InForm

Integrating Nanomaterials in Formulations

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InForm

INTEGRATING NANOMATERIALS IN FORMULATIONS

Executive summary

This report contains an overview of the outcomes of InForm, to provide a general view on the activities carried out during the project and the lessons learned as a result of them.

The report takes examples from the meetings, researcher exchanges, fact finding missions and other activities carried out over the past 3 years to highlight the state of the art in the six areas covered by this project:

Nanobiomaterials
Nanopowders
Stability of suspensions and processing
Physical chemistry at the nanoscale
Films, tapes and coatings
Heath and environmental aspects

An analysis of the innovation pathways observed in different success stories is presented, with some case studies to illustrate the different pathways, and an overview of the innovation stakeholders in the development of formulated products containing nanostructure materials is presented, and recommendations for future needs.

Finally, the expected impact of the project is detailed in terms of the reinforcement of the international dimension of EU research within FP7, the new approach to International scientific and technological cooperation, the facilitating joint projects and the realisation of future coordinated calls as a result of the activities carried out in InForm.

InForm

InForm is an FP7 coordination action, aiming to facilitate the exchange of ideas, knowledge and best practices in the formulation community, to facilitate incorporating novel nanostructured materials into formulated products. As a result, InForm has brought together various stakeholders in the product innovation chain, including academic and research institutions, SMEs, large companies, and learned societies, among others.

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Project description: nanomaterials in formulations

Formulated products make our lives healthier, safer and more comfortable, ranging from medicines and personal care products, to coatings that will prevent corrosion or reduce energy waste. A formulation contains all the information about the ingredients needed and the necessary method to obtain a product that will have a commercial value. The best cocoa beans will not necessarily give you the best chocolate … the secret is in the method of preparation. The same applies to cooking and other types of preparation or formulations.

At present, the design of formulated products is based on repeated cycles of measurements and testing, and the optimisation strategy depends, to a large extent, on the "experience" of the formulator. Formulation design has been identified as the bottleneck in the development of new products, and it will certainly continue to be as the range of "ingredients" that can be added to a formulation to provide a specific function increases, and as new technologies to assemble them are developed.

During the last decades, the investment in research in nanostructured materials has been impressive. FP6 allocated €1,300 million and FP7 budget is €3,475 million, while in the USA the National Institute of Nanotechnology will receive $1.5 billions funds in 2009, and more initiatives are springing up in Asia and the USA, including the Nanoscience and Nanotechnology Initiative (NUSNNI) in Singapore. Current research activities in Europe and the rest of the world are creating a significant knowledge base in the synthesis of new materials with predictable properties and specific functionalities. Therefore proper coordination mechanisms are needed to fully take advantage of those materials in consumer oriented products (formulations), as well as to provide feedback to the research community on the suitability of the materials that have been developed, and identify problems that cannot be addressed with currently available materials, as well as the desirable targets for the development of novel nanostructured materials.

The range of nanomaterials that can be incorporated in formulations is extremely wide, because formulations include a broad spectrum of products; titanium dioxide and zinc oxide nanoparticles have been included in sunscreen lotions to protect us from sun burns and prevent skin cancer, nanostructured controlled release devices and self-assembled structures of chitosan and polyvinylacetate have been created to deliver the appropriate amount of a drug to a patient, nanoparticles have demonstrated increased cytotoxic activity in the fight against cancer, a number of biomolecules are formulated as nanoparticles to increase their potency and reduce dosage levels, and designed copolymers can create smart surfaces and coatings that will respond to changes in the environment. The introduction of such novel materials in formulations also requires a careful evaluation of the environmental impact and toxicological effects.

InForm was established as an FP7 coordination action, aiming to facilitate the exchange of ideas, knowledge and best practices in the formulation community, to facilitate incorporating novel nanostructured materials into formulated products. As a result, InForm has brought together various stakeholders in the product innovation chain, including academic and research institutions, SMEs, large companies, and learned societies, among others.

InForm aimed to create a simple and efficient method for the coordination of research activities in the area of nanomaterials in formulations. InForm created appropriate platforms for dissemination of first hand knowledge of the state of the art for the synthesis, handling and use of nanoparticles and nanostructured materials in formulations, establishing contacts between researchers from Europe, USA and Asia-Pacific

working in academia, public research laboratories and industry in order to identify and enhance complementary interests. This network eventually reached other world regions.

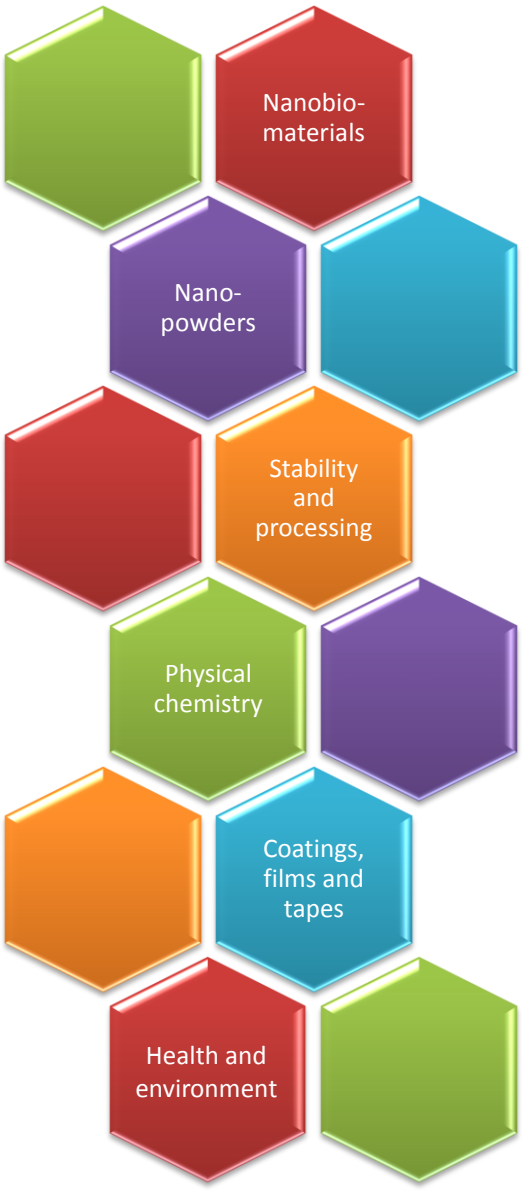
The specific objectives of InForm can be summarized as follows:

1. To facilitate access to people in academia, research institutions, industry and SMEs working in formulations using nanomaterials, or on the development of new materials with exciting properties, to high quality, EU funded, networking events to identify and enhance complementary interests within Europe and targeted regions: America and Asia-Pacific.

2. To create appropriate international forums and activities to obtain first hand knowledge of the state of the art in the six targeted areas of knowledge relevant to the use of nanomaterials in formulations.

3. To establish a short term researcher exchange program to seed new collaborations and create partnerships within Europe and between Europe and targeted regions.

4. To establish easy access and readily available networking tools that will facilitate the creation of partnerships within Europe and targeted world regions, and provide up to date information for funding applicable to the incorporation of nanomaterials in formulations.



A wide variety of activities were implemented as part of InForm to accomplish these objectives. The flagship activities were a series of three international meetings branded as NanoFormulation, which took place in Stockholm (2010), Singapore (2011) and Barcelona (2012).

The meetings consisted on conference like sessions, but additional structured networking activities, fact finding missions, and training sessions were organised, covering the six areas relevant to formulation of nanomaterials:

- Nanobiomaterials
- Nanopowders
- Stability of suspensions and processing
- Physical chemistry at the nanoscale
- Films, tapes and coatings
- Health and environmental aspects.

