Processing and control of novel nanomaterials in packaging, automotive and solar panel processing lines.
The OptiNanoPro project is introducing nanotechnology into production lines as nanoparticles dispersed in the material bulk or applied on the material’s surface.

The OptiNanoPro project will deliver nano-enabled coatings, electrospray solutions and compounds formulations for packaging, organic photovoltaic (OPV) and automotive sectors, as well as online monitoring and nanoparticles dispersion systems to warranty constant and optimal quality of the nano-enabled materials.
In the OptiNanoPro project, a network of different open access pilot and open to market pilot lines has been set up toward the introduction of nano-enhanced material in existing production lines. The respective business model for accessing each pilot site for new industrial applications is defined here.
Semi finished Nano Enhanced Materials

**Pilot Business Model**
- Material and process development/modeling
- Material recipes and process parameters
- Know-how Transfer

**Technology**
- Magnetic and high shear stirring to prepare nanoparticles dispersions.
- Cationic exchange reaction for functionalization of clays.

**Size / Constrains**
- Reactors of 20 and 100 L. capacity.
- They work in inert atmosphere.

**Internal Quality Capabilities**
- Particle size distribution, FTIR, TGA, viscosity

**Material addressed in OptiNanoPro**
- Stable dispersions of nanoclays in aqueous solutions.
- Functionalized nanoclays for food packaging applications.
- High concentrated dispersion of nanoclays in organic/aqueous solutions

**Location**
- ITENE, Valencia, Spain
- Juan Macia, juan.macia@itene.com, http://www.itene.com/

**INPUTS**
- Raw NPs
- Commercial NPs
- Solvents
- Modifiers

**OUTPUTS**
- NPs dispersed in solvents
- NPs functionalized

**Diagram**
- Reactor / Dispersion
- Functionalised nanoparticles & Solutions

- **Schematic**
  - Reactor Diagram
  - Clay Particle Diagram
The mechanical force exercised by the impacting ball on the material in High Energy Ball Milling produce nanodispersion by generating nanoparticles in situ already within the solid or liquid matrix.

Reactors chamber for up to 20L per day of treated material. Works in inert atmosphere.

SEM and optical microscopy, Particle size distribution, Surface Area and XRD

In situ delamination of Talk and Clay with polymers for the production of master-batches, Dispersion of nanoparticles in solvents

MBN nanomaterialia, Treviso – Italy
Alvise Bianchin, alvise.bianchin@matres.org, http://www.mbn.it
Semi finished Nano Enhanced Materials

**Compounding** → **Nanocomposite Pellets**

**INPUTS**
- Polymer - Fiber/Filler - Reactive component

**OUTPUTS** In pellet form
- Polymer blend - Filled compound - Special compound

**Pilot Business Model**
A) Process development service provision  
B) Material development -> test material supply 
C) Process/equipment development -> data supply 
D) Product development -> pellets for product component supply

**Technology**
Compounding for different specialities:  
A) polymer blends  
B) particle & fiber filled polymers  
C) reactive compounding

**Size / Constrains**
Different machines = lot sizes available 
- a) Small = 2 – 5 kg 
- b) medium = 5 – 30 kg 
- c) scale-up to production size = 50 – > 100 kg

**Internal Quality Capabilities**
Tests that can be executed:  
- a) mechanical (E-modulus, impact…)  
- b) rheological  
- c) optical (morphology, particle/fiber distribution…)

**Material addressed in OptiNanoPro**
polymer compound with distributed NP´s + other additives

**Location**
HPX Polymers GmbH, Tutzing, Germany  
Uwe Boelz, info@hpx-polymers.de, http://www.hpx-polymers.de

**HPX Polymers**
Final Nano Enhanced Products

Nanodeposition, Coating & Lamination → Gas Barrier & easy emptying tubes

Inputs
- foil - nano enhanced coatings

Outputs
- laminate - tubes

Pilot Business Model
Product development -> Product component supply

Technology
Coating, lamination, tubes production

Size / Constrains
Coating 50m/min, width: 200 mm, tubes production 15 mio/year

Internal Quality Capabilities
Mocon oxygen barrier measurement

Material addressed in OptiNanoPro
Industrial validation of packaging laminates

Location
Verovškova 66, 1000 Ljubljana, Slovenija
Urška Sušnik Pivk, urska.susnik-pivk@tuba.si, http://www.lajovic tuba.com/
### Final Nano Enhanced Products

**Nanodeposition, Injection Moulding** → **Gas Barrier & easy emptying tubes shoulders**

**INPUTS**
- Nano compounded
- Thermoplastic
- Nano dispersion

**OUTPUTs**
- Gas Barrier & easy emptying tubes shoulders

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**Pilot Business Model**
- Product development -> Product component supply

**Technology**
- Injection & co-injection moulding and electrospray

**Size / Constrains**
- Production of barrier shoulders can be up to 250k pcs/day
- Production of easy emptying shoulder limited to speed of electrospray process, 1500 pcs/day

