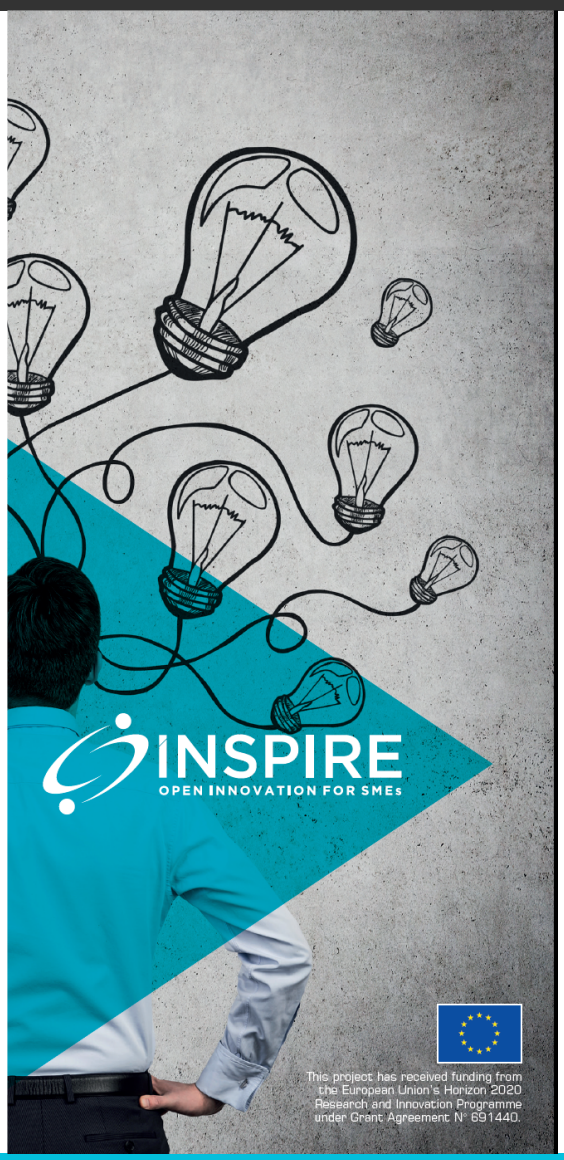

NANOPHOS

Greece, www.nanophos.com

A Greek SME participated in an R&D project with leading research institutes and technology centres to develop and commercialize an innovative product to protect our cultural heritage

Executive Summary

The materials out of which architectural structures and monuments are built tend to be weathered both through natural processes and anthropogenically-induced environmental pollution. The conservation of our cultural heritage through new technologies has received particular interest over the last twenty years. However, such activities which involve the application of new technologies (e.g. nano and microtechnology applications, materials science, etc.) can only be effective through synergies and collaboration among multiple groups and scientific disciplines, e.g. architecture, engineering, technology. Through its strategic collaboration with a strong team of research and technological partners, NanoPhos SA. was able to scale up its formulas and co-develop, demonstrate and commercialize an innovative hybrid nano-material (SurfaPore FX) capable of enhancing the mechanical strength of building surfaces and stabilizing loose surfaces, which is ideal for the restoration, long-term protection and weathering resistance of monuments.

CASE N°: SE28

SECTOR: NANOTECHNOLOGY

TECH INTENSITY: HIGH-TECH

LIFE CYCLE STAGE: ESTABLISHED

INNOVATION VECTORS: PRODUCT

OI PARTNERS: PSR, APPLIED RESEARCH & TECHNOLOGY CENTRE

KEYWORDS: Nanotechnology, consolidants, buildings, cultural heritage

- BACKGROUND FRAMEWORK
- INNOVATION CHALLENGE & MARKET OPPORTUNITIES
- OI TRAJECTORY
- BUSINESS IMPACT
- LESSONS LEARNED

NanoPhos
Pioneering Nanotechnology

BACKGROUND

NanoPhos was founded in 2005 with a vision to "Tune the NanoWorld to serve the MacroWorld", thereby bringing to the market nanotechnology innovations which respond to the challenges of everydaylife. NanoPhos SA engages in the development, production and sale of chemical and nano- technology products for cleaning, waterproofing, protection and the restoration of surfaces (cement, clay based, marble, granite, wooden surfaces etc.). The company is also active in the paint and coatings industry and offers a series of nanotechnology and microtechnology-based products: ready to use paints, as well as additives for acrylic water based paints which increase their thermal insulating and water repelling properties.

The company, which is based in Lavrio, Greece, sells its products through an extensive distribution network across 25 countries in Europe, the Middle East, Asia and America. Dr. Arabatzis, the managing director of NanoPhos SA, holds a PhD in Chemical Engineering from the National Technological University of Athens (NTUA), an MBA from ALBA Graduate Business School and a BSc in Chemistry from the University of Ioannina.

