

Nanotechnology as a platform for innovation areas

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Nanotechnology is widely seen as one of the key technologies in the upcoming century, since it can be generally considered as the synthesis, modification, control, manipulation, and characterization of particles and structures on the scale between 1 and 100 nm at least in one dimension, providing improved or new properties and functions not achievable with macroscopic structures.

Besides of existing and established nanotechnology based approaches new materials and systems enabled by nanoscaled structures offer an enormous broad variety of new properties and functions leading to diverse new emerging applications in material and in life sciences as well. In the most cases elements of nanotechnology cover a widely extended upstream range of the value chain with nanoobjects at the beginning over nanointermediates and finally enabling high value final products or systems at its end.

Because of these common features of nanotechnology it can be commonly recognized as a versatile platform for various innovation areas today and in the future.

Based on general technical future scenarios high market volumes and growth rates are predicted for nanomaterials, nano-enabled intermediates and products by a multitude of market studies. The predictions range between 1.000 and 3.000 billion US \$ for 2015 and several studies expect a high double digit annual growth for the near future in special emerging segments. However, a significant market already exists today for established nanotechnology consisting of e.g. polymeric blends, dispersions, and nanosized particles. Based on these economic expectations the public and private investments in research & development regarding nanotechnology have been enormously increased during the past years, up to 12-13 billion US \$ in 2006, supporting and accelerating the progress of innovations along the value chain.

Many general broad and versatile features of nanotechnology are already utilized today as a powerful tool to develop innovation areas and accelerate their growth within several diverse commercial segments.

The entire Bayer Group - according to its slogan 'Science for a Better Life' focusing on innovation driven and technology intensive core areas of health care, nutrition and high tech materials - can be seen as a representative for the industrial use of nanotechnology today in terms of a tool and a platform for various innovation and growth areas along the value chain, mentioned above more general.

In life sciences increased bioavailability and controlled release of active ingredients offer new opportunities for Bayer HealthCare and CropScience. The inclusion of active ingredients (a.i.) into nanosized and surface modified liposomes provides an improved control of the release behavior of a.i. and might contribute to the suppression of unintended side effects.

In addition, new surface modified paramagnetic nanoparticles as contrast agents for medical diagnostics in Bayer HealthCare deliver an improved resolution of magnetic resonance imaging of specific organs to identify irregularities or tumors more reliably. The nature of particles, their specific surface modification and the imaging procedure are essential elements of nanotechnology.

Especially for Bayer MaterialScience, intelligent materials and functional surfaces can be approached by the nanotechnology platform today, combining classical chemical synthesis and elements of nanotechnology along different steps of the value chain.

Intelligent flame retardance in combination with superior long lasting mechanical properties of housings for electronic devices (such as TV and computer housings) are improved by the use of appropriate nanoparticles with the right surface modification in polymeric nanocomposites.

Increased scratch resistance and lower sensitivity against the attack by chemicals in coatings are achieved by the use of

suitable surface modified nanoparticles in combination with a polymeric binder, tailored cross-linker and the adjusted application procedure.

Beyond this, a significant range of nanotechnology applications can be identified at the interface between life and materials science, such as tailor made nanostructured surfaces in medical technology.

Future businesses and growth are generally driven by the development of new technology options (technology push) in combination with the future market i.e. customer demands (market pull). In several fields of future nanotechnology businesses technology push and market pull has to be adjusted to each other in order to bridgeover the value chain starting at nanoobjects and ending by nano-enabled systems. Very often a significant change of paradigm is needed - by using new approaches, business models and partnerships - to enable or accelerate rather parallel than serial developments, i.e. stronger collaboration with partners - suppliers and customers - along the value chain.

Especially large companies have to use new internal processes to promote the transformation of new projects to attractive emerging businesses. Representatively the 'Greenhouse' of Bayer MaterialScience – as an internal venturing like structure - can be considered as a harbor to incubate and develop promising projects to profitable future businesses. The first nano related internal start up incubated in the 'Greenhouse' is focused on the production, application development and marketing of multi wall carbon nanotubes – Baytubes®.

The commercialization routes of such novel nanoobjects indicate very clearly that traditional serial developments along the value chain will have to be more and more replaced by parallelized and also open innovation approaches in the future. The combination of public and private funding – such as 'Pennsylvania Nanomaterials Commercialization Center' in Pittsburgh, co-funded by Bayer MaterialScience as a public-private-partnership organization - can be helpful to speed up developments, can create new application and technology based networks and can complete existing R&D-chains to support today's new business creation efforts in addition.

The success of nanotechnology in the future will depend on the one hand on disruptive innovations leading to strongly emerging markets for novel products and applications and on the other hand on the level of responsible care taken with that technology along all levels of the value chain. Hence, from the industrial perspective all efforts and actions have to be taken, in order to ensure that the production, handling, transport and use of nano-enabled products are safe.

Again representatively Bayer MaterialScience is committed to an extensive Product Stewardship program to ensure safe handling and care of nanomaterials for human health and environment. The development of nanomaterials is taking place within the framework of the chemicals industry's Responsible Care® Global Charter. In addition, Bayer MaterialScience contributes to nanomaterial health, safety & environment research projects funded by the German Ministry of Education and Research (BMBF), such as NanoCare and TRACER, which focus on the characterization and the development of a broad scientific consensus on measurement methods and testing procedures for nanomaterial safety assessments.

The view back to the history and the comparison with other well developed enabling technologies might show that nanotechnology starts with already existing established applications and markets but finally it will lead to completely new emerging and fast growing markets deeply influencing our daily life in the future.