INNOVATIVE PACKAGING SOLUTIONS FOR STORAGE AND CONSERVATION OF 20TH CENTURY CULTURAL HERITAGE OF ARTEFACTS BASED ON CELLULOSE DERIVATE

A huge percentage of the European cultural heritage (CH) can be found in movies, photos and posters produced between 1895 to nowadays were made using cellulose derivatives. More than 75 years of visual and audio memories are up to now in serious danger to be lost due to the natural instability cellulose acetate (CA) and cellulose nitrate (CN) material.

Once initiated, degradation cannot be prevented, reversed or stopped, but only inhibited or slowed. Inhibitive conservation of cellulose derivates can either involve the removal or reduction of factors causing degradation including light, oxygen, acids, fungus and relative humidity among others, as well as cost-sensitive processes such as freeze.

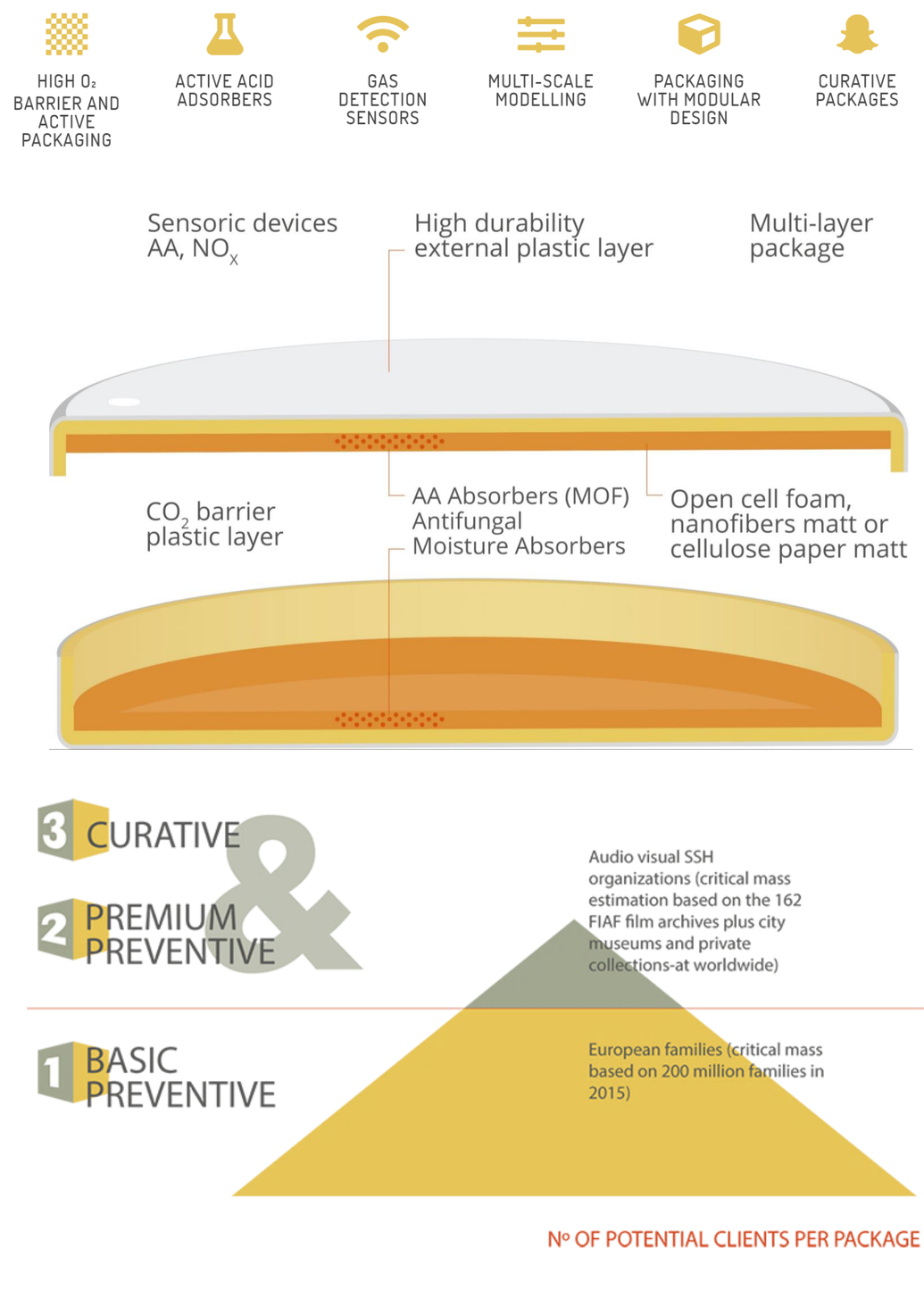
The main target of NEMOSINE project is the long-term preservation of films based on cellulose derivatives, cellulose acetate and cellulose nitrate from photographic, movies and audio supports collections