A researcher exchange program was also developed to facilitate the formation of specific partnerships.

Project outcomes

Within InForm, we have reviewed the state of the art, challenges and needs for successfully incorporating nanomaterials in formulations. We have identified six main topics of interest to cover different aspects of product formulation where nanostructured materials play an important role:

Nanobiomaterials
Nanopowders; solid formulations and handling
Stability of suspensions and processing
Physical chemistry at the nanoscale
Films, tapes and coatings
Heath and environmental aspects

Each of these areas faces some particular challenges to facilitate innovation and the successful incorporation of nanomaterials in formulated products. Nevertheless, all of them share some common aspects. Within InForm we have been able to identify that the pathways for innovation are shared between different types of formulations, regardless whether it is a powder or a film. We have also identified the different needs, bottlenecks and opportunities where future coordination actions are expected to have a strong impact in the innovation process. We also identified the challenges in the particular areas where fundamental research is needed, others where the fundamental research is considered sufficiently solid but proof of concept for specific applications is needed, and those where benchmarking and standardization are currently the limiting factor for the successful commercialization of formulations containing nanostructured materials.

The following sections describe the main outcomes of the project, initially focusing on the six thematic areas, the nanoformulation conference series and the researcher exchange programme, and finally bringing together the knowledge gathered to understand the innovation pathways for the development of formulated products that contain nanostructured materials, followed by some recommendations.

Nanobiomaterials

Formulation of materials at the nanoscale is scientifically challenging requiring novel physico-chemical and technological approaches. The formulation of nano-biomaterials is even more challenging due to specific requirements for biomedical applications such as biocompatibility, bioavailability and specific targeting. The use of nanomaterials in medicine provides new and unique medical effects, mainly by adding new functionalities to existing products (as drug delivery systems) or by playing a therapeutic role.

During the three-year InForm activities, it has been evident that the basic knowledge on formulation of drug delivery systems (DDS) at the nanoscale is fairly good. The most developed DDS are based either on soft materials (such as vesicles, micelles, nano-emulsions) or on hard matrerials (such as inorganic, organic, hybrid nanoparticles). Control of size, shape and drug loading as well as improvement of drug bioavailability, targeting to specific sites and ability to cross biological barriers are aspects that at laboratory scale are fully developed, as pointed out Prof. Chrsitine Vauthier at NanoFormulation2011.

It is also worth noting the development of nanoscale materials based on dendrimers and fullerenes for medical applications, as discussed by Prof. Toyoko Imae in NanoFormulation2010. Among the most interesting developments on nano-formulations, nanosheets as biomaterials intended for multiple applications deserve special attention. These nano-scale materials were introduced by Prof. Shinji Takeoka in NanoFormulation2011 in his lecture “Fabrication and Properties of Ultra-thin Films (nanosheets) as Innovative Biomaterials”. The most promising strength of nano-biomaterials is their great potential for multifunctionality, combining several useful properties acting in coordinated way allowing for enhanced efficacy. In addition, the interest of the nanosheet development is their production at a large scale, in contrast to most of nano-biomaterial developments which have not been scaled up.

As a result of the discussions during the three meetings, it became clear that characterisation of nanobiomaterials is of paramount importance. The surface properties of nanoparticles and other nanostructures can change dramatically as a result of changes in the surrounding media, which can result in a different behaviour from what was originally intended.

Nanopowders

An extraordinary range of nanoparticles and nanopowders have been developed over the past years, as those outlined by Prof. Kitagawa in Nanoformulation2011. The progress on tailoring their surface properties has been remarkable, but challenges in processing nanopowders still remain unsolved.

Much of the interest in nanopowders resides on their remarkably rapid solubilisation rates due to their high surface to volume ratio. Evidence of this was seen in a number of presentations during NanoFormulation2010 and NanoFormulation2011. Nanopowders can also exhibit high reactivity, not only due to the high surface area, and the metastable nature of freshly prepared nanoparticles can lead to a large range of functionalities, as described by Shu-Hong Yu in NanoFormulation2011.

Nanopowders show strong cohesive energies which prevents processing them efficiently in traditional equipment like fluidized beds. Nanoparticles may not exist as such in all processing steps and processing agglomerates may be a suitable option in some cases. Nevertheless, breaking the agglomerates to form fully dispersed systems requires skill, experience and potentially energy intensive processing. A recent review by van Ommen et al. (J Nanopart Res (2012) 14:737) describes the state of the art in nanopowder fluidisation. Understanding the advantages of different processing routes can lead to efficient scale-up of new synthesis methods. For example, the use of supercritical carbon dioxide in the production and processing of nanoparticles with a controlled size range was discussed by Satoru Watano in NanoFormulation2011. Dr. Philippe Rogueda in NanoFormulation2012 also highlighted some important differences in handling and drying model powders and nanopowders of importance in the pharmaceuthical industry. Discussion around this topic also showed the need for knowledge transfer, as some fundamental knowledge that exists in Universities has not made its way to Industry.

Do we always need Nano?

Nanostructured materials are not the answer to every problem. Nanopowders are not effective drug delivery carriers for inhalation therapy as they are not retained in the alveoli and are expelled when breeding out.

Suspension stability and processing

A variety of technologies are involved in the entire process chain of making soft formulations based on both soft and hard nano-particles. This includes the production of the nanoparticles in itself, but more importantly also their direct processing into formulated end-products. These topics not only span across different applications areas and industrial sectors but also across different fields of science and technology.

Contributions from scientists and technologists working towards the understanding and production of nanoparticle dispersions intended for biomedical (diagnostic and therapeutic) and pharmaceutical (drug delivery) applications have been abundant at all sessions. It is also within these fields of application that the more concrete examples of work addressing scaling-up issues have come from. This is noteworthy and reflects the advance and relative openness due to positive public perception this area has in relation to other application areas.

A large number of research groups around the world devote their efforts to the investigation of the stabilization and properties of hard nanoparticle suspensions. Many interesting examples of this type of work were presented at NanoFormulation events, in particular in regards to rheological behaviour of nanoparticle suspensions and novel types of stabilizers. At the same time, the ultimate challenge with nanoparticle and nanoformulation production remains the translation of elaborate and difficult laboratory processes (usually involving multiple batch steps) into large reproducible, economically viable processes. A glimpse into the challenges and advances in this area was presented by technologists from the academic (engineering) and instrumentation world. A good example of this is the work presented by Prof. Robert Prud´homme at NanoFormulation2010 on a nanoparticle production process which was successfully

commercialized to 1400 Kg/day and combines novel impinging jet mixing technologies and the use of block copolymer stabilizers. Another example was presented by David Weiss in NanoFormulation2010 on the scale-up of microfluidic processes to produce highly controlled drops and emulsions. Charles Zukoski in NanoFormulation2012 described the importance of nanostructures as polymer fillers and emphasised in the use of predictive tools to improve the selection of starting materials as well as processing conditions.

Successful scale-up was consistently identified as a bottleneck for commercialisation of the products, even though excellent examples of innovative scale-up processes were also presented during the meetings. We expect that some ideas will be borrowed between different fields to improve other processes.

Physical chemistry at the nanoscale

Physical chemistry, particularly surface and colloid science, is the most important underpinning science base for nanotechnology. The reason why nano-sized materials are not already familiar to the general public is that they are difficult to make, and when made, are inherently unstable. Their routine synthesis and stabilisation requires innovative manufacturing routes accompanied by a step-function improvement in the understanding of their structure and properties.

