NANORESTART (NANOmaterials for the REStoration of works of ART)

Una delle sfide più attuali e pressanti nell'ambito della conservazione dei beni culturali riguarda il mantenimento di manufatti artistici moderni e contemporanei quali dipinti acrilici, oggetti in materiali plastici, e opere composite polimateriche. La composizione di queste opere è diversa da quella del patrimonio artistico classico, pertanto le metodologie sviluppate fino ad oggi sono spesso inefficaci nel contrastarne il degrado.
Il progetto "NANORESTART" (NANOmaterials for the REStoration of works of ART), con un costo di circa 9 M di euro finanziati dalla Comunità Europea nell'ambito del programma Horizon 2020, mira quindi alla messa a punto di nanomateriali e di metodologie avanzate, e a basso impatto eco-tossicologico, per preservare il patrimonio moderno/contemporaneo. A tale scopo l'ente coordinatore del progetto (CSGI, Consorzio Universitario per lo Sviluppo di Sistemi a Grande Interfase) ha riunito una partnership internazionale che raccoglie centri di eccellenza di scienza dei materiali, musei e centri di conservazione di alto prestigio, e industrie di primo piano nel settore dello sviluppo di materiali. Il CSGI stesso è ente leader nel settore della conservazione, avendo già coordinato progetti per la preservazione del patrimonio classico.
Il progetto NANORESTART si svolgerà nel triennio 2015-2018, ed i nuovi materiali sviluppati includeranno sistemi detergenti per la pulitura delle opere (gel, microemulsioni), materiali compositi per il rafforzamento meccanico e la protezione di superfici artistiche, e tecniche di rilevazione fine dei prodotti di degrado sviluppati dalle opere d'arte durante il loro invecchiamento.

Lista dei partecipanti al progetto NANORESTART:
Centre for Colloid and Surface Science, University of Florence
Chalmers University of Technology
Antonio Mirabile, Paper conservator
National Museum of Denmark
National Research Council
Tyndall National Institute, University College of Cork
MBN Nanomaterialia
National Institute of Chemistry
Aurelia Chevalier Atelier
UFRGS – Universidade Federal do Rio Grande do Sul
University Ca' Foscari of Venice
AkzoNobel

CEA - Commissariat à l'énergie atomique et aux énergies alternatives
Museo Soumaya – Fundacion Carlos Slim
Arkema
Dirección General de Promoción Cultural y Acervo Patrimonial - SHCP
University of Santiago de Compostela
University College of London
Zentrum für Bucherhaltung GmbH
University of Barcelona
Tate
Associazione Italiana per la Ricerca Industriale
Art Institute of Chicago
Instituto del Patrimonio Cultural de España
Rijksmuseum Amsterdam
University of Amsterdam
Universidade Federal do Rio de Janeiro (UFRJ), School of Fine Arts
Peggy Guggenheim Collection
Accademia delle Belle Arti di Brera

Project abstract

NANOmaterials for the REStoration of works of ART

Currently there is a lack of methodologies for the conservation of modern and contemporary artworks, many of which will not be accessible in very short time due to extremely fast degradation processes. The challenge of NANORESTART (NANOmaterials for the REStoration of works of ART) will be to address this issue within a new framework with respect to the state of the art of conservation science. NANORESTART is devoted to the development of nanomaterials to ensure long term protection and security of modern/contemporary cultural heritage, taking into account environmental and human risks, feasibility and materials costs. The market for conservation of this heritage is estimated at some €5 billion per year, and could increase by a significant factor in the next years due to the wider use of nanomaterials. The new tools and materials developed will represent a breakthrough in cultural heritage and conservation science and will focus on: (i) tools for controlled cleaning, such as highly-retentive gels for the confinement of enzymes and nanostructured fluids based on green surfactants; (ii) the strengthening and protection of surfaces by using nanocontainers, nanoparticles and supramolecular systems/

assemblies; (iii) nanostructured substrates and sensors for enhanced molecules detection; (iv) evaluation of the environmental impact and the development of security measures for long lasting conservation of cultural heritage. Within the project the industrial scalability of the developed materials will be demonstrated.
NANORESTART gathers centres of excellence in the field of synthesis and characterization of nanomaterials, world leading chemical Industries and SMEs operating in R&D, and International and European centres for conservation, education and museums. Such centres will assess the new materials on modern/contemporary artefacts in urgent need of conservation, and disseminate the knowledge and the new nanomaterials among conservators on a worldwide perspective.

NANO Cathedral. - Nanomaterials for conservation of European architectural heritage developed by research on characteristic lithotypes.