NEMOSINE improves traditional storage solutions, such as freeze storage (below 5ºC), by developing an innovative package with the main goal of energy saving and extent conservation time. NEMOSINE will develop:

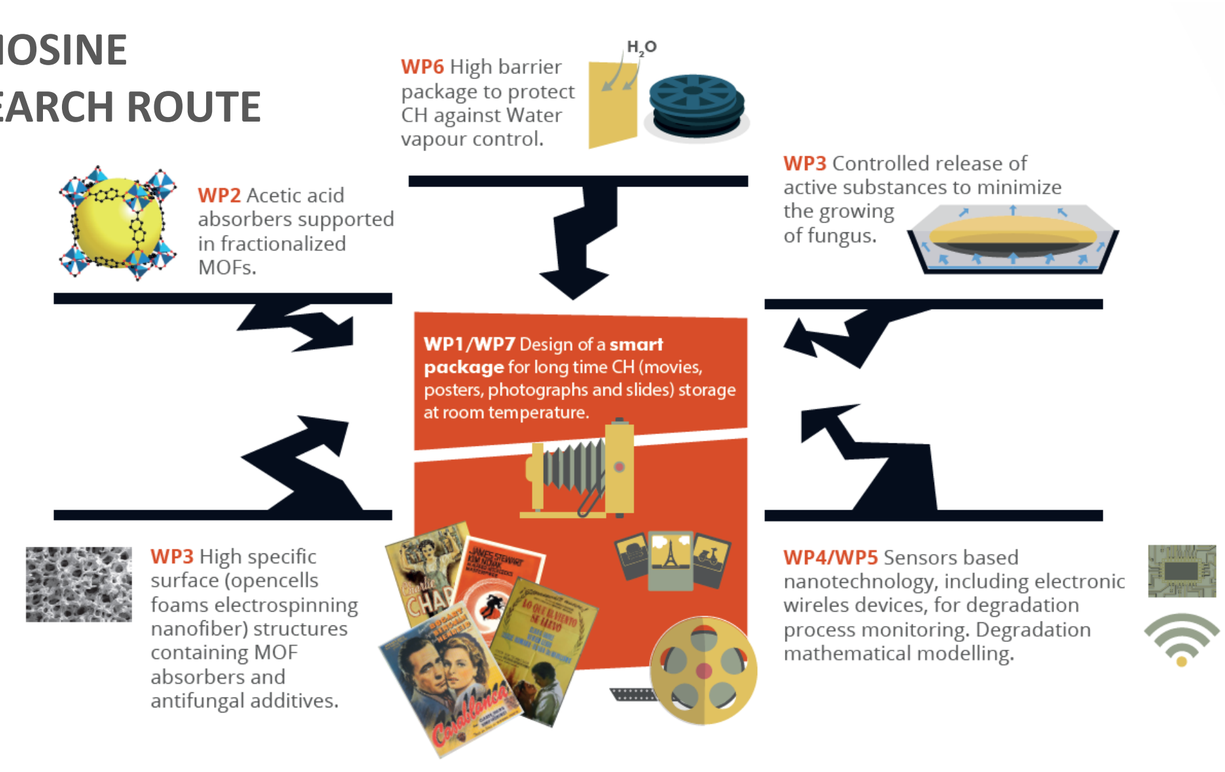
- High O_2 barrier and active packaging using non-odour additives;
- Active acid adsorbers based on functionalized Metal Organic Framework (MOFs) integrated in innovative structures;
- Gas detection sensors to monitoring AA, O_2 & NO;
- Multi-scale modelling to correlate degradation & sensors signals;
- Packaging with modular design to fulfil the technical & economical requirements of the different CH made by cellulose derivates.

These innovative solutions will be shaped as three packages' prototypes with different functionalities and target customers: preventive (basic & premium) and curative. Based on the same outside box possessing high barrier properties to oxygen, they differ on the devices inside: i) basic preventive package with a monitoring gas sensor; ii) premium preventive with a gas sensor and an adsorbent device; and iii) curative package with an antifungal system.

