LCC analysis of hydrothermal synthesis of nanomaterials

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Abstrakt

Cílem příspěvku je představit projekt SHYMAN (Sustainable Hydrothermal Manufacturing of Nanomaterials), který se zabývá analýzou výroby nanomateriálů pomocí hydrotermální syntézy. Tato metoda je alternativou k metodám jako je ball milling, plazmová syntéza a další. Jedním z cílů projektu je prokázat nižší nákladovost výroby nanomateriálů pomocí hydrotermální syntézy oproti ostatním metodám výroby. Náklady jsou analyzovány z pohledu nákladů životního cyklu (LCC).

Abstract

The objective of this paper is present the project Shyman (Sustainable Hydrothermal Manufacturing of Nanomaterials), which analyzes the production of nanomaterials by using hydrothermal synthesis. This method is an alternative to methods such as ball milling, Plasma synthesis and more. One of the objectives of the project is to demonstrate lower cost of production of nanomaterials using hydrothermal synthesis over other methods of production. Costs are analyzed in terms of life cycle cost (LCC).

Klíčová slova

Životní cyklus, náklady životního cyklu, hydrotermální syntéza, nanomateriály.

Keywords

Life cycle, life cycle costs, hydrothermal synthesis, nanomaterials.

Introduction

The SHYMAN *(Sustainable Hydrothermal Manufacturing of Nanomaterials)* project will establish continuous hydrothermal synthesis as one of the most flexible and sustainable means of manufacturing nanomaterials on a large scale, serving industries of strategic importance to Europe.

Projekt

Continuous hydrothermal synthesis is an enabling and underpinning technology that is ready to prove itself at industrial scale as a result of recent breakthroughs in reactor design which suggest that it could now be scaled to over 100 tons per annum. First phase is laboratory scale. In this phase research center try to create samples of nanomaterials. Second pilot scale prepare samples on full scale.

Case studies

The SHYMAN project focuses on case studies such as:

Healthcare and medical – bones implants and bone scaffolds
Printed electronics - organic light-emitting diodes, organic field-effect transistors, organic photovoltaics

Hynrid polymers and materials – such as Polyether polyols based on propylene oxide
Surface coatings – materials with "superhydrophobicity" and the self-cleaning ability

Project participants

18 European participants are working on the project.

Table 1. *– Project participants*

Participant name	Country	Organisation type
The University of Nottingham	UK	University
Universidad de Valladolid	ES	University
Instytut Wysokich Cisnien PAN	PL	Research Institute
Czech Technical University in Prague, Faculty of Mechanical Engineering	CZ	University
Trinity College Dublin	IE	University
GTVT s.r.o.	SK	SME
Promethean Particles Ltd	UK	SME
Centro Ricerche FIAT SCpA	IT	Large Enterprise
PPG	FR	Large Industry
REPSOL	ES	Large Industry
Solvay S.A.	BE	Multi National, Industry
Endor Nanotechnologies SL	ES	SME
TopGaN Sp.z.o.o	PL	SME
ITAPROCHIM S.r.l	IT	SME
Lewar GmbH	DE	Industry
Ceramysis	UK	SME
Van Loon Chemical Innovations	NL	SME
Pielaszek Research Sp	PL	SME

Objectives of the Project

In summary – the SHYMAN project is project based on a technology with a solid foundation and will focus themes, specifically:

Scale up – what are the limits for scale up? How can these limits be impacted by better process design?
Formulation – how flexible is the process to allow online pre-treatment of the nanoproduct?
Weight loading – how can the concentration of the final product be increased from 1% to 30%?

Objectives of LCC a LCA

Cost – how low can opex (Operating Expense) be driven to make this one of the most sustainable manufacturing processes of the future?
Sustainability – what are the environmental benefits of the process?

Nanomaterials

Nanomaterials are product of nanotechnologies. They contain nanoparticles, smaller than 100 nanometres in at least one dimension. Because the nanomaterials are very small, they have special properties.