As an example, the microfluidics technology described by Panagiotou in NanoFormulation2011 offers a range of methods for the production of various nanoparticles including both liquids and organic solids. Other types of particles, even very high melting point materials, can be made (see Mikac et al, NanoFormulation2011).

Phase behaviour and stability of these novel materials are at the heart of formulation development. The wide range of currently available nanoparticles and nanostructured materials has an extremely rich phase behaviour. For example, unseen collective behaviour is observed in rod shape liquid crystals packed in nanodroplets induce ordering of water and surfactant molecules at the drop interface which can lead to important effect in terms of drop stability (Nature, 2012; 485 (7396): 86).

Extraordinary properties can also be observed in a polymer based composite material with carbon nanotubes fillers gets stronger from repeated stress much like the body strengthens muscles after repeated workouts. The complex dynamic interface between nanostructures and polymers in carefully engineered nanocomposite material can lead to this phenomenon. (ACS Nano 2011, 5(4), 2715).

Two other topics stand out in this area within the NanoFormulation conference series: materials characterization and the use of computational tools to predict and understand complex behaviour. For example, Prof. Frenkel showed that computer simulations can help us understanding crystallization in NanoFormulation2011. During the training session on characterization methods, several advantages of microscopy and spectroscopy approaches were discussed, nevertheless, the importance of using traditional technologies (such as centrifugation) was also highlighted. Establishing full nanoparticle characterization, including mass, size and density, remains an extremely complex exercise. Nevertheless, it has been suggested that it is possible to obtain a complete characterization of a core-shell nanoparticle by using analytical ultracentrifugation (Nature Communications, 2011, 2:335)

Coatings, Films and tapes

The development of coatings using nanoparticles or nanopatterns is probably one of the most active research areas that have led to a number of products, from sensors to superhydrophobic surfaces and from corrosion protection to art restoration. Examples of these applications have been highlighted during the NanoFormulation meetings.

On NF2010 Prof. Klibanov presented a lecture on special antimicrobial coatings where an active ingredient is bound covalently and does not leach from the surface. The use of polyion matrices provides an alternative to water purification and eliminates the production of harmful disinfection byproducts. Later this subject was broaden to water purification filters, see Onnis-Hayden, et al. "An Antimicrobial Polycationic Sand Filter for Water Disinfection" Water Sci. and Technol. 2011 63(9):1997-2003.

The importance of nanocarbons in formulations was presented by Dr. Michael Berkei in NanoFormulation2010 entitled "Smart Nanotechnology for Functional Coatings", from applications in scratch resistant to conductive pains. He described that elastic properties of nanoparticles can be responsible for scratch resistance in coatings, by providing more flexibility to thin films. He also showed how dispersions of carbon nanotubes can lead to highly conductive paints and coatings.

Sebastian Koltzenburg presented a lecture on NanoFormulation2011 "Organic Nanoparticles Formation of Organic Nanoparticles from Active Molecules" highlighting differences between inorganic and organic nanoparticles and their inclusion in formulated products.

The presence of nanoparticles in thin films can also alter the thermal conductivity of the materials, leading to better conductors or insulators, depending on the nature of the nanoparticle and the matrices. In NanoFormulation2011 Olga Levinson, CEO of Ray Techniques Ltd, described an environmentally friendly approach to produce nanodiamonds based on laser ablation and highlighted their novel thermal properties and potential to replace currently used insulating pastes in electronic materials.

Safety and environment

Safety assessment is an essential component of modern and responsible nanotechnology research and development. There is a common understanding in the European Chemical Industry that the development of new technologies must be accompanied by correlating research to identify and manage safety issues. The chemical industry is specifically aware of safety aspects of nanomaterials and their formulation. Also most researchers in chemistry and materials science are aware of this highly important issue. A lot of new research results have been shown during the last nanoformulation conferences and Inform as a whole has contributed to raise awareness in this topic.

At the beginning of the project it was often stated, that in contrast to applications of nanomaterials the knowhow on their toxicity was poorly developed. Even so this statement was not completely true (some facts were simply ignored by some stakeholders), certain international and national initiatives were started to close this gap with research work and with information on the results of this research for the broad public

and experts in the corresponding fields. Fortunately, all participating parties realized, that communication must be a integrative part of actual research on nanomaterials to avoid major misunderstandings as it happened in past research areas, e.g. for GMOs.

With the InForm conferences it was intended and today it is obvious that this was fully successful to contribute to a better information level of scientists who are focusing on nanomaterials and formulation of nanoparticulate matter. A number of renowned experts in toxicology of nanomaterials have been invited to the Inform conferences and they reported on actual research in the field. They pointed out, that at the present state no severe additional risk is known for nanomaterials and their applications in today's consumer products compared to bulk materials and their applications.

For a better understanding of the behaviour of nanomaterials in humans and in the environment, it was also shown that further research is still necessary. But it can be clearly stated that in the last few years a lot of knowledge has been created out to better understand the properties of nanomaterials. Many nanomaterials do not show toxicology issues other than the corresponding micro- or bulk-materials but in some cases (especially when quantum size effects occur) they do. In these cases the behaviour of nanomaterials often results from the increased surface to volume ratio leading e.g. to a bigger (kinetic) availability of ions. For example this is the case for the much discussed nano-silver, where the uptake of a relatively big amount of silver in nanoparticulate form in a small cell may lead to toxic effects.

A very general result of the InForm project is that the discussion on a risk of nanomaterials for the society is a very unexcited discussion in most countries. This is most probably due to the fact, that information politics concerning nanotechnology has very much improved compared to earlier topics which were more intensely discussed. The information standard of all groups, being more interested in nanotechnology has improved a lot and hence the scare mongering headlines did not completely disappear but they have become more short-dated.

In addition to funding future research activities related to safety aspects of nanomaterials, the European Union should foster an intensified communication process of safety research results. This does also include education and training of researchers to enable them to deal with toxicological issues. Furthermore quality control of research in toxicology must be improved, too. In the opinion of the scientists related to WP8, too many scientific articles are published today, where it is not clear, whether fundamental quality criteria like well characterized nanomaterials or clearly marked concentration conditions are fulfilled (e.g. working in overdose conditions). Finally public and scientific community awareness of corresponding toxicology data could be improved as well, e.g. via the "DaNa" database on applications and properties of nanomaterials www.nanoobjects.info.

Project outcomes: NanoFormulation conferences

NanoFormulation2010

For the first annual event InForm has been integrated with the Formula VI conference running 7 – 11th June 2010 at the Aula Magna in Stockholm University.

NanoFormulation2010 was held June 9-11, 2010 at the same venue as Formula VI – Aula Magna, Stockholm University. NanoFormulation2010 was the first in a series of 3 annual conferences and attracted 91 delegates, where 25 delegates received travel grants. A dedicated project website was launched at http://www.nanoformulations2010.com/ and this is now a forum to share presentations from the conference.

NanoFormulation2010 was inaugurated with a fact-finding mission to YKI, Institute of Surface Chemistry, and an evening lecture, Designing New Chemical Products, from Prof. Edward Cussler. An organised networking event that actively facilitated interaction between participants followed. Parallel sessions took place in the following days, including both lectures and panel discussions.

NanoFormulation2011 was the second annual event organised by InForm partners. The meeting was organised as an independent symposium under the umbrella of ICMAT (International Conference on Materials for Advanced Technologies), an event organised by the Materials Research Society of Singapore. ICMAT attracted 4 Nobel Prize winners and 7 keynote speakers in addition to the NanoFormulation2011 programme.

NanoFormulation2011 took place in Suntec City, Singapore, between the 26th of June and the 1st of July 2011. A dedicated project website was launched at http://www.nanoformulation2011.com/ and the project website now contains a repository of the presentations.

