member of the MC will report on gender related issues and early career researcher activities.

A core group of the MC will be nominated to assure more rapid, efficient and flexible coordination of NanoTP. This core group (CG) comprises the NanoTP chair person, WG leaders, and three emerging researchers nominated by the MC as dissemination manager, STSM manager and editorial manager. The CG will prepare the various documents (scientific, orientation, etc) for the MC meetings.

(ii) Dissemination of the Action:

The dissemination manager will oversee the creation and maintenance of a website in accordance with COST office requirements. This interactive web site will contain information about partner groups, research activities, conference/workshops/symposia, list of potential host groups for short visits/training, forthcoming activities, device/sample exchange. It will faithfully provide the agenda and minutes of each MC meeting; include annual, cumulative and final reports; provide a complete list of NanoTP MC members and a short CV of each member.

(iii) Coordination of networking and capacity building activities:

These activities will be coordinated by the four WGs managers and the chairperson:

1. Organisation of the various training opportunities such as summer/winter schools, short term scientific missions, hands-on training at selected centres participating in the NanoTP;
2. Encouragement of publication of scientific collaboration within NanoTP in special issues of scientific journals;
3. Fostering links with other relevant EU programmes and industry;
4. Organisation of joint workshops with other COST actions on interdisciplinary areas.

(iv) Coordination of NanoTP meetings and workshops

1. The Action will organise a kick off meeting to which all members will be invited. During this meeting the detailed work plan and the management structure will be discussed and decided;
2. MC meetings will be held twice per year where the forthcoming Action activities will be planned and those that have taken place will be reviewed;
3. The Action attaches upmost significance to the training of early career researchers. Therefore, in addition to the short term scientific missions, there will be a summer/winter schools on a specific topic every year;
4. The Action will complete its activities via the organisation of an international conference: "Designing novel materials for nanodevices"

Deliverables and Milestones:

Year	Milestones	Deliverables
1	<p>Month 3: Kick of meeting. MC set up, Work Plan is established</p> <p>Month 6: MC meeting1; Scientific Strategic meeting 1</p> <p>Month 6: Call for NanoTP Training Schools</p> <p>Month 12: MC meeting 2; Scientific Strategic meeting 2</p>	<p>Publication of NanoTP list of infrastructures</p> <p>STSM report</p> <p>WGs reports</p> <p>Annual Report</p> <p>Interactive web site fully operational.</p> <p>Publication of Curricula for year1 and year2</p> <p>Training Schools</p> <p>Summer School1</p> <p>Workshop1</p> <p>Workshop2</p>
2	<p>Month 18: MC meeting 3; Scientific Strategic meeting 3</p> <p>Meeting/Discussion to identify the best dissemination activities</p> <p>Month 24: MC meeting 4; Scientific Strategic meeting 4</p> <p>WG Chair meeting to review the NanoTP scientific strategies.</p> <p>Month 25: Interim report containing summary and ideas from the workshops</p>	<p>STSM report</p> <p>WGs reports</p> <p>Annual Report</p> <p>Publications of Joint Scientific Activities</p> <p>Winter School 1</p> <p>Main parts of the website translated into the languages of the NanoTP countries</p> <p>Overview of the plans and themes for future workshops</p> <p>Workshop3</p> <p>Workshop4</p>
3	<p>Month 30: MC meeting 5; Scientific Strategic meeting 5</p> <p>Month 36: MC meeting 6; Scientific Strategic meeting 6</p>	<p>STSM report</p> <p>WGs reports</p> <p>Annual Report</p> <p>Publications of Joint Scientific Activities</p> <p>Summer School 2</p> <p>Review paper or report on Nanotechnology</p> <p>Workshop5</p> <p>Workshop6</p>
4	<p>Month 42: MC meeting7; Scientific Strategic meeting 7</p> <p>Month 48: MC meeting 8; Scientific Strategic meeting 8</p>	<p>STSM report</p> <p>WGs reports</p> <p>Annual Report</p> <p>Publications of Joint Scientific Activities</p> <p>Proceedings of International Conference</p> <p>Winter School 2</p> <p>International Conference is held</p> <p>Workshop7</p> <p>Workshop8</p>

E.2 Working Groups

The Management Committee (MC) defines 4 initial workgroups (WGs):

WG1: Engineering of novel nanostructures

WG2: Characterization of nanostructures and nanoscale junctions

WG3: Integration of nanostructures in demonstrator devices

WG4: Theoretical modelling

Each WG will have a chair person and a vice-chair person who are selected by, and report to the MC. They will coordinate the WG networking and capacity building activities and stimulate short term mission activities. They will also provide their WG's contribution to the annual reports via reporting on activities within their WGs. To maximise the impact of the COST Action all four WGs will very closely collaborate. Interactions amongst these WGs will build-up a multi-/interdisciplinary Action that will be responsive, adaptive and flexible to new scientific and technological demands.

Each WG will house a number of ESRs and women from the member states. Other WGs may be added and modifications of any existing WG (addition of members with new competences) may take place during the course of NanoTP.