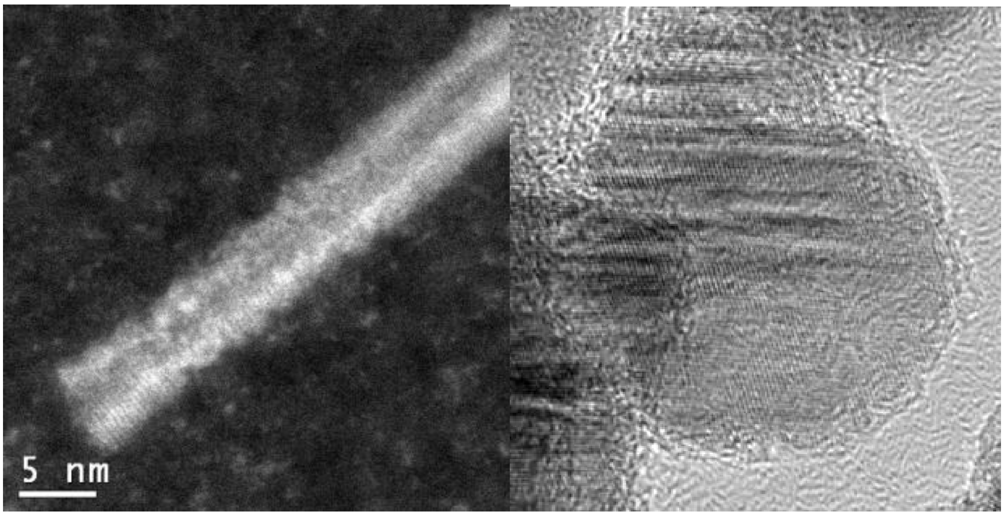

Figure 1. *(a) WO_3 (gas sensors) (b) ZnS (electronics)*

Mechanical properties

The large amount of grain boundaries in bulk materials made of nanoparticles allows extended grain boundary sliding leading to high plasticity.

Catalytic Properties

Due to their large surface, nanoparticles made of transition element oxides exhibit interesting catalytic properties.

Magnetic Properties

In magnetic nanoparticles, the energy of magnetic anisotropy may be that small that the vector of magnetization fluctuates thermally; this is called superparamagnetism. Such a material is free of remanence, and coercitivity.

Optical Properties

Distributions of non-agglomerated nanoparticles in a polymer are used to tune the index of refraction. Additionally, such a process may produce materials with non-linear optical properties.

Nanotechnologies

There are different ways to produce nanomaterials. We can divide nanotechnologies into two groups. *Dry nanomanufacturing methods* such as ball milling, combustion synthesis, flame pyrolysis or plasma synthesis and *wet nanomanufacturing methods such as* sol-gel or hydrothermal synthesis.

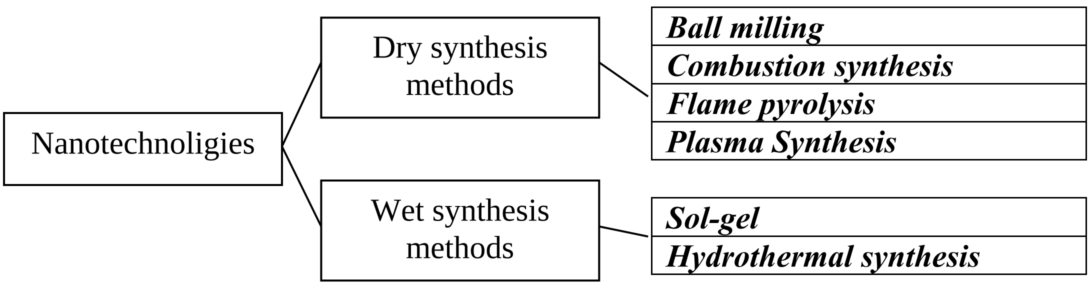

Figure 2. *Nanotechnologies*

Ball milling is one of the few 'top down' methods and relies on mechanical attrition through the energy of impaction imparted through milling media.

Currently the most commercially used techniques for producing nanomaterials are considered to be 'bottom up' approaches that are dry based technologies from molecular to nano assembly. Many of these technologies often generate low specification dry powders (wide particle size distribution, highly agglomerated particles of basic materials) that have to be reprocessed before use. ***Combustion synthesis*** or ***Flame pyrolysis*** methods are dry techniques that use a high temperature zone to convert dissolved metal species into nanoparticles.