The combination of activities and quality of presentations guaranteed the impact of the meeting. Colloid scientists were exposed to essential aspects of product formulation, formulators learned about new and exciting properties of nanostructured materials, and aspects like processing and safety relevant to industry and end-users were addressed. Additionally, a trade day and a training day were organised, and a series of 1-2-1 meetings were scheduled to facilitate networking between the meeting attendants.

NanoFormulation2011 had an extraordinary line-up of invited speakers for the conference sessions and the training day, including prestigious scientists from the USA, Europe and Asia, such as Daan FRENKEL,

University of Cambridge, UK, Matthew LYNCH, *Procter and Gamble Company, University of Delaware, United States and* Jackie YING, *Institute of Bioengineering and Nanotechnology, Singapore.*

Discussions on our understanding and interpretation of toxicological information of nanoparticles, the role of surface chemistry and the dangers of generalising particular results were carried out. Similarly, the potential design of novel nanostructures with unique functionalities and the challenges for using them in practical applications were highlighted by the speakers. The meeting established a good working framework for the community and promoted networking between partners. Comments received after the meeting include:

"I found the conference extremely interesting and useful and learnt a great deal. I met lots of people and it also gave me a far better understanding of the work of organisations such as the FSTG and encouraged me to find out more!" - Joanna Thorne, University of Greenwich

NanoFormulation2011 was an official event of the International year of Chemistry.

For the final annual event InForm was held as an independent conference in Barcelona, from the 28th of May to the 1st of June 2012.

We exceeded our expectations in terms of attendants, and reached 225 participants, from Europe, Asia, Australia and the America to NanoFormulation2012. Travel grants facilitated the participation of 36 researchers, where in addition to top quality invited speakers, the highlights of the meeting were vibrant poster flash mini-sessions followed by the poster session and highly successful 1-2-1 sessions, where meetings between participants of different institutions, sectors and backgrounds were facilitated.

The inaugural talk was presented by Dr. Valerie Andre from BASF, where she indicated the importance of new materials and technology for companies like BASF and provided some examples as case studies from the company. Prof. Charles Zukoski from University of Illinois at Urbana Champaign who has been commissioned by NSF to assess the extent to which knowledge and knowhow generated in USA research institutions in the area of nanomaterials is successfully transferred to industry was one of the invited speakers from WP5. He delivered an insightful talk on the use of nanofillers in polymers and the challenges in processing and scaleup and actively participated in the 1-2-1 sessions to understand the differences between knowledge transfer opportunities in the USA and Europe. He highlighted the important role that societies and organisations such as FSTG-RSC and Dechema play in bringing communities together, as well as the funding provided by the EC to enable such events.

Fact finding missions

The fist fact finding mission was organised to coincide with NanoFormulation2010, showcasing Swedish research related to nanomaterials to at NanoFormulation2010 participants. A fact finding mission was also organised to showcase research related to nanomaterials in Singapore during NanoFormulation2011. A session with four presentations of successful entrepreneurs, including Prof. Jackie Ying, preceded the visit to the Institute of Chemical Engineering Science in Jurong Island, the centre for chemicals production in Singapore.

For the final meeting, NanoFormulation2012, a fact finding mission was organised at Alicia Foundation. Alicia stands for "Alimentació i Ciencia" (Food and Science), where we witness different aspects of science and formulation related to food preparation.

The visit offered the opportunity to experience how nano-research is carried out in the food industry using current advances in nanotechnology for formulated products.

In particular we looked at ingredient substitution for celiac's diets, and preparation of non-conventional emulsions that mimic mayonnaise. We also looked at encapsulation of different products for the delivery of particular textures and flavours.

Training day

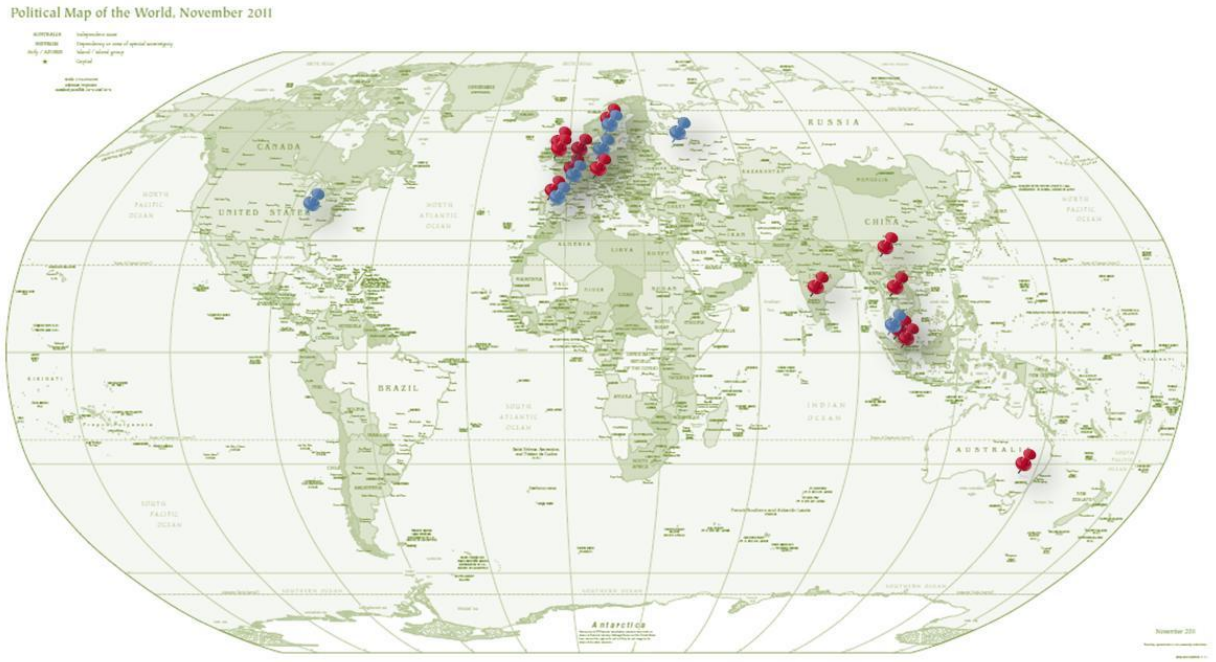
The final day of NanoFormulation2011 was used as a training day at IMRE, Singapore's leading research institute in materials research.

Characterisation of nanostructures in formulations is one of the important challenges that have been identified in this project, in part due to the complexity of the problem, and in part due to the lack of standards. These issues were addressed in the training day, where the application of techniques from STEM to centrifugation, and including techniques to characterise nanoparticles in vivo.

Project outcomes: Researcher Exchange Programme

There have been **20** completed exchanges within the InForm project, involving 7 European countries and 6 countries outside Europe, with emphasis on the Asia-Pacific region (shown in red in the map below). The aim of the exchange was to initiate or strengthen collaboration between researchers/research groups with an overall aim for long-term cooperation. Successful collaborations with immediate outcomes include written articles, presentations (posters/oral) at NanoFormulation2011/2012 and presentations at other nanoformulation conferences. A number of exchanges (7) plan to write scientific articles in the near future following further analysis of results and the intention for future collaboration by actively looking for funding possibilities is very encouraging with 12 exchanges wishing to collaborate further if possible. The knowledge transfer between visitor and host was obvious in all the exchanges. For the two exchanges which involved industry it was interesting to note that the approach for the exchanges was quite different. One exchange focussed on information transfer from academia and for the other the exchange focussed on utilising expertise to evaluate new scientific methods for industrial products. Interestingly one exchange report also mentioned that they learned mentoring skills which they plan to utilise in their own country to attract more women to careers in science and engineering.