List of participants

Participant No *	Participant organisation name	Short Name	Country	Type
1	National Inter University Consortium of Materials Science and Technology	INSTM	Italy	UNI
2	Opera della Primaziale Pisana	OPAE	Italy	Private non-profit org.
3	Warrant Group S.r.l.	WG	Italy	SME
4	Istituto Superiore per la Conservazione ed il Restauro	ISCR	Italy	Public Body
5	Colorobbia Consulting S.r.l.	COLOR	Italy	IND
6	Chem Spec S.r.l.	CS	Italy	SME
7	Metropolitankapitel der Hohen Domkirche Köln – Dombauhütte	HDK	Germany	Private non-profit org.
8	Otto-Friedrich-University	UBAM	Germany	UNI
9	Karlsruhe Institute of Technology, Institute for Applied Biosciences, Department of Microbiology	KIT	Germany	RTD
10	Wiedemann GmbH	WIED	Germany	SME
11	Fundación Catedral Santa María	FCSM	Spain	Public Body
12	Diputación Foral de Álava	DFA	Spain	Public body
13	Tecnologia Navarra De Nanoproductos S.L.	TECNAN	Spain	SME
14	Dombausekretariat St. Stephan	DBHWIEN	Austria	Private non-profit org.
15	University of Applied Arts Vienna Institute of Arts and Technology/Conservation Sciences	IATCS	Austria	UNI
16	Forschungsbereich für Ingenieurgeologie, Institut für Geotechnik, Technische Universität Wien	BI.GEO	Austria	UNI
17	Architectenbureau Bressers bvba (Sint-BaasfKathedral)	ARCHI	Belgium	SME
18	Organic Waste Systems nv	OWS	Belgium	SME
19	Oslo Opera House - Statsbygg	DNO	Norway	Public Body

The project NANO-CATHEDRAL aims at developing, with a nano-metric scale approach, new materials, technologies and procedures for the conservation of deteriorated stones in monumental buildings and cathedrals and high value contemporary architecture, with a particular emphasis on the preservation of the originality and specificity of materials. The objective is providing "key tools" for restoration and conservation:
•On representative lithotypes
•On European representative climatic areas
•With a time-scale/environmental approach
•With technology validated in relevant environment (industrial plant and monuments)
•Exploiting results also on modern stone made buildings

A general protocol will be defined for the identification of the petrographic and mineralogical features of the stone materials, the identification of the degradation patterns, the evaluation of the causes and mechanisms of alteration and degradation, including the correlations between the relevant state of decay and the actual microclimatic and air pollution conditions. Moreover, innovative nano-materials will be developed suitable for:

•Surface consolidation: in this case water-based formulations based on nano-inorganic or nano-hybrid dispersions such as nano-silica, nano-titania, nano-hydroxyapatite, nano-calcite and nano-magnesia as well as their synergic combinations with organic and inorganic compounds will be considered.

•Surface protection: in this case, innovative composites will be developed consisting of polymers and nano-fillers. The use of hydrophobins, nano-assembled hydrofobic proteins extracted from fungi, and photocatalytic nano-particles (for favoring the decomposition of volatile organic molecules carried by polluted atmosphere and to prevent biofilm growth) will be considered. The project will contribute to the development of transnational cultural tourism and to the development of common European shared values and heritage, thus stimulating a greater sense of European identity.

1.1 Objectives

The project NANO-CATHEDRAL aims at developing new materials, technologies and procedures for the conservation of deteriorated stones in monumental buildings and cathedrals and high value contemporary architecture, with a particular emphasis on the preservation of the originality of materials and on the development of a tailor-made approach to tackle the specific problems related to the different lithotypes. In fact the objective is providing "key tools" in terms of innovative nano-structured conservation materials, for restoration and conservation *on a full European scale, thanks to the research work made onto lithotypes representative of different European geographical areas and styles (Table 1) and of different climate and environmental conditions (Table 2).*

Monument Town	Building period	Architectural Style	Main lithotypes classes
Pisa	Medieval Age	Pisan Romanesque	Mount Pisano marble /black limestones /Apuan marble /Proconnesian marble /calcarenite /granitoid rocks /serpentinite
Koln	Medieval Age (1248–ca. 1520) 19th Century (1842 – 1880)	Gothic Neogothic	Drachenfels Trachyte / Schlaitdorf Sandstone / Obernkirchen Sandstone / Savonnieres Limestone / Volcanic Tuffstones / Basalt lava
Vitoria	Medieval Age 13th - 16th Centuries	Gothic	Lumachella from Ajarte /sandstone from Elguea /calcarenite from Olarizu
Wien	Medieval Age (1140-1513)	Late Romanesque and Gothic	Limestones from Leitha-mountains and Vienna, few siliceous sandstones from Lower Austria
Ghent	Medieval Age (942-1038) 14th-16th Centuries (1300-ca. - 1569)	Romanesque Brabantine Gothic	Arenaceous limestone belonging to the Lede Formation (Belgium), and Belgian and French limestones as replacement materials (from Gobertange, Euville, Savonnières and Massangis)
Oslo	2003-2007	Contemporary	White Carrara marble