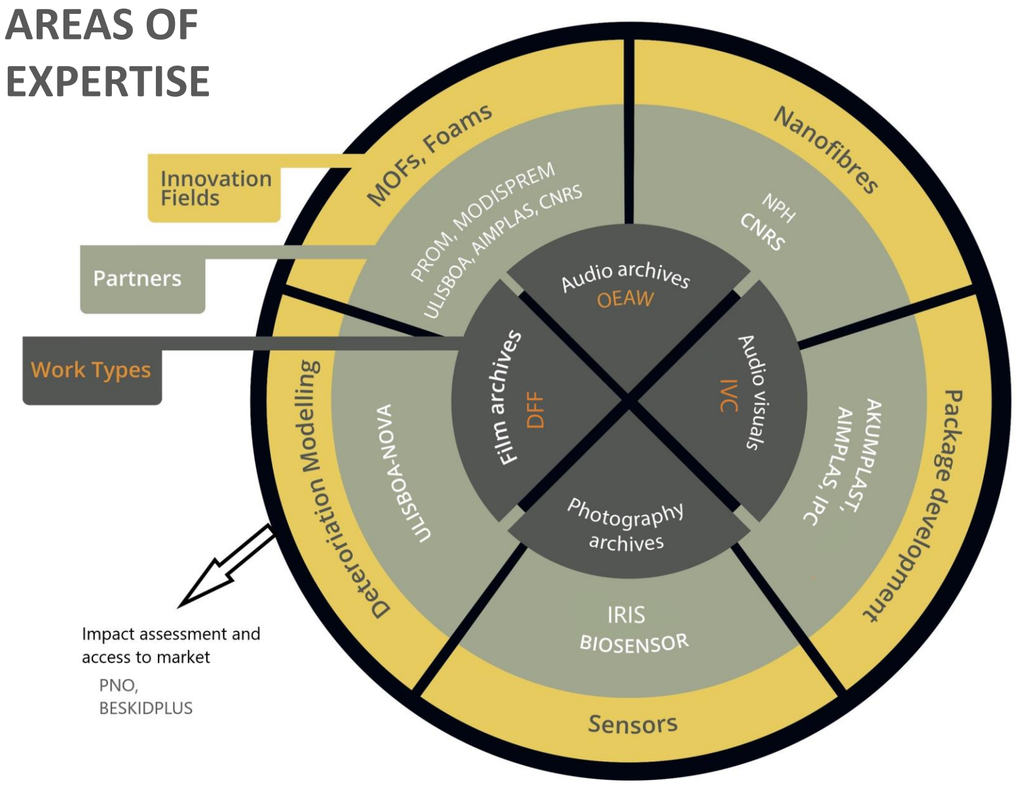
NEMOSINE SMART PACKAGE CONCEPT



NEMOSINE RESEARCH ROUTE



AREAS OF EXPERTISE



PARTNERS

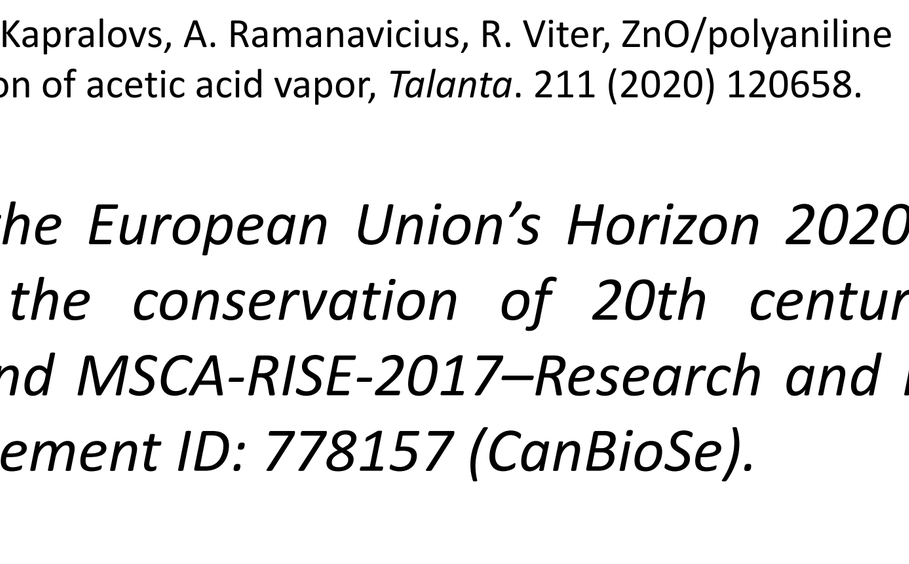
MORE INFO AT:

- https://nemosineproject.eu/
- https://www.linkedin.com/in/nemosineproject/
- https://twitter.com/nemosineproject

NEMOSINE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760801.