His major research interests include applied nanotechnology and semiconductors chemistry. He is the co-author of more than 20 scientific articles. His journal contributions have received more than 500 citations from fellow scientists all over the world. Today Dr. Arabatzis is proud to realize his dream by dedicating himself to transferring technology into every day applications.

In 2014 NanoPhos decided to transfer all its experience and successes from the construction market to marine coatings. NanoPhos Marine was established to bring innovative solutions based on the unique properties of nanotechnology to the maritime industry. The NanoPhos Marine product portfolio already includes 25 products focusing on maintenance, cleaning, hull protection, antifouling and fuel saving.

Since December 2015 and following a strategic cooperation agreement between NanoPhos SA and Advanced Polymer Coatings, NanoPhos Marine became the exclusive representative of MarineLine 784 in Greece and Cyprus. MarineLine 784 is the industry-leading cargo tank coating system available for chemical and product carriers, and the only high performance lining that withstands all IMO approved chemical cargoes.

INNOVATION CHALLENGE & MARKET OPPORTUNITIES

Shortly after its foundation, Nanophos managed to establish fully operational internal R&D and production activities. At the same time, however, the company acknowledged the need to be engaged in a constant dialogue with its external environment (research centres, industrial manufacturers, customers, end users) to identify unsolved problems that could be solved potentially with the power of nanotechnology so as to turn them into business opportunities or R&D challenges.

Furthermore, they recognized that joint R&D and pilot testing would help to improve the integration of NanoPhos proprietary technologies into industrial applications, enable access to new markets and provide greater visibility for the company's solutions, both at industrial and retail level. A key vehicle for engaging and advancing joint prototype, testing and demonstration activities has been national and EU funding instruments (FP7, H2020, NSRF, etc.).

The materials out of which architectural structures and monuments are built tend to be weathered both through natural processes and anthropogenically-induced environmental pollution. Over the last decades, a good deal of research has been carried out into the production of silicon-based polymeric resins to be used as strengthening and protective agents for such porous building materials.

This family of materials presents many advantages but also several disadvantages like cracking and insufficient bonding to carbonaceous substrates. A multidisciplinary team was formed in an attempt to improve the performance of this group of materials and thereby develop hybrid consolidants which would strengthen and protect buildings and monuments of cultural heritage by improving the performance characteristics of stones with different porosities.

This effort was selected and co-financed (through EU and national funds and own contributions) under the Synergasia programme, an action supporting strategic collaboration between Greek companies and research organizations with the aim of co-developing new knowledge and technologies (NANOBIODOMYL project).

The consortium comprised two top research institutions in the area of materials and treatments

for the conservation and restoration of historic buildings and monuments, which already had a successful track record of cooperation. The partners included the Laboratory of Materials for Cultural Heritage and Modern Building of the School of Architectural Engineering, Technical University of Crete; Laboratory of Archaeometry, Institute of Material Science at the National Center for Scientific Research Demokritos, NanoPhos, a nanotechnology company (NanoPhos) with a proven track record in the research, development, production and sale of chemical products for cleaning and protecting surfaces and nanotechnology products, as well as MIRTEC (Materials Industrial Research & Technology Center) a highly accredited technological centre, active in applied research, technological development, certification and quality control in a wide range of materials and products with its own laboratories for testing and analyzing materials and products.

For the SME NanoPhos, this was a unique opportunity to work with a strong R&D partnership and to scale up its formulas, based mainly on its SurfaPore™ technology which provided effective water proofing, stain proofing, protection and "shielding" of different surfaces through water-based formulations. The key outcome would be the creation of a consolidant, able to enhance the mechanical strength of building surfaces and stabilize loose surfaces, applicable to its key target market.

OPEN INNOVATION TRAJECTORY

Concept development

The consortium focused its efforts in developing, testing and commercializing nano-hybrid bio-inspired products in the form of alcohol or water-based suspensions and powders to be used as surface protection and consolidation of traditional and modern building materials.

The development process, IPR and competition strategy

The development of a novel nano-composite consolidant (SiOx), which was based on the modification of tetraethoxysilane (TEOS) after incorporating in the silica matrix nano-particles of calcium oxalate monohydrate, required a concrete set of activities for the synthesis, characterization (determination of their physico-chemical characteristics, evaluation of physico-chemical stability through mineralogical analysis) and the improvement of the new SiOx hybrid nanomaterials.

An assessment of the consolidation of SiOx applied to stone samples was carried out with a view to evaluating the performance of the synthesized SiOx products in a laboratory-scale case study. The final products were applied to stone specimens of a porous bioclastic limestone, similar to that occurring frequently in historical and modern architectural structures in the Mediterranean basin. Tests were carried out in treated and non-treated stones, aiming to test and evaluate colour changes, changes induced by the treatment in the morphology and texture, as well as changes in the porosity and pore size distribution. The product was then evaluated in terms of its consolidation and protective effect in relation to building materials: the nano-composite consolidant as well as the treatment process were characterized, analyzed and assessed.