Plasma Synthesis is a similar process where the metal precursors travel in a spray through a plasma under vacuum to form nanoparticles. These techniques are relatively simple and easily scalable, hence their overall appeal to industries that require large quantities of material.

Sol-Gel is a wet based technology that involves hydrolysis and polycondensation of metal alkoxides or chlorides in a sol gel phase. The process is relatively easy to carry out, with a good control over particle size and crystal structure and can produce a relatively high weight loading in dispersion.

Hydrothermal synthesis is an alternative route to manufacture that offers opportunities for the synthesis of high quality nanoparticles. The reactor technology uses a process known as continuous hydrothermal synthesis to produce inorganic nanoparticles suspended in water as an aqueous dispersion. Supercritical water is simply the scientific term for hot, hi-pressured water and it has different properties to those you would normally expect of water, one of which is to allow the synthesis of nanoparticles. In hydrothermal synthesis the hot, hi-pressured water is mixed with a metal salt solution, such as iron nitrate solution, and a reaction occurs and nanoparticles form.

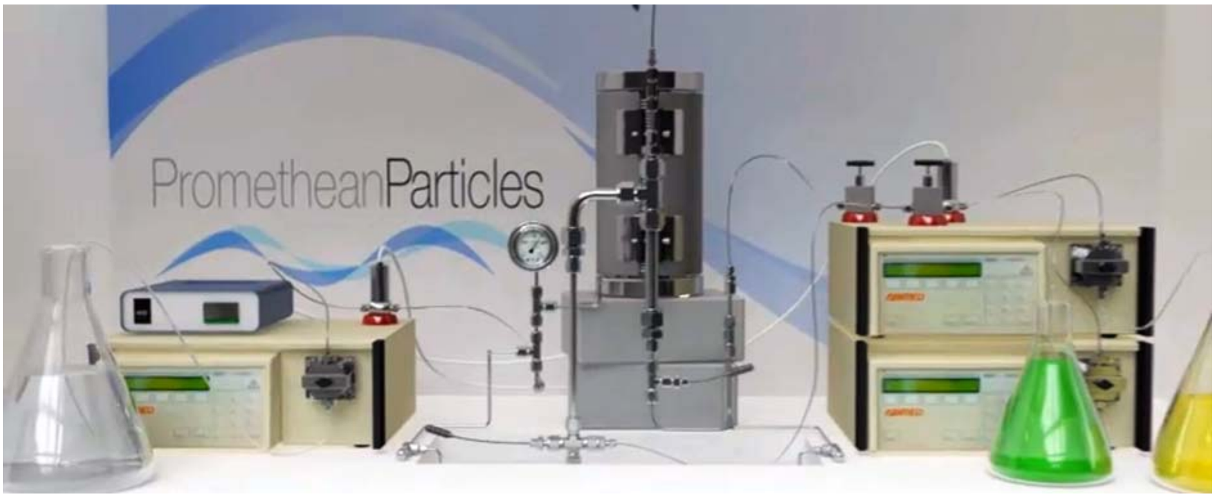

Figure 3. *The SHYMAN continuous hydrothermal reactor*

During the process occurs:

Hydrolysis: $ML_x + xOH^- \rightarrow M(OH)_x + xL^-$

Dehydration: $M(OH)_x \rightarrow MO_{x/2} + {}_{x/2}H_2O$

The process inside a reactor:

Hot, pressurised water flows into the reactor from the top
Cold, salt solution is pumped in from the bottom.
The two fluids mix efficiently at the interface created by the patent protected nozzle where the reaction occurs
Newly formed nanoparticles flow up and out of the reactor with the water.
The aqueous dispersion of nanoparticles is cooled and collected.

Life cycle costing - LCC

Life cycle costing is a method of economic analysis for all costs related to building, operating, and maintaining a project over a defined period of time. The aim of the life cycle cost analysis is evaluate cost optimization life cycle in compliance with specified requirements for performance, security, reliability, maintainability and other properties.

Because the SHYMAN project is in first laboratory scale we try to create production model. This production model will be used to create a cost structure.