**Internal Quality Capabilities**
- 3D measuring contour probe, optical measurement camera, hand held devices etc.

**Material addressed in OptiNanoPro**
- Sibo will provide a an intermediate good for the final product by processing provided nano enhanced raw material

**Location**
- SIBO, Kidričeva 99, 4220 Škofja Loka, Slovenia,
  Blaz Osterman, blaz.osterman@sibo-group.eu, http://www.sibo-group.eu/
Final Nano Enhanced Products

Nanodeposition, Encapsulation  ➔  Self cleaning Organic Photovoltaics

INPUTS
- OPV - Modules - Laminates with nano-coating

OUTPUTs
- Self-cleaning and UV-resistant OPV-modules

<table>
<thead>
<tr>
<th>Pilot Business Model</th>
<th>Product Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Printing of organic photovoltaic modules;</td>
</tr>
<tr>
<td>Size / Constrains</td>
<td>Up to 1m width and rolls of 100m</td>
</tr>
<tr>
<td>Internal Quality Capabilities</td>
<td>Photovoltaic parameters, Accelerated Lifetime testing; Outdoor Testing;</td>
</tr>
<tr>
<td>Material addressed in OptiNanoPro</td>
<td>Outer layer; encapsulation layer with UV-blocking and self cleaning properties</td>
</tr>
<tr>
<td>Location</td>
<td>Opvius, Nurnberg – Germany Pavel Schilinsky, <a href="mailto:pavel.schilinsky@opvius.com">pavel.schilinsky@opvius.com</a>, <a href="http://solarte.de">http://solarte.de</a></td>
</tr>
</tbody>
</table>
**Injection Moulding**

Injection moulding is a manufacturing process for producing plastic parts by injecting material into a closed mould. It is typically used for high quantity product from the small to the big parts too.

**Size / Constrains**

Injection moulding machines up to 2600t clamping force with closed dryer system

**Internal Quality Capabilities**

Dimension, mechanical, reology, colour and gloss, flammability and weather resistance

**Material addressed in OptiNanoPro**

The industrial validation of the developed materials. Scale up production of products with nano composites and light weighted materials by injection moulding.

**Location**

PEMU Plastic Processing Co. Ltd./ Hungary-Solymár
Mr. Szabolcs Nagy, szabolcs.nagy@pemu.hu, www.pemu.hu

**Pilot Business Model**

Product development -> Product component supply

**Technology**

Injection moulding is a manufacturing process for producing plastic parts by injecting material into a closed mould. It is typically used for high quantity product from the small to the big parts too.

**Final Nano Enhanced Products**

Injection Moulding → Light weight car parts, Barrier Containers

**INPUTS**

- compounds with nanoparticle in granules

**OUTPUTs**

- light weight car parts (eq. door panel) - containers

**OPEN MARKET**
Nano Enhancement Systems

Control of nanodeposition, coating & lamination lines → Monitoring System

Pilot Business Model:
- Development and Supply of equipment

Technology:
- Optical monitoring system for online control of the thickness of the applied nanocoating and/or micro-coating along and across the web

Size / Constrains:
- Adjustable to the throughput of the production line

Internal Quality Capabilities:
- Preliminary offline calibration tests to determine the right optical technique(s) prior to integration in the intended application

Material addressed in OptiNanoPro:
- Nanoparticles nanocoatings (based on SiO2, TiO2, etc.)
- Nanostructured micro-coating (eg. whey-protein based coatings with clays)

Location:
- IRIS, Castelldefels (Spain)
- Elodie Bugnicourt, ebugnicourt@iris.cat
- www.iris.cat

Inputs:
- Nanoparticles
- Nanoenhanced (bio)polymer coating suspension

Outputs:
- Nanocomposites microcoatings
- Nanoparticles coatings
- With constant quality
## Pilot Business Model
- Material development → ingredient supplier for product manufacturers
- Process & equipment development → adaptation and integration into production lines if the manufacturing process requires it

## Technology
Electrospray nanodeposition (Electro-hydrodynamic Atomization of nanoparticles)

## Size / Constrains
Coating speed is highly dependent on the solution and the film properties.

## Internal Quality Capabilities
- Off-line measurements of solution properties (before processing)
- On-line control of process parameters: flow, distance to collector, speed and voltage.

## Material addressed in OptiNanoPro
Nanodeposits of SiO2 and TiO2 onto plastic films for packaging and organic photovoltaics applications

## Location
BIOINICIA S.L.- Paterna, Valencia, SPAIN.
Sara Castello, projects@bioinicia.com
www.bioinicia.com
## Nano Enhancement Systems

**Inputs**
- Nanoparticles - (Bio)Polymer suspension or pellets

**Outputs**
- Nanocomposites coatings and compounds with optimal dispersion and properties

### Pilot Business Model
- Development and Supply of equipment
- Ultrasound-assisted dispersion
- Adjustable to the throughput of the production line
- Preliminary sonication tests to determine the right parameters to obtain an optimal nanoparticle dispersion in the intended application