High-tech project focused on sustainable cities and communities by impacting cultural heritage conservation

- We developed a simple, low cost a low-power solution to detect the degradation of Cultural Heritage artifacts based on cellulose acetate at early stages, Optical sensors based on Zin Oxide and Metal Oxide semiconductors sensors were chosen. The last sensors are constituted by an interdigitated electrode, on top of which a thin layer of metal oxide is deposited. The whole system is heated by a heater circuit underside. When in contact with air, an equilibrium is established between air molecules and the surface of the metal oxide, resulting in a certain electrical resistance across the interdigitated circuit. When the analyte encounters the sensing surfaces, it alters the electron distribution, resulting in a measurable change of electrical resistance.
- We developed a sensing solution which was accurate in detecting the target gas (acetic acid) and not be affected by other volatiles released by the cultural heritage artifacts, a two-sensors array was assembled and tested, first on pure volatiles and then on real film samples.
- A mathematical elaborator was created, capable of calculating acetic acid concentration regardless of other volatiles present. A software with graphical interface was created, allowing the user to directly read both the raw values and the acetic acid concentration when the board is connected to the PC via USB. The system was successfully tested on more than forty film samples, comparing the result obtained with those calculated employing the reference methodology, Acid-Detecting strips.



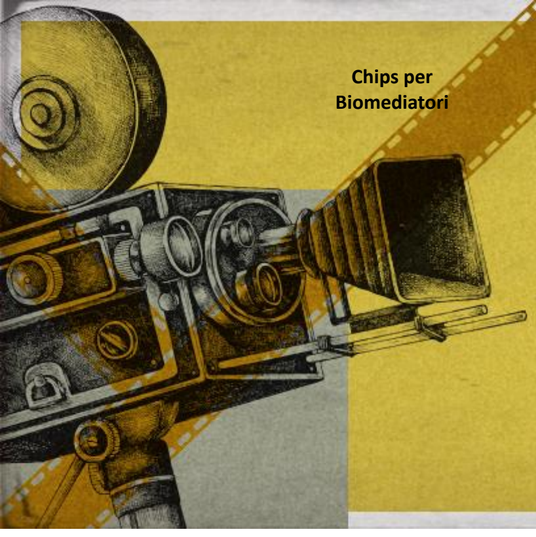
Real-time monitoring of cinematographic films. Integration into Nemosine's container was done in collaboration with IRIS and Lisboa UNI.

Daniele Zappi, Gabriele Varani, Igor Iatsunskyi, Nadja Wallaszkovits, Josef Bailer, Maria Teresa Giardi. High-Sensitivity Metal Oxide Sensors Duplex for On-the-Field Detection of Acetic Acid Arising from the Degradation of Cellulose Acetate-Based Cinematographic and Photographic Films. *Chemosensors* 2022, *10*(2), 60; https://doi.org/10.3390/chemosensors10020060

M. Turemis, D. Zappi, M.T. Giardi, G. Basile, A. Ramanaviciene, A. Kapralovs, A. Ramanavicius, R. Viter, ZnO/polyaniline composite based photoluminescence sensor for the determination of acetic acid vapor, *Talanta*. 211 (2020) 120658. https://doi.org/10.1016/j.talanta.2019.120658

This research has received funding from the European Union's Horizon 2020 Program: NMBP-35-2017–Innovative solutions for the conservation of 20th century cultural heritage (Grant agreement ID: 760801), and MSCA-RISE-2017–Research and Innovation Staff Exchange H2020- EU.1.3.3-Grant agreement ID: 778157 (CanBioSe).

Chips per Biomediatori



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NEMOSINE has receibed funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760801.

BIOSENSOR

Biosensor Srl is a SME founded in 2003. It has its main activity in Via Olmetti 44, Industrial Area of Formello - Rome. It also has two small subsidiaries in Pozzuoli – Naples – and in Trieste.

Biosensor works in the field of production and commercialization of bioassay and biosensor systems based on the use of biologic material such as enzymes, antibodies, microalgae and small living organisms.

The activities are reported in the following:

- **Sensors and biosensors for the agri-environmental and biomedical sector**
- **Optical and electrochemical biosensors for agri-environmental contaminants and pesticides**
- **Optical and electrochemical biosensors for the diagnosis of biomarkers**
- **Immunobiosensors for disease diagnostics and drug discovery, detection of contaminants, allergens, toxins**
- **Development of miniature devices for sensor applications**

- **Organs on a chip**
- **Design of materials and devices for biosensors**
- **Bioconjugation of nanoparticles with bioreceptors for biosensing**
- **Materials and nanomaterials for the design of biosensors**

- **Design, synthesis and development of peptides, peptidomimetics and peptides for diagnostic applications**

- **Devices for Space research**

- **Microalgae biotechnology**
- **Microalgae for biofuel production**
- **Microalgae for the extraction of compounds for nutraceutics**
- **Molecular nutraceuticals**
- **Sensors for cultural heritage**
- **ICT applications**

Biosensor has previous experience working in projects both at national and European level. Biosensor is a consortium member of the projects NEMOSINE – Innovative packaging solutions for storage and conservation of 20th century cultural heritage of artefacts based on cellulose derivative https://nemosineproject.eu/, EUCALIVA – EUCAlyptus LIgnin VAlorization for Advanced Materials and Carbon Fibres http://eucaliva.eu/), CanBioSe – Novel 1D photonic metal oxide nanostructures for early stage cancer detection https://www.canbiose.lu.lv/en/), TRUST-ME – Quick test on urinary, blood or salivary sample with immunosensors for diagnosis of infectious diseases.