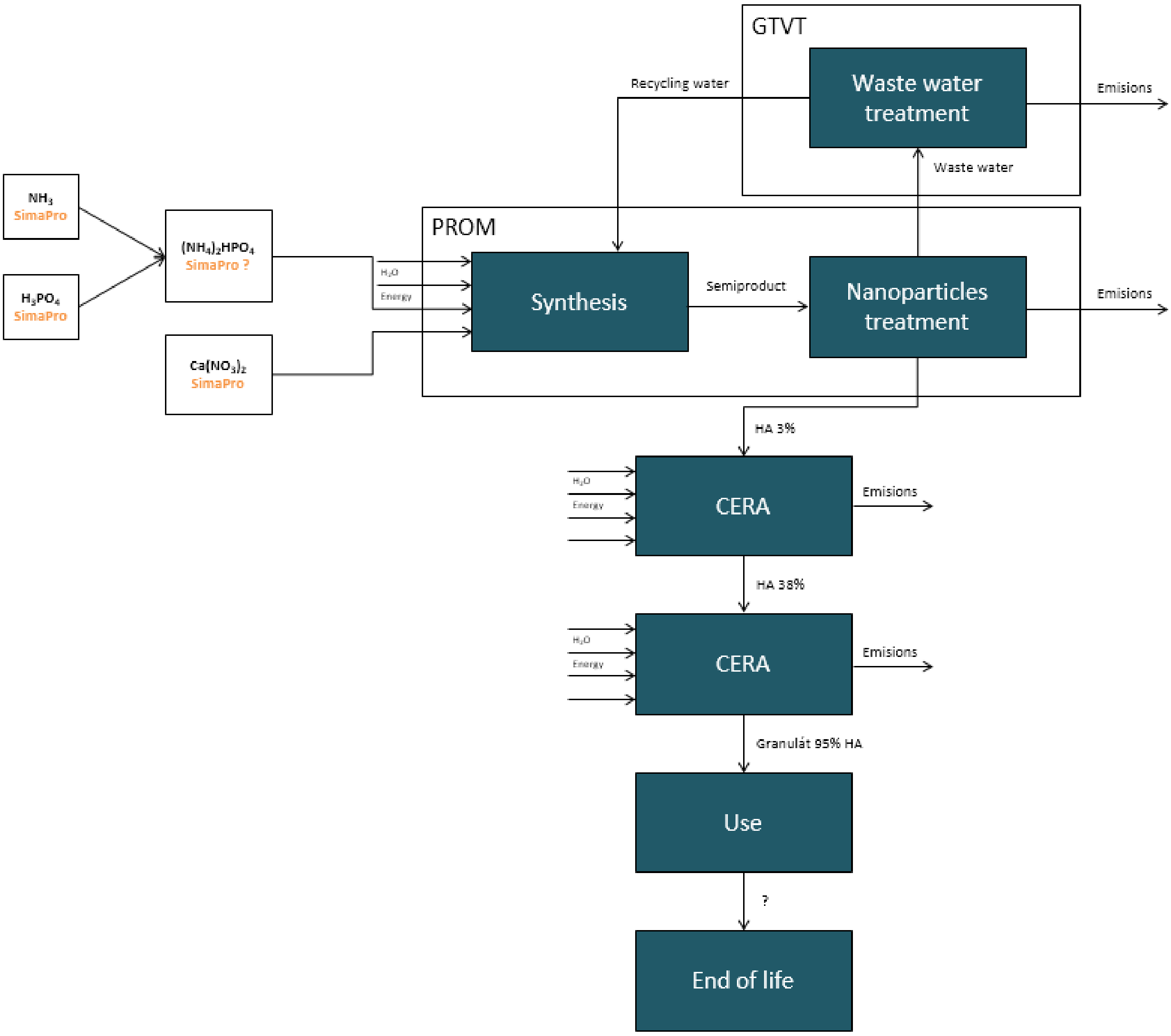

Figure 4. *Flow chart of hydroxyapatit*

Conclusion

The aim of this article is familiarize readers with the project SHYMAN. Given that the project is in the first stage of obtaining data, the content is more informative.

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