Three fact finding missions were organised at the time of the NanoFormulation conference series: Stockholm (2010), Singapore (2011) and Barcelona (2012), which were open to all conference participants. Additionally, partners of the project participated in fact finding missions coinciding with the partners meetings in Paris (2011) and Leverkusen (2012). Two InForm partners also participated in the Formulation fact finding mission to the USA (2011) organised by the Chemistry Innovation Knowledge Transfer Network. The fact finding missions are shown as blue pins in the map.



Map highlighting the regions were researcher exchanges (red) and fact finding missions (blue) were carried out.

Project outcomes: Innovation pathways

During NanoFormulation2010, Prof. Ed Cussler outlined the differences between the key drivers for innovation in the commodities, products and nanostructures markets. Commodities are driven by cost and traditional unit operations are the basis for process development. Products, such as pharmaceuticals, are driven by speed to market and they rely on the chemical synthesis of new active ingredients. Nevertheless, nanostructured materials are defined by their functionality that depends on their structure, and the key to their development is to understand the science behind them. Nevertheless, there is no single recipe for innovation.

Different components contribute to innovation, but in general we have seen that product innovation can be driven by a scientific challenge, a technological challenge or a market need. Most successful innovations will have a combination of these three drivers, but the one that dominates establishes the pathway for innovation. During the InForm main events, the NanoFormulation conferences series, the researcher exchange programs and the fact finding missions we have observed successful examples of all three innovation pathways. In this section we describe briefly these pathways, providing some examples to illustrate them, highlighting the benefit of the approach, their weaknesses and the role that product formulation plays in the different pathways.

Science driven innovation

We call science driven innovations the pathway that starts with a scientific challenge, from showing that it is possible to synthesize a Janus particle, with different chemical functionalities on the opposing sides of the particle, to creating a buckyball of something different than carbon. These innovations start with a drive to understand the world around us, to push the boundaries of what is currently known and to create something radically new. The potential impact of this pathway can be incredibly high, as a single innovation can lead to applications in many fields, such as graphene. Having as a starting point a scientific problem ensures the support of the scientific community from academia and research institutes, to understand the underpinning science behind the innovation and to expand its depth and breadth. Nevertheless, many science driven innovations have difficulties finding practical applications and face challenges from scale-up to consumer confidence when attempting to replace an existing product. In most science driven innovations in the area of nanomaterials, product formulation is not taken into account until a suitable application is found. This can prove problematic in some cases, because not many efforts have been devoted to understand the role of carriers, matrices, solvents and stability of the systems of interest, both for processing and for application of the formulated product.

Case study: Nanomaterials ltd (Israel)

Nanomaterials Ltd is a company that commercializes sulphur based nanoparticles as additives for lubrication. The idea of the sulphur based nanoparticles was born with Prof. Tenne at Weismann Institute (Israel). The discovery that it was possible to synthesise nanoparticles based on an inorganic shell similar to the buckyballs but based on other elements has opened many fields of research.

Nanomaterials Ltd has successfully scaled up the technology to move from grams of product to kilos, and realized that to commercialized the product it needed to be presented as a formulation. Product formulation is still not considered the main aspect of the business, but it is recognized as an essential step. The general director at Nanomaterials considers that increasing networking opportunities with non-competitive stakeholders is essential to improve their product formulations, as practices used by others to ensure stability of their products can be extended to the products manufactured by Nanomaterials, rather than devoting a significant amount of resources in research and development of formulations.

Case study: Graphene (UK)

Graphene is a single atomic plane pulled out of graphite with remarkable properties. It is the thinnest material one can imagine and the strongest one ever measured. This material, although theoretically described decades ago, it was elusive and scientists found difficult to obtain it. The scientific drive to prove the theoretical predictions led to many efforts to develop the necessary basic research to obtain single graphene sheets.

The experimental discovery of graphene led to a deluge of international research interest. Not only is it the thinnest of all possible materials, it is also extremely strong and stiff. Moreover, in its pure form it conducts electrons faster at room temperature than any other substance. Its charge carriers have zero effective mass and can travel micron distances without scattering under ambient conditions. Graphene can sustain current densities thousands times higher than copper, shows record thermal conductivity and stiffness, is impermeable to gases and liquids. It reconciles such conflicting qualities as brittleness and ductility. Electrons in graphene behave in such a way that this allows the investigation of relativistic quantum phenomena in a bench-top experiment.

Engineers at laboratories worldwide are currently scrutinizing graphene to determine whether it can be fabricated into products such as supertough composites, smart displays, ultrafast transistors and quantum-dot computers.

Technology driven innovation

We distinguish between science and technology driven innovations when the challenge rests on proving that a technology is capable of producing a known nanostructure material, where the technology is safer or more sustainable than currently used technologies. Technology driven innovations do not always find support from academic and basic research institutes because the progress in the area may be perceived as incremental rather than step changing. Such projects are not often funded by research councils, but can find a support from innovation incubators. The risks associated to this type of innovation range from proving that the new technology is able to deliver a product with the same quality (or better quality) than the one currently available, to finding new applications and markets for a nanostructured material that can now be produced at a lower cost, or 'in larger scale. The advantage of this pathway is that the need for the product may be well established, and intimate knowledge on the processing aspects reduces the risks associated to scale-up. Nevertheless, in this innovation approach, product formulation is only considered at the end of the innovation chain, when the application is defined and the product needs to be presented, tested, or benchmarked as a formulation in comparison with available alternatives.

Case study: Ray Technologies (israel)

Ray Technologies has developed an environmentally friendly approach to produce nanodiamonds based on laser ablation. The product existed on the market, and the properties of nanodiamonds were known to some extent. The driver for this innovation was to prove that laser ablation was a suitable technology for the production of nanodiamonds. Olga Levinson, CEO of Ray Technologies, indicated that the scale-up in production is limited due to the lack of trust of consumers in such a new technology.

Product driven innovation

Product driven innovation is considered by some people the most efficient approach for innovation. The problem starts with identifying a product need, whether it is an improvement on an existing product (such as low temperature detergents) to the development of a product that does not exist in the market but its introduction will benefit society (for example a targeted anticancer drug). This innovation pathway requires one or more people working closely together that will be driven by the application and development of state of the scientific concepts into the development of specific products.

Case study: Drug delivery systems (Singapore)

Prof. Jackie Ying, CEO of the Institute of Bioengineering and Nanotechnology in Singapore gave an excellent example of product driven innovation: a targeted drug delivery system for cancer tumours. The work builds on her basic knowledge in catalysis and materials, and her drive for the improvement of human wellbeing.

They developed safe polymer-based carriers with nanometer particle size and narrow size distribution, high drug loading capacity and kinetic stability to transport small molecular anticancer drugs to tumour cells based on passive and active targeting. They tailored the properties of core-shell nanoparticles, using block copolymers to achieve precise phase transitions and exploit small temperature differences between tumours and healthy organs. Then, only when the nanoparticle reaches the tumour, the slightly higher temperature causes the polymer to collapse and release the anticancer drugs. In this innovation, the product formulation was part of the innovation process, as only materials that could deliver the desired function and fulfil other criteria such as biocompatibility were of interest.