E.3 Liaison and interaction with other research programmes

The interaction with other COST Actions and other European and International programmes will be maintained throughout the duration of the programme. These will be achieved via:

1. Fostering links with other relevant EU programmes;
2. Organisation of joint workshops and seminars with other COST actions on inter disciplinary areas;
3. Organisation of annual WG meetings together with activities (conferences/meetings) of other relevant Actions;

NanoTP partners already participate in other European programmes and bilateral actions between European countries.

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

This Action will respect an appropriate gender balance in all its activities and the Management Committee will place 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.

NanoTP will link the research disciplines of electrical and electronic engineering, physics, chemistry and material science through pools of teams from at least 17 European countries. It will enhance/accelerate exchanges of expertises between ESRs from various states and it will extensively involve women in networking. An extensive contribution of women scientists will be encouraged. Men and women will have equal opportunities in all the activities (including management, spreading excellence, research, networking and scientific integration) of this COST Action.

All the members of NanoTP support fully that:

- (i) Women's participation in research must be encouraged both as active participants and within the evaluation, consultation and implementation processes;
- (ii) Research must address equally women's and men's needs;
- (iii) Research must be carried out to enhance the inter-gender understanding and to contribute to gender issues in general.
- (iv) Research must be carried out to enhance all unrepresented groups in science such as ethnic minorities and physically handicapped.

This COST Action is committed to the following:

- (i) Specific measures will be taken to increase the number of women working in the Action and to bring them into key positions in the Action;
- (ii) NanoTP will appoint a member of the MC for taking responsibility for gender issues and the involvement of ESRs. This will be made an agenda item at a MC meeting when necessary;
- (iii) Female participants will be encouraged to be on the MC and lead the WGs;

- (iv) Affirmative actions (ex. preference for hosts with available children care) will be taken to enable ESRs of both genders to attend workshops and summer/winter schools.
- (v) Attention will be paid to gender balance in invited external experts and new teams.
- (vi) To further address gender issues, a direct link will be established with the European funded network "Diversity".

We note that the research activities coordinated in NanoTP are in a domain that has no direct relevance to the gender of the participants, so that there is no gender issue in the technical research to be carried out.

Due to beneficial importance of the collaboration between experienced researchers and early stage researchers, NanoTP will promote this collaboration placing both at the same management levels. Each WG will include a number of ESRs selected from participating countries.

In addition, during the meeting of WGs and training schools, team leaders will favour the invitation of ESRs to present communications and participate in their organisation.

A major advantage of the COST framework is associated with STSM since techniques applied within WGs are highly specialised and cover various disciplines, expensive equipment and different scientific expertise. Acquisition of knowledge in such techniques will result from training in this Action.

F. TIMETABLE

The Action will proceed over four years. Below is given a tentative timetable. Due to the nature of the COST framework of collaboration, the specific topics of the work may be shifted with time in order to adjust to specific needs identified by the Action.

The first period of six month is devoted to building the WGs in line with the topics outlined in Section D. The MC will ensure that the work is well focussed, that fruitful collaborations between the participants are either initiated or developed and that synergy is created between the WGs.

Activity	Year 1	Year 2	Year 3	Year 4
WP1				
WP2				
WP3				
WP4				
Other Activities:				
- Kick off meeting	X			
- Establish work plan	X			
- Set up website	X			
- Workshop	X	X	X	X
- Training school on specific themes	X	X	X	X
- Scientific Retreat		X	X	X
- Training activity		X	X	X
- Final meeting of WG				X
- International Conference				X
Management Committee	2 meetings	2 meetings	2 meetings	2 meetings

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, DK, FI, FR, DE, GR, IE, IT, NL, PT, SI, ES, SE, CH, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 60 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

The NanoTP Dissemination Strategy will be responsible for and flexible acceptable to the needs of the different target audiences through a wide range of highly adaptable communication channels whereas working towards its objectives. NanoTP will adapt the nature of the message to its target audiences. Target groups are expected to evolve with The Action development and innovative ways to address them will be sought.

The following target groups have been identified:

- Opinion formers, European-level and regional-level Research Policy decision-makers
- National and European Research agencies
- Media: scientific and non-scientific press, digital media and TV
- Universities/Research Institutions/Academies
- Research funding/performing organisation (e.g. Science Parks or Museums)
- Nanotechnology based industries (manufactories, service providers and analysis equipment industries).
- Other COST Actions, European Cooperation projects, Network of Excellence
- Individual Researchers: Early stage researchers and other researchers working in the field, and graduate and PhD students
- General public

H.2 What?

The dissemination plan is designed to achieve a maximum transfer of new knowledge to be gained by NanoTP. To maximise the dissemination of the results and progress of this Action four distinct routes will be used:

1. A dedicated interactive website will set up with two levels of access:
A dedicated website will be set up on a server of one of the partner's institutions. It will include a private area, accessible to the NanoTP partners only and a public area. The website will be maintained by the Dissemination Manager appointed by the MC and supported by the CG.

(i) Public accessible level

The public area will allow broad dissemination of the Action outcomes in form of common scientific publication database and information on past and upcoming events. This will contain information about the management structure, contact points and activities of the Action including conferences, workshops, symposia, training schools, training events (both within the network and worldwide), list of potential host groups for technical visits and training. Links to publications and articles in scientific and technical journals, proceedings, job opportunities, project opportunities, PhD and MSc studentships will also be available.