Table 1: main characteristics of monuments involved in NANO-CATHEDRAL

CLIMATE AREA	COASTAL	CONTINENTAL	LATITUDE[1]
South European	Pisa	Vitoria-Gasteiz	42-43°
Central European		Wien	48°
North European	Ghent	Koln	51°
Scandinavian	Oslo		60°

Table 2: selected sites having different climatic conditions in Europe.

The objective of the NANO-CATHEDRAL project will be achieved with a specific survey of the selected monuments, through:

1. Indirect analysis of historical and documental sources.
2. Direct analysis of building materials and their state of conservation.

For this purpose a general protocol will be defined for the identification of the petrographic and mineralogical features of the stone materials, the identification of the degradation patterns according to ICOMOS documents[2], the evaluation of the causes and mechanisms of alteration and degradation, including the correlations between the relevant state of decay and the actual microclimatic and air pollution conditions. Moreover, nano-additives and nano-structured composites will be developed suitable for:

- **Surface consolidation**[3] (a material that penetrating by capillarity into the micro-structure of the decayed stone, is able to strengthen it by replacing lost original mineral bridges, and partially recovering lost mechanical properties).
- **Surface protection**[3] (a material that penetrating by capillarity into the micro-structure of the stone, is able to prevent the ingress of liquid water, without any change in aesthetical, optical and chemical properties of the substrate).

The preparation and selection will be carried out with the aim of providing the best technological answer for the preservation of different types of stones found in the selected cathedrals representative of the diversity of European architectural heritage.

For reaching the goal of consolidation, water-based formulations based on nano-inorganic or nano-hybrid dispersions such as **nano-silica**, **nano-titania**, **nano-hydroxyapatite**, **nano-lime** and **nano-magnesia** as well as their synergic combinations with organic (e.g. **fungal hydrophobins**) and inorganic compounds will be considered. Stone specimens, both as aged *in situ* (small or micro-samples) and as obtained on purpose from the original quarries (taken as such or after accelerated aging), will be tested before and after application of the consolidation and protection materials to evaluate the effectiveness of the treatment, according to relevant European standard protocols[4], current scientific literature and the development of new in situ testing procedures. Modelling algorithms will be developed as predictive tools for the assessment of effectiveness of the formulations depending on the different types of stone.

To achieve the goal of stone protection, innovative composites will be developed consisting of **polymers** and **nano-fillers**; the use of **hydrophobins**, nano-assembled hydrophobic proteins extracted from fungi[5], will be also considered. The nano-structured protective materials will be designed to achieve improved soil and water-repellence. In addition, photocatalytic nano-particles will be employed in order to favour the decomposition of volatile organic molecules carried by polluted atmosphere and to prevent biofilm growth.

The specific requirements for consolidants and protectives are reported in Scheme 1.

Consolidants	Protectives
• Good adhesion to the stone substrate • Negligible color alteration • Adds no gloss or sheen • Improvement of mechanical and microstructural properties • Do not produce any harmful by-products (salts, VOCs, organic compounds, etc.) • Economic affordability	• Negligible color alteration • Adds no gloss or sheen • Applies as waterborne system • Water repellent • Water vapor permeable • Stable under a variety of environmental conditions, including temperature cycling and UV exposure • Reversible or re-treatable

Scheme 1: requirements for consolidants and protective treatments

Two main problems will be specifically addressed: *the durability of effective protective treatments and, at the same time, the re-treatability of the stone materials to allow adequate maintenance works.*

The LCA approach applied to NANO-CATHEDRAL will allow to keep into account the environmental and health impacts related to both the production and the application of the developed materials and processes. As this point is particularly important, because of the incalculable value of the monuments and for their worldwide impact, such analysis will be made before the scaling-up of the studied processes. The exploitation of the project will bring about the adoption of best practices for cathedral preservation by selecting the most advanced nano-technologies. The dissemination activities, carried out both in the six strategic regions and in all Europe, will allow to spread and strengthen the awareness, at the European level, of the contribution of nanoscience and nanotechnology to cultural heritage preservation.

Moreover the inclusion in the consortium of the Oslo Opera House, representing a high value contemporary architecture coated with white Carrara marble, will give the possibility of scaling-up the process and validating the selected materials and methodologies for the protection of new stones at work, thus expanding the exploitation field of the proposed nano-technologies.