Project outcomes: Innovation stakeholders

The companies who make and sell formulated products are under ever-increasing pressure to make better use of existing chemical ingredients. These pressures arise from the regulatory requirements which reduce ingredient choice and from the demands of society to reduce energy use and carbon dioxide emissions. This causes significant challenges for those researchers and developers who are responsible for the design and processing of new and improved formulated products. Those involved in the design of formulated products need to have a better understanding of the fundamental processes and interactions between components that define the properties of these complex systems. Much effort has been spent on nanoparticle design and production, but excellent formulation is required to exploit such nanotechnology to the full. Additionally, improved analytical tools are required to probe the complex micro- and nanostructures so that these structures can be related to properties and product performance. Those involved in processing and manufacture of formulated products need to consider novel, more energy-efficient processing methods such as particle engineering and to be sure that processes can be scaled up from the laboratory, through pilot scale and onto full-scale production.

Research laboratories, Universities, small and large companies are essential elements to innovation, and each of them plays an important role.

Additionally, we have identified a number of stakeholders that play an important role in formulation innovation, from facilitators that enable knowledge to be transferred between universities and SMEs or large companies, to technology incubators that provide space and facilities for proof of concept developments.

One cannot neglect the important role that the general public, regulatory and funding agencies play. Public perception and irresponsible distribution of information can seriously damage the drive of a company to include nanomaterials in their formulated products.

Universities

Research at universities is often driven by scientific curiosity; it is fundamental in nature and can open doors to radically new materials and processes. Even when some success stories can be found of commercialized products that had their origins in a university laboratory, the role of the universities is focused on providing high quality and unbiased research that can aid in the development of new formulations and products. Training is another important role of universities, where the development of new programs at different levels is often driven by industry needs to recruit highly trained personnel.

Research institutes

Research Institutes are often seen as a bridge between purely academic research that is carried out in universities and highly applied research that is carried out in industry. Their role is essential, as they have much more flexibility than universities in channelling their resources to particular projects, and are better equipped to carry out short term projects of fundamental nature that can aid the development or improvement of formulations. The European Association of Research and Technology Organisations

highlights that research institutes occupy a nodal position within the innovation landscape bringing together research in private and public sectors in order to build competency, develop technology and disseminate information.

Research Institutes are specialized knowledge centres providing research technology services in collaboration with companies, governments, and universities. They are generally non-profit organizations, with their revenues being reinvested to fund new innovation cycles. Research institutes acts as bridges between purely academic research that is carried out in universities and highly applied research that is carried out in industry. One example is The Institute for Surface Chemistry, YKI, which focuses on applied surface and colloid chemistry. YKI develops and transfers competence, solutions and new technologies to industrial sectors where surface chemistry is of importance. YKI has developed vast experience in such domains as Formulation technologies and applications, Interfacial technologies and applications, Materials and nanotechnologies and applications, Controlled delivery and release technologies and applications, and Clean technologies, where the whole development chain from research into industrial development and practical implementation on-site has been covered often in consortia with industrial partners and authorities.

The role of research institutes is essential in the innovation process, as they have much more flexibility than universities in rapidly channelling their resources to particular projects, and are better equipped to carry out short term projects of fundamental nature that can aid the development or improvement of formulations.

SMEs

Although Small and Medium-sized Enterprises (SMEs) are small their role is critical in innovation. European innovation programmes encase SMEs at the heart of research and development. SMEs are central to economic growth as they exploit new technologies and can respond quickly to changes in market needs. They actively seek new applications for their research through knowledge transfer and technology transfer. SMEs are acutely aware of the competition for products and services in the global market. They help develop the fundamental science, transforming scientific excellence into better and safer products, and are continually looking for support and opportunities to grow. In the area of nanomaterials in formulations SMEs play a wide range of roles, from the development and production of novel nanostructured materials, to the development of tools and services for their characterisation, benchmarking and analysis.

Large companies

Large companies have resources that SMEs can only dream of to aid innovation, but also face a number of obstacles, from structural inhibitions based on established procedures and approaches, the desire of predictable and consistent results, training of personnel in very specialised areas and not giving personnel a broad technological or economical perspective, Large companies often rely on collaborations with Universities and Research Institutes as a source for innovation. In the area of formulation, on the other hand, much of the product innovation is done at the companies due to IP protection issues and the desire to reach market fast. They also rely on facilitators, such as Knowledge Transfer Networks, to incorporate new discoveries and technologies in their business.

Facilitators

Facilitators are usually SMEs that can act as consultants as in the case of Higgins Consultancy Limited, or have a broader spectrum of activities as in the case of Intelligent Formulation Ltd.

Intelligent Formulation Ltd is a not for profit company which specialises in helping companies to innovate better in formulation. Intelligent Formulation helps companies address their challenges and create opportunities with formulated products. These challenges range from opportunities for ingredients with novel functionality, through development of new products to the fundamental understanding of how their products work. Intelligent Formulation regularly run events, both physical and web-based for its partner community: on average, two events per month, as well as training and CPD courses via the web and in person.

The following example illustrates Intelligent Formulation's work. Intelligent Formulation supported a collaborative project in the area of microemulsion formulation. The company Syntopix (now called Evocutis) devises new formulations of antimicrobials for topical application and was challenged to choose optimal "green" surfactants for microemulsion products. Traditionally, developers use the HLB parameter for a surfactant to guide the choice of surfactants but HLB is a "blunt instrument" which does not take into account the nature of the oil phase or the packing geometry of the surfactant. Intelligent Formulation supported Syntopix by helping to build an international project team consisting of consultants, academics and service providers which tackled the problem differently, by using a newer computational tool for surfactant choice, namely HLD-NAC. The fundamental properties of surfactants were measured using automated high-throughput laboratory experimentation which enabled more data to be generated than would have been possible by conventional means. As a result Syntopix successfully identified several "greener" surfactants for further investigation in their formulated systems.

The challenge for Intelligent Formulation and their clients is to keep up to date with novel methodologies and to make the contacts with providers who can help solve formulation challenges. Despite the rise of electronic communications and social media, Jim Bullock, CEO of Intelligent Formulation considers that it is often essential to meet and communicate face-to-face.

A different type of facilitator is the role played by Knowledge Transfer Networks (KTN), such as the Chemistry Innovation KTN. Chemistry Innovation is a knowledge exchange business at the forefront of the chemistry-using industries. Chemistry is a key enabling science for a major part of the UK economy and it is Chemistry Innovation's mission to support the chemistry-using industries, driving innovation and value across the chemistry-using industries. This includes chemical and pharmaceutical sectors, chemistry dependent sectors such as home and personal care, food and drink, polymers, crop protection and lubricants, as well as sectors which require substantial chemistry input, including oil, gas, materials and electronics.

Through the nature of Chemistry Innovation, which is independent, industry led and backed by the Technology Strategy Board, the company is able to provide a leading coherent and influential voice to government, informing and advising on the technological needs of the sector and issues that enhance/inhibit innovation.

Chemistry Innovation offers a range of (free) services to help companies and research organisations successfully participate in collaborative projects. These include identifying and promoting the most relevant funding opportunities for the Chemistry-Using Industries, providing advice and guidance with respect to the

eligibility of your project idea for different funding schemes, reviewing project proposals and making suggestions regarding how to maximise your chance of success, providing support to help you identify appropriate partners for your project consortium, acting as a partner to provide experienced project management and/or wide-reaching project communication and dissemination mechanisms.

Innovation incubator

Innovation incubators, such as The Accelerator at the University of Mississippi in the USA, Daren Laboratories in Israel, or BioCity in the UK are designed to support companies and enable product innovation. The business structure may be very different between them, and some focus specifically in product formulation, providing access to state of the art technology that will enable the application of material science in the development and commercialization of new products, while others provide a space with standard sets of facilities that enable start-up companies to prove the concepts behind their innovation and attract investors interest that will enable them to establish a commercial venture. Probably the most important aspect in innovation incubators is that they provide a cost effective approach for start-up companies. Nearby facilities can also play an important role, but the appeal will be different depending on the client. Proximity to well recognized research institutes or universities may be beneficial in some cases, while others will benefit from the flexibility provided by the location close to an industrial park.