We are open to participate as partners in European project or as subcontractors for specific tasks involving our area of expertise, with the aim to form strong research groups and deliver high-end research results

Beyond the smart box for cinematographic and photographic films: The preservation of cellulose nitrate and cellulose acetate 3D objects

Artur Neves[1,2], Robert Friedel[2], Maria João Melo[1] and Ana Maria Ramos[1]

[1]LAQV/REQUIMTE, Department of Conservation and Restoration and Department of Chemistry, NOVA School of Science and Technology, Universidade NOVA de Lisboa, 2829-516, Caparica, Portugal

[2]Department of History, University of Maryland, College Park, MD, 20742, USA

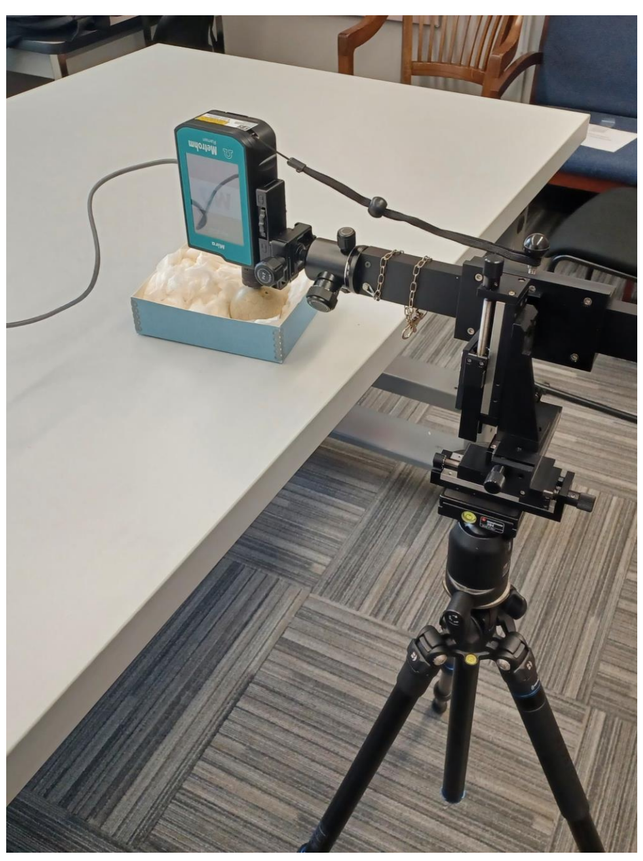
In this poster, the idea of adapting the NEMOSINE smart box for 3D objects is introduced. 3D objects made of cellulose nitrate and cellulose acetate are ubiquitous in modern heritage collections. Because of these materials' intrinsic chemical instability, it is crucial to 1) identify, 2) characterize, determine the conservation condition and 3) design the best preservation strategies. A handheld Raman MIRA DS spectrometer (Metrohm) was used as an *in situ* tool for the first two steps in three different cultural American institutions. NEMOSINE financed the purchase and transportation of a micrometric tripod, allowing an *in loco* precise application of the equipment. This work was carried out by team member Artur Neves under a Fulbright fellowship with the support of the Fundação Portuguesa para a Ciência e a Tecnologia (FCT).