(ii) Password-protected level

This access-level will allow private information exchange about available facilities and work in progress for members of this COST Action only. It will contain information about MC meetings, scientific reports, non technical interim and annual reports, STSM reports, financial reports, working papers, guidelines and manuals.

- An internal Virtual Research Centre will be established to ensure maximum knowledge transfer amongst members. Information from current scientific activities of each partner will be displayed in this reserved area of the web-page.
- There will be an “e-lab_book” containing information of all activities related to NanoTP. The main objective of the e-lab_book is to facilitate and track device/sample exchange, characterization results and validation tests inside the Action; page encryption may be implemented to guarantee the documents.

3. Shared electronic documents and an e-mail network will be established for the whole Action.

4. Electronic discussion forums

5. Scheduled meetings will be established: workshops, seminars, retreats and conferences will be organized by the MC, in parallel with national and international conferences and symposia

6. Regular researcher exchanges between sites.
7. Participation in industrial forums such as “TRIZ-Conference: Current scientific and Industrial Reality - Chamber of Commerce and Industry Frankfurt-Germany”.
8. Training schools and training events will be organized, as well as lectures by leading scientists and engineers from both academia and industry.
9. Links with others Actions, NoE, ITN-MC, NMPs - links will be established with the most relevant funded projects with proximity and/or complementarity objectives.
10. Publication of articles in peer-reviewed scientific and technical Journals
11. A virtual centre for external visibility and dissemination of best results will be implemented; this will be updated for release with a professional broadcast quality documentary with S&T advances related to NanoTP - this will be available streamed from a science communication expert website. It will be directed primarily towards the general public. It will include a strong two-way communication to ensure efficient dissemination, while at the same time obtaining input from the general public about their concerns on nanotechnologies. To address concerns such as human hazards and exposures, hazards and fate of nanomaterials in the environment and impact assessment, a direct link will be established with the European funded network: “NanoImpactNet”.
12. Non-technical publications: Press Briefings and Press Releases will be available for public dissemination. Technical publications will be prepared by the respective partners.

H.3 How?

NanoTP Outreach strategy follows the integrated communications approach:

- End-user oriented: NanoTP commits to the end-user by focusing on end-user friendly and end-user active communication.

- Consistent yet adaptable: NanoTP achievements will be present in a consistent (especially when explaining scientific results) yet adaptable as different target end-users require different sort of information (e.g. some require a specific terminology whereas others require jargon-free information) to receive the same intended information
- Innovative yet appropriate: messages and communications activities will be aligned with the promise they will deliver.
- Feedback-oriented: Feedback tools will be implemented in all applicable dissemination activities. The Outreach strategy will be adapted to arising needs and internal and external communication processes can be improved.

The following selected routes will contribute to dissemination activities:

1. The website will be a vital point for dissemination by providing information about the Action, including the management structure and contact points as well as its activities including conferences, workshops, symposia, training schools, publications and articles and technical journals, proceedings, job opportunities, project opportunities, PhD and MSc studentships, access to scientific, interim and annual reports, case study and STSM reports, device/sample exchange, financial reports, working papers guidelines and manuals.
2. Mailing lists for the committees and members of WGs will allow coordination and information exchange at each level.
3. Workshops, seminars and conference organised by the MC will also be key dissemination points to other research groups and industrial players. Particular attention will be paid to organization of such events in conjunction with other international activities to enable dissemination to broader audiences.
4. Scientific Retreat: Although internet communication tools are available for all partners, NanoTP will further promote cooperation between partners with the use of a scientific retreat, creating a distraction free environment allowing intensive discussion, debate and brainstorming. The retreat will be used as a tool for the network, creating space/time for participants to plan collaborative experiments, write joint papers and grant applications together.

5. Training schools, training events as well as lectures given by leading scientists and engineers from both academia and industry will enable dissemination primarily to ESRs and PhD students. The progress of the Action as well the results of its evaluation will feed in to uploading the dissemination plan during the course of the Action.
6. Training in advanced techniques of science communication will be included in the training activities targeting ESRs.
7. Subject to copyright and licensing arrangements, a copy of publications arising from and supported by this COST Action (including journal articles, books and conference and workshop proceedings) will be deposited in the e-print repository of the COST Office.
8. The Final Evaluation Report will cover the dissemination and exploitation of the results in line with the DC's Terms of Reference

The MC will produce, following the DC's Terms of Reference requirements, a revised dissemination plan and will include it in the annual report to be approved by the DC. Therefore, once the action begins, there will be a continuous monitoring of the dissemination by checking the following indicators:

- (i) Increased number of European scientific workshops and conferences in the field by scientists in the Action.
- (ii) Increase in the collaborative work and joint publications between partners of the network;
- (iii) Increase in distribution of information and documentation of scientific data and materials via the dedicated Web site;
- (iv) Increased number of available PhD and MSc. in the Action field;
- (v) Increased number of STSMs and participants of training schools, workshops and training events.