Funding agencies

Funding agencies play an important role in the innovation map. The decisions to provide funding to specific areas or activities can make innovation flourish, but restrictions in the type of activity (basic research vs. applied research) may hinder some innovation pathways. The wide range of novel nanostructured materials is a result, in part, on the investment in the development of nanoparticles, multifunctional, smart materials, etc. Some of the difficulties in incorporating nanomaterials in formulations reside on the limited compatibility between the nanomaterials, as synthesized, and the matrices or vehicles that are needed for their utilisation. Understanding the different innovation pathways is important to provide balanced resources that will result in benefits for society.

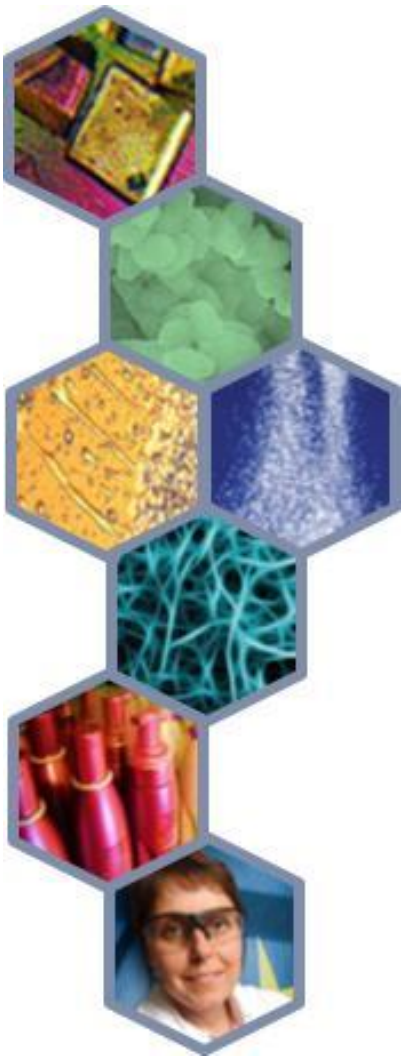
General public

Public opinion plays an important role in the commercialisation of new formulated products. It affects significantly the product driven innovation pathway, but it only touches the other innovation pathways at the point of commercialization.

Project outcomes: Future needs

The successful incorporation of soft and hard nanoparticles into formulated end-products (up-scaling) requires the joint efforts of colloid chemists, specialists (e.g. biologists, polymer chemists, physicists) chemical and process engineers. Certainly, a number of examples of collaboration across scientific disciplines have been discussed and presented during the course of NanoFormulation events. However, the number of such type of collaboration work has been limited compared to the vast amount of work that is being carried out by research groups and entities working within the boundaries of a specific field of research. It has also been especially challenging to attract process engineers, which reflects the difficulties involved in overcoming the barriers between researchers and engineers in industry. Although it might be difficult to attract industrial engineers, collaboration with engineers active in academia may be a more feasible route.

Overall, a number of areas need to be addressed to enhance progress in the incorporation of nanomaterials in formulations:



Improve understanding of the interactions between nanoparticles or nanostructured materials with solvents and carriers, from stability, phase behaviour and rheology, to facilitate their processing and improve their use as formulated products.

Enhance the integration between synthesis, characterisation and processing encouraging efforts that integrate scientists and engineers.

Once stable nanosize compositions have been elaborated special emphasis should be focused on the toxicological comparison between micronsized and nanosized particles. This is also necessary in order to discuss and further refine the current definition of nanomaterials on the basis of real comparable results.

Some SME considered that public support is important for scale up and benchmarking, while some large companies considered that these activities should be funded by the company and devote public funds to facilitate start-up companies and research at Universities.

Maintain open discussion forums to facilitate the transition from basic science to useful product developments, with affordable participation, especially for SMEs that may find difficult justifying attendance to expensive, well-establish conference series that cover a broad spectrum of topics.

Facilitate events where new product developments can be showcased and attract potential investors.

Additionally, a number of specific areas were identified to lead to important breakthroughs in formulated products:

Fundamental understanding of bioactive nanomaterials and their interactions with surfaces

Development and benchmarking of novel coatings, including those for energy savings and antimicrobial coatings for public places.

Development of predictive capabilities on the behaviour and performance of formulations

Assessment of current standards for characterisation of nanomaterials in formulations and development of accurate indicators of the performance of formulations.

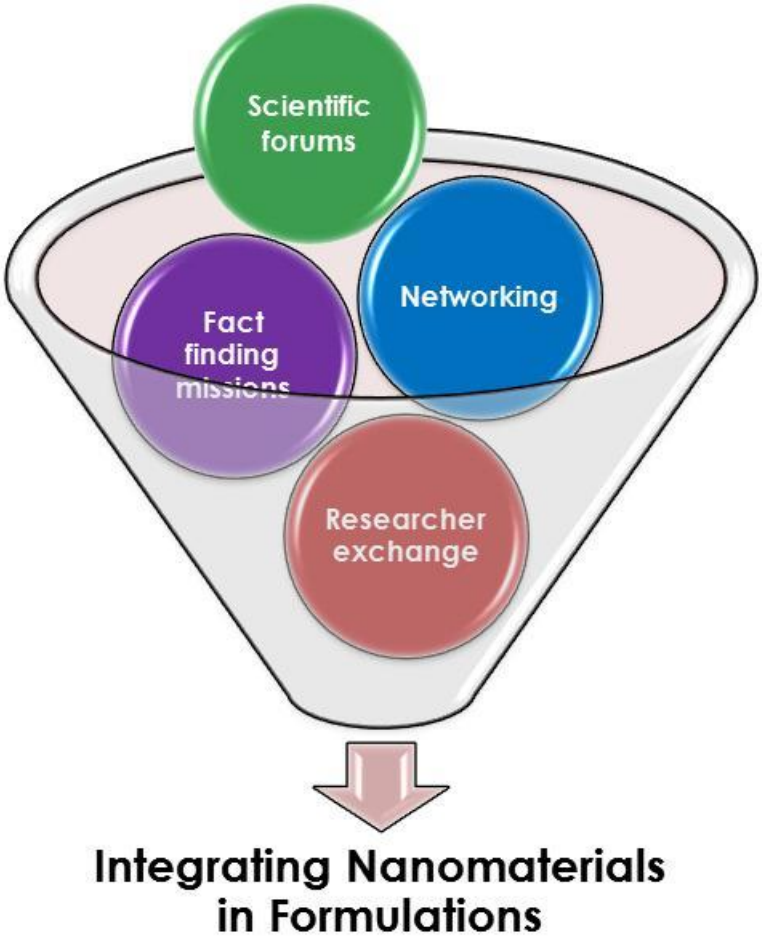
Enhance the understanding on processing nanomaterials and the challenges involved from a technological and safety perspectives.

Support activities for public dissemination and education, especially in the area of safety and outreach to children.

Finally, remember that the innovation process is like a plum tree that at first drops many green, hard, inedible plums to the ground. Unless you are willing to wait, you may miss the tasty, ripe plums that the tree will eventually produce (Aulet et al. MIT Entrepeneurship Review 2010). Not all activities will lead to successes, but it is part of the risk in innovation.

Potential impact

It is very difficult to quantify the potential impact of a project, and InForm is not an exception. We decided to focus the attention of the broad impacts of the project, rather than on benefits to individual partners, therefore by looking at the main activities of InForm: the scientific forums, the fact finding missions, networking events and researcher exchanges, we have identified that the most important impact of this project is the creation of a new community with interests in nanomaterials and formulations.