NATIONAL MUSEUM OF AMERICAN HISTORY
BEHRING CENTER

with Drs. Kristen Frederick-Frost and Deborah Warner

John Wesley Hyatt's 1868 "original" celluloid billiard ball

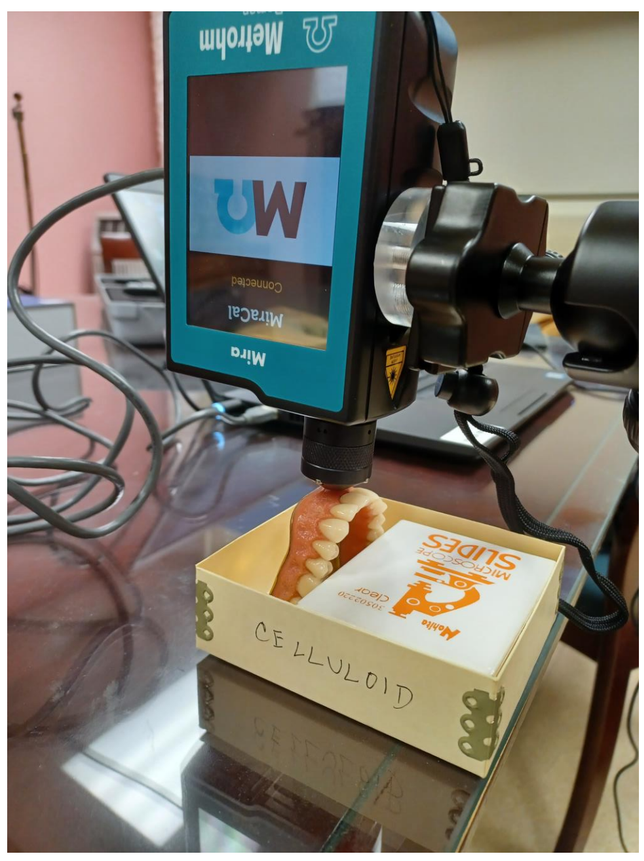
21119424



the smile experience
The Dr. Samuel D. Harris NATIONAL MUSEUM of DENTISTRY

with Dr. Scott Swank

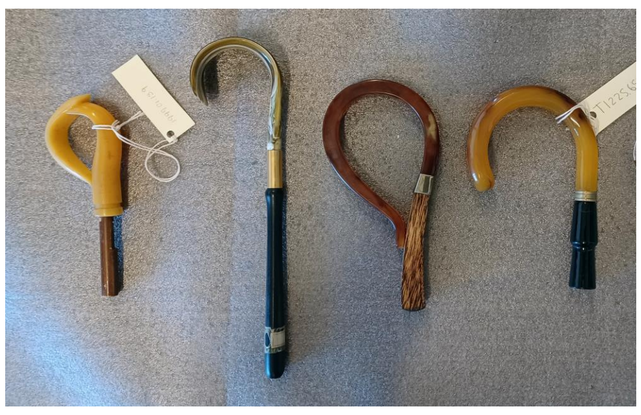
Maxillary dental plate with swaged gold base with celluloid gums and porcelain teeth. Late 19th century

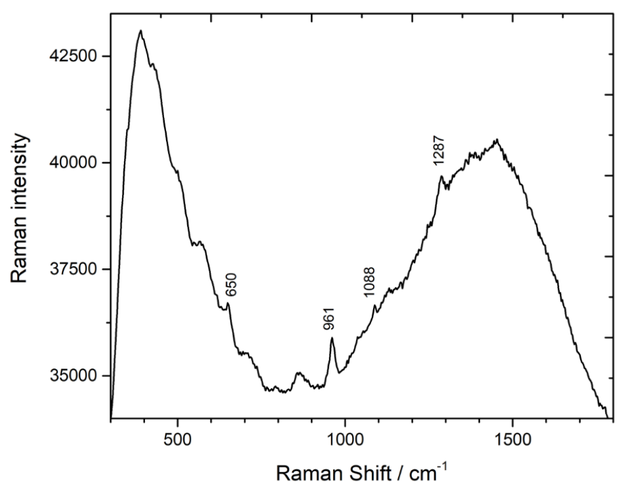


BMI Baltimore Museum OF Industry

with Dr. Curtis Durham

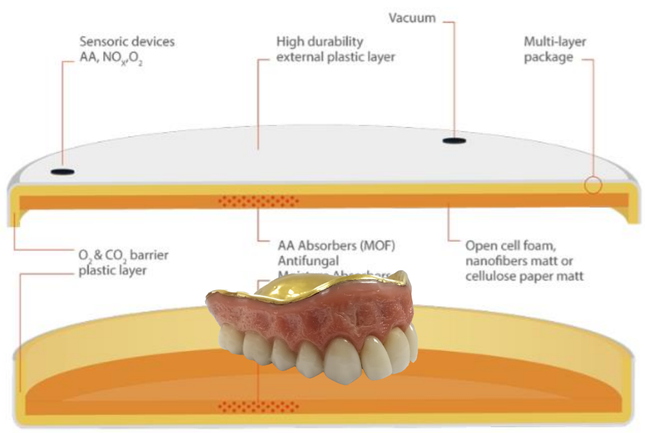
Celluloid and cellulose acetate umbrela handles from Polan Katz. Early XX century





Raman spectrum of John Wesley Hyatt's "original" billiard ball: cellulose nitrate (1287 cm^{-1}), camphor (650 cm^{-1}), hydroxyapatite (961 cm^{-1}) and calcium carbonate (1088 cm^{-1}). Results confirmed by Fourier Transformed Infrared and X-Ray Fluorescence spectroscopies.