### Material addressed in OptiNanoPro
- Nanoparticles liquid suspensions (eg. whey-protein based coatings)
- Thermoplastic-based nanocomposite compounds (eg. with PP, HDPE, PHB matrix)

### Location
- For suspensions: IRIS, Castelldefels (Spain)
  - Elodie Bugnicourt, ebugnicourt@iris.cat
  - www.iris.cat
- For compounds: EURECAT, Cerdanyola del Vallès (Spain)
  - Germán PEREZ, german.perez@eurecat.org
  - http://eurecat.org

### OPEN MARKET
Nano Enhancement Systems

Compounding formulation development

INPUTS
- Nanoparticles - Polymer matrix (pellets)

OUTPUTs
Nanocompounds

Pilot Business Model
Open Access Material development -> Know-how Transfer

Technology
Twin screw extrusion-Compounding assisted by an ultrasound system to enhance the dispersion of nanoparticles – Optimal formulations

Size / Constrains
Pilot scale extruder – throughput up to 40 kg/h

Internal Quality Capabilities
High dispersion of nanoparticles coupling the ultrasound system to the die extrusion. Test for mechanical properties: Tensile tests, flexural tests, melt flow index, DSC, GPC and IR.

Material addressed in OptiNanoPro
Thermoplastic-based nanocomposite compounds (eg. with PP, HDPE, PHB matrix) with nanoparticles (eg. with nanoclays or nanotalc)

Location
EURECAT, Cerdanyola del Vallès (Spain)
Germán PEREZ, german.perez@eurecat.org, http://eurecat.org
### Pilot Business Model

| Open Access Material and process development/modeling | Material recipes and process parameters | Know-how Transfer |

### Technology

- Formulation development / preparation as well as wet chemical coating technology

### Size / Constrain

- Up to 10kg/batch. Coating speed up to 30m/min. Coating width up to 460mm.

### Internal Quality Capabilities

- Viscosity, Color, Barrier and Mechanical Properties, Degree of denaturation, Surface characteristics, DSC, AFM, FT-IR

### Material addressed in OptiNanoPro

- Nano enhanced whey protein-based coating formulations and processes

### Location

- Fraunhofer, Freising, Germany
- Markus Schmid, markus.schmid@ivv.fraunhofer.de, www.ivv.fraunhofer.de

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**Nano Enabling Support**

**Coating formulation development**

**INPUTS**
- Nanoparticles coating dispersions

**OUTPUTS**
- Barrier laminates

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[Image: nano_enabling_support.png]

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Support Services

Nanosafety Assessment, Integration in circular economy of and Business Exploitation

Support Services: Implementation of responsible risk management practices, based on a sound understanding of the hazards, exposures and risks with nanotechnology.

Location: Institute of Occupational Medicine, Edinburgh UK
Steve Hankin, Steve.Hankin@iom-world.org
http://www.iom-world.org/

Support Services: Environmental and economic impact assessment (LCA & LCC), organic recycling (compostability), biodegradation & toxicity testing

Location: OWS, Belgium, Steven Verstichel, steven.verstichel@ows.be
http://www.ows.be/

Support Services: Tasks related with the preparation of the exploitation of the project results, IP management

Location: LC Innoconsult, Hungary
Mogyorosi Péter, Mogyorosi.peter@lcinnoconsult.com
http://www.lcinnoconsult.com/
Through the industrial integration along the supply and value chain of the previous developed formulations, processes as well as customized dispersion and monitoring systems for ensuring constant material quality, the project will deliver new competitive products for packaging, automotive and OPV with a high potential impact on the market.
Targeted PROPERTIES

✓ Cost effective sustainable nanocomposite solutions to reduce injected car parts weight by up to 20%

Market IMPACT

✓ Reduced fuel consumption
✓ Maintained structural performance and improved flame resistance
✓ Reduced greenhouse gas
Targeted PROPERTIES

➢ Cost effective sustainable nanocomposite solutions to reduce packaging permeability by 50 to 75%

Market Impact

✓ Barrier materials for weight reduction and performance improvements
✓ Increased food shelf life
✓ Resource efficiency
✓ Reduced waste
Targeted PROPERTIES

- Cost effective sustainable nanocoatings solutions to reduce product’s residues at end of packaging life by a factor 2

Market Impact

- Reduced waste of cosmetics and pasty food in packaging
- Increased customer satisfaction
- Eased recycling
Targeted PROPERTIES

➢ Cost effective sustainable nanocoatings solutions to decrease OPV maintenance frequency by a factor 2 and increase energy harvesting by 10%.

Market Impact

✓ Increased photo-efficiency of the OPV
✓ Reduced maintenance
✓ Increased durability
✓ Contribution to increasing the share of renewable energy
The partial or total substitution of selected value chain components by the key-enabling nano-enhancement technologies developed in OptiNaNoPro and the replication of new production line for nano-enhanced products all over Europe will meet growing market trends for innovative and sustainable solutions addressing the packaging, automotive and OPV markets and beyond.

For more info: www.optinanopro.eu

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