The hybrid SiOx product which improves the performance characteristics of stones with different porosities was developed. Its ability to perform effectively as a consolidant by improving the performance characteristics of porous limestone without significant alteration of the microstructure and consequently its ability of liquid and vapor circulation in its bulk was demonstrated. Moreover, the incorporation of CaOx into TEOS offered the further advantage of a crack-free material which is important for the successful application of consolidants.

These beneficial properties were significantly improved by reducing water absorption mainly due to the presence of calcium oxalate, which is the main compound identified in well-preserved surface patina layer on stone monuments. The designed SiOx therefore provided a compatible structure to the deteriorated stone with the ability of strengthening and protecting it from environmental loading.

The method for producing a nano-oxalate/ silicate gel and applications thereof in construction materials was patented in Greece (National IP Organization: 1007392, granted to the research partners as inventors and owners in 2011). The related co-development activities, the characterization and formulation of the consolidants as well as the demonstration activities and knowledge management procedures where covered by the project Grant Agreement clauses.

The new material was developed and evaluated to have improved characteristics and functionalities

in comparison to other commercial products: the new product creates a continuous and cohesive structured surface with increased mechanical strength. Furthermore, its easy application ensures its dual role both for the protection as well as the repair of already degraded surfaces. The absence of resins ensures increased lifetime and action. As NanoPhos focused at the time on B2B agreements for the new material, no specific competition strategy was formulated.

Commercialization and follow-up

A long-term licensing agreement was signed among the project partners to enable the exploitation of the designed nanocomposite. This agreement was the cornerstone of NanoPhos' strategy to scale up the production of the consolidant and commercialize it under the brand SurfaPore FX. (sold both as a retail and wholesale product).

SurfaPore FX enhances the mechanical strength of building surfaces and enables the stabilization of loose surfaces with the aforementioned properties. After the application and penetration on the substrate, the nanoparticles "anchor" chemically the application surface and additionally bond between them. This results in a dense three-dimensional network, which enhances the mechanical properties of weathered or "sensitive" surfaces. The nature of inorganic nanoparticles ensures chemical compatibility and easy application to building materials. The nanoparticle does not close the pores, but mechanically supports the mircocracking and "discontinuity" of the materials. In this way, the physical appearance, porosity and breathability of modified surfaces remain unaffected.

The company's B2B focus drove their marketing efforts via targeted company missions, participation in international exhibitions and affiliation schemes with networks and clusters such as:

- Hellenic Federation of Enterprises - www.sev.org.gr
- Hellenic Association of Chemical Industries - www.haci.gr
- HEMEXPO Hellenic Marine Equipment Manufacturers and Exporters - www.hemexpo.gr
- European Cool Roofs Council - coolroofcouncil.eu

As a follow-on activity in 2015-2016, the Lab of Materials for Cultural Heritage and Modern Building (MaCHMoB) of the School of Architectural Engineering, Technical University of Crete, along with Betong Consult AS, NanoPhos SA, the Laboratory of Materials and Methods for Cultural Heritage of the Politecnico di Milano and the Surfa Products Scandinavia AS carried out the joint project: "The Oslo Opera House – Condition analysis and proposal for protection and maintenance of exterior marble", in Oslo, Norway. The Oslo Opera House is a listed building. The project was carried out in close cooperation with the Norwegian Directorate for Cultural Heritage (Statsbygg) and focused on the conservation of approximately 23 000 m² of Carrara marble that decorates the external facades and roof of the Opera House.

BUSINESS IMPACT

The company benefited from the complementary know-how and research expertise that the partners brought to the project in order to create, evaluate and at the end commercialize a product that has innovative characteristics.

NanoPhos was able to develop, test and commercialize a whole range of SurfaPore FX consolidants, a set of smart materials with differentiated attributes, which could be sold in NanoPhos' target market, i.e. building and construction. There are no figures for the direct commercial impact of the OI project.

LESSONS LEARNED

Through its strategic collaboration with a strong team of partners in the framework of the NANOBIODOMYL collaborative project, NanoPhos SA was able to scale up its formulas and create SurfaPore FX, an innovative hybrid nano-material able to enhance the mechanical strength of building surfaces and stabilize loose surfaces. The SME was able to develop, test and commercialize a whole range of SurfaPore FX consolidants, a set of smart materials with differentiated attributes, and sell them in its target market, i.e. building and construction.

Main lessons learned:

1. Opportunities to participate in R&D projects can have substantial impact on research-intensive SMEs through win-win collaboration with different types of actors (SMEs, RTOs) and taking advantage of the

partners' skills and added value. Through this specific project the company was able to scale up its formulas and create a new product for its target market.

2. Successful OI projects can lead to further strategic collaborations, such as the Oslo Opera House large-scale demonstration project.