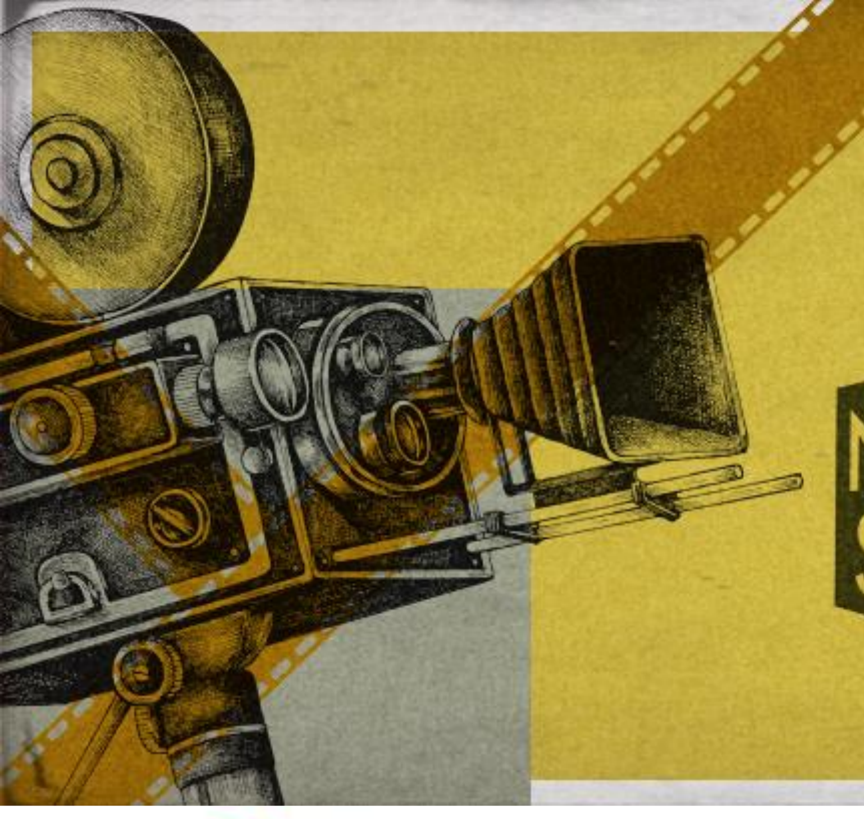
Future: adaptation of the NEMOSINE boxes for 3D objects?



Acknowledgements

This work thanks Drs. Kristen Frederick-Frost and Deborah Warner, Smithsonian Institution; Dr. Curtis Durham, Baltimore Museum of Industry; and Dr. Scott Swank, Dr. Samuel D. Harris National Museum of Industry. Artur Neves thanks professors Philip Soergel, Department of History, and Ray Phaneuf, Department Material Science and Engineering, University of Maryland, College Park. This work was funded by a Fulbright Fellowship with the support of Fundação para a Ciência e a Tecnologia (FCT), Portugal (Grant PS00326022); Associate Laboratory for Green Chemistry- LAQV financed by national funds (UIDB/ 50006/2020 and UIDP/50006/2020. The Raman tripod purchase and transportation was financed by the European Union's Horizon 2020 Research and Innovation Programme (H2020-NMBP-35-2017), Grant agreement no 76081, Project NEMOSINE.

NOVA SCHOOL OF SCIENCE & TECHNOLOGY
LAQV requimte LABORATÓRIO ASSOCIADO PARA A QUÍMICA VERDE
FULBRIGHT Portugal
FCT Fundação para a Ciência e a Tecnologia