We have structured this section to highlight the creation of a new community and a sustainable conferences series. Other impacts of the project will also include new partnerships formed as a result of the researcher exchange programme and fact finding missions. Finally, we summarise the main dissemination activities planned to enhance the impact of the project.

New community

InForm provided a sustainable platform to facilitate the coordination of research activities, by allowing easy access to relevant and accurate information, a forum for discussion, networking and exchange of ideas, and assist in the creation of partnerships for new projects.

The project was planned and configured in a way that benefited the largest possible number of scientists, technologists and other stakeholders interested in the incorporation of nanomaterials in formulations. The project **reinforced the international dimension of EU research within FP7** as a result of the interaction with leaders in formulation science and nanomaterials design, synthesis and production in targeted world regions (Asia-Pacific and America), during the NanoFormulation meetings, the fact finding missions and the researcher exchanges. We saw the community grow over the years, and the InForm platform was used by several FP7 funded projects to disseminate their results to a wide audience.

During the NanoFormulation meetings, it was clear the diversity of backgrounds of the attendees, from synthetic chemist to electrical engineers, all interested in different aspects of formulations, but with a similar objective, to deliver a product with novel capabilities. Simon Gibbons, chairman of the FSTG-RSC indicated that he would not normally go to a conference where he could talk to a materials scientist, a physicist and an engineer in the same afternoon. The added value of brining such a diverse group of researchers and technologists together was fundamental to the success of the project. Therefore, one of the main impacts of this project is expected to be this new international, multidisciplinary and multisectorial community.

Sustainable conference series

The concept of the NanoFormulation meetings was a departure from traditional scientific meetings, as they contained a variety of activities, which included scientific forums, networking events, fact finding missions and trade missions. We consider that this combination of activities was attractive to a wide audience and provided an excellent opportunity for the **reinforcement of the international dimension of European research within FP7**, as well as **providing a new approach to International scientific and technological cooperation.**

The nanoformulation community will be nurtured by a sustainable conference series. We have demonstrated the importance and interest of the topics discussed in these meetings by the growing number of attendees, and increased participation in the organised activities. At the moment we have the commitment of different partners to carry out future NanoFormulation meetings, alternating between different parts of the world:

NanoFormulation2013 – Manchester, UK

NanoFormulation2014 – China

NanoFormulation2015 – Germany

NanoFormulation2016 – Malaysia

The commitment of the partners to continue these activities beyond the life of the project is testimony the importance they place on this topic and the potential benefit they expect from hosting the meetings. Nevertheless, there is a concern that without the support from the EC, the variety of activities that were offered in the NanoFormulation conferences will not be available, and that the cost of participation will increase significantly, making it prohibitive to attend for some stakeholders. We are committed to monitor the attendance to the meetings and make all possible efforts to widen participation for the success of the conference series and for the benefit of the community.

New partnerships

The researcher exchange program and the fact finding missions were the vehicles for the creation of new partnerships. After the exchange of ideas and identification of complementary skills or products, the birth of a new partnership were fuelled through the research exchange program, that allowed an initial contact between partners to crystallise new ideas into projects.

The researcher exchange program was specifically targeted to facilitate joint projects between EU researchers and those in other major world regions. Some of them have already resulted in successfully funded partnerships, while others are at an early stage of development.

InForm reduced some of the risks associated with new partnerships and facilitate the elaboration of joint projects by allowing short researcher exchanges, mainly between Europe and other world regions. The researcher/visitor exchange program enabled seeding of new collaborations between partners in different world regions. Member from academia, research institutes and industry benefitted from this scheme. The researcher exchange also facilitated transfer of skills between sectors (industry vs. academia), as well as knowledge and strategies from other world regions to the European Union.

Examples of new partnerships created include:

Daren Labs secured two FP7 projects (calls FP7-KBBE-2012-6-singlestage and FP7-SME-2012) following the attendance to EuroNanoForum2011 to promote InForm activities.

The University of Malaya secured a 2.5 M € High Impact Research Grant from the ministry of Higher education in Malaysia to continue the collaboration with CSIC (Spain) that was initiated with a researcher exchange between University of Malaya and CSIC.

Based on the activities carried out during the InForm exchange, Dr Grassia from the University of Manchester has successfully applied for follow on funding. He has been awarded a Royal Academy of Engineering/Leverhulme Trust Senior Research Fellowship commencing in January 2013. Travel funds attached to the fellowship will facilitate continued collaboration with InForm project partners. Dr. Andrew Kraynik was awarded a Visiting Research Fellowship at the University of Durham, which will take place between April and June 2013, to continue his work on foams.

Dissemination activities

The dissemination strategy involved a number of elements: At one level we have the dissemination of information of the project activities and results, while dissemination of knowledge generated as a result of EU funded projects and other national or regional initiatives took place in the different activities organised during the yearly events.

The most important forum for dissemination of knowledge were the NanoFormulation meetings. Selected presentations of these meetings and material generated are available at the project website. Information is available for free, but users are required to register, allowing us to keep track of the website activity and improve the portal.

The project website was a fundamental part of the dissemination strategy given the physical distances separating both the consortium members and wider stakeholders, and given the number of stakeholders involved. The website will continue to operate after the termination of the project and will be maintained by Automaxion. Automaxion aims to use the material produced as a commercial venture that will generate income to the EU.

Dissemination of the project activities and outcomes were carried out through a variety of channels, from press releases, journals and magazines, direct mailing of flyers to the attendance and participation at relevant meetings.

Additionally, participation at museum exhibits (Catalyst museum in Warrington and Museum of Science and Industry in Manchester) allowed us to disseminate the project outcomes to a general public audience.

Dissemination strategy also included the establishment of communication lines with research policy makers, directly or through research platforms. Some partners of InForm are also members of the Suschem platform which allowed direct dissemination of the project activities and outcomes. Additionally the FSTG-RSC has worked with the CIKTN and DTI, providing information about the project outcomes to aid policy makers.

Project website and contact information

The project website, which continues to operate, is available at:

http://www.nanoformulation.eu

Lead scientists at the partner institutions are:

Beneficiary Number *	Beneficiary name	Beneficiary short name	Lead scientist
1 (coordinator)	University of Manchester	UNIMAN	Coordinator: Flor R. Siperstein Project manager: Helen Dutton
2	Formulation Science and Technology Group of the RSC	FSTG-RSC	John Jones Matthew Giles
3	Dechema	DECHEMA	Andreas Foerster Christoph Steinbach
4	Société Française de Chimie – Formulation Group	SFC	Alain Durand
5	CSIC	CSIC	Conxita Solans Jordi Esqeuna
6	YKI, Stockholm	YKI	Karin Persson Isabel Mira
7	Automaxion SARL	AUTOMAXION	Stephen Bysouth
8	Daren Laboratories and Scientific Consultants Ltd.	DLab	Faina Solomon Tsvetkov Steve Daren
9	David Higgins Consultancy	HCL	David Higgins
10	Novartis	NOVARTIS	Philippe Rogueda
11	Bayer CropScience Aktiengesellschaft	BAYER	Malcolm Faers Wolfgang Wirth
12	University of Sydney	SYDNEY	Daniela Traini
13	Institute of Chemical and Engineering Sciences	ICES	Reginald Tan Ng Wai Kiong
14	Universiti Malaya	UM	Rauzah Hashim
15	Southwest Forestry University	SWFU	Guanben Du
16	Indian Institute of Technology Madras	IITM	Ramnarayanan Ramanathan
17	Strider Research Corporation	SRC	John Texter