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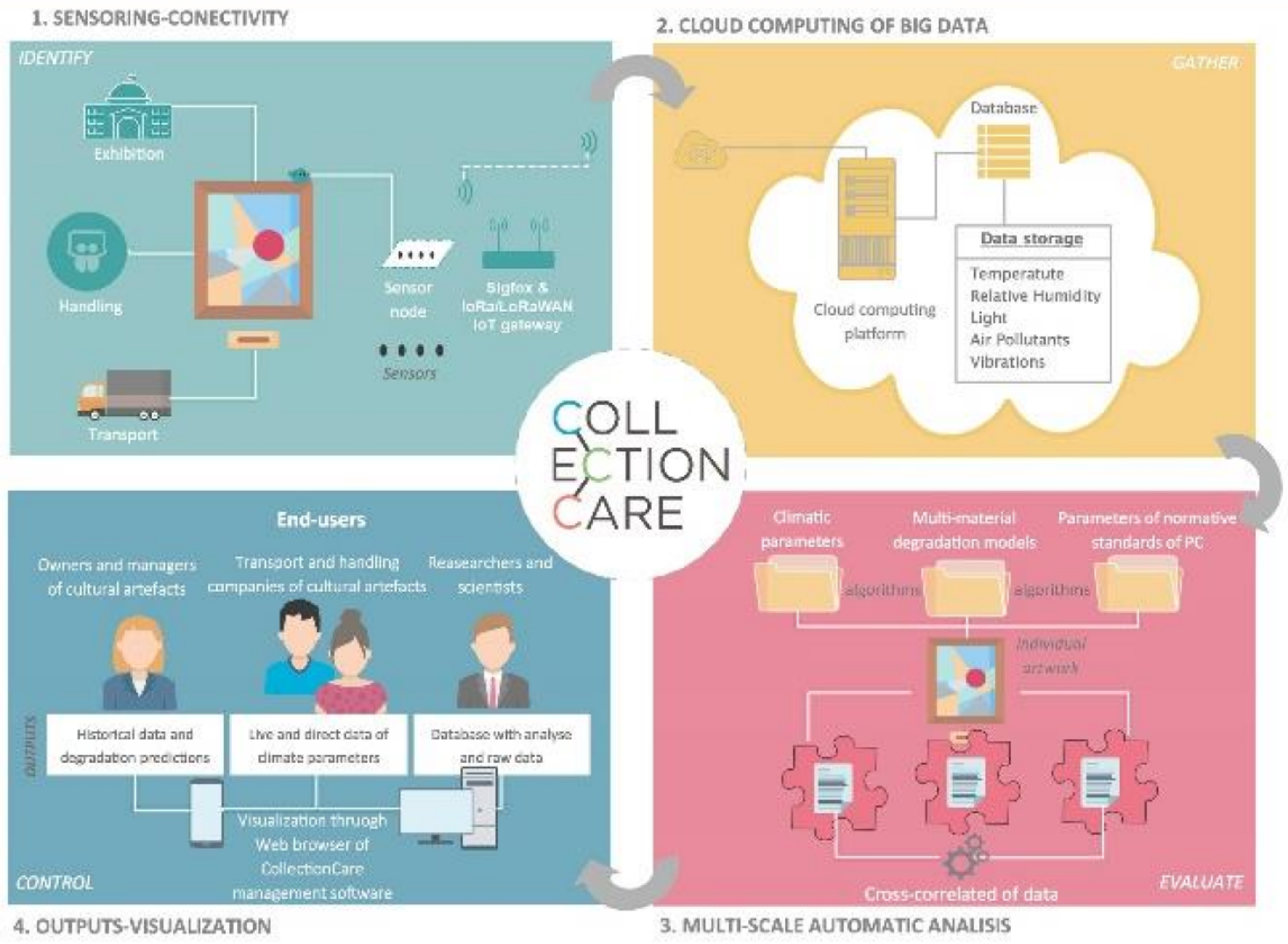
Innovative and affordable service for the Preventive Conservation monitoring of individual Cultural Artefacts during display, storage, handling and transport

Authors: Andrea Peiró-Vitoria (1); Ana María García-Castillo (1); Jaime Laborda Macario (1); Ignacio Díaz Arellano (1); José Dahoui Obón (1); Laura Fuster-López (2); Angel Perles Ivars (1)

Institution: 1 ITACA Institute, Universitat Politècnica de València (UPV); 2 Instituto Universitario de Restauración del Patrimonio, Universitat Politècnica de València (UPV)

CollectionCare aims to develop an innovative PC decision support system targeting the needs of small to medium sized museums and collections. It integrates current research and technological advances in monitoring systems (sensor nodes), wireless communications, big data, cloud computing and material and multi material degradation models into a single affordable system. This way, the CollectionCare system will be able to monitor the environmental conditions of each artefact individually at any place (on display or in storage, handling or transport), provide degradation predictions of multi-material cultural artefacts and offer suitable recommendations for their proper conservation.



HOW CollectionCare system works?

1. First, CollectionCare system monitores the environmental conditions (relative humidity, temperature, light, UV radiation and air pollutants) with a low cost wireless sensor node that will be attached strategically in the room, on the cultural artefact or nearby.

2. Secondly, the data collected by the sensors is transmitted to a cloud computing platform for Big Data using LPWAN technologies.

3. Then, the recorded data is automatically stored, analysed and crossed in the cloud with advanced multi material degradation models, as well as with the European Standards and Guidelines parameters.

4. And finally, CollectionCare system will provide degradation predictions for multi-material cultural artefacts, alarms and appropriate recommendations for preventive conservation to control and minimise their degradation, thus ensuring their preservation.

For WHOM is it targeted?

Collectioncare is intended as a preventive conservation decision support system for small to medium sized museums, collections, archives, galleries, etc. that often cannot afford sophisticated environmental monitoring systems or qualified maintenance or conservation staff. That is why it is an economical, accessible and low maintenance system.

Which IMPACTS are expected?

It is expected to improve the efficiency, costs, sustainability and versatility of existing preventive conservation options on the market and to contribute to the overall knowledge and citizens' awareness of cultural heritage preservation.

Impacts

TECHNOLOGY DEVELOPMENT

Sensor Node Design. The sensor node has been designed taking into account both the technological side and the aesthetics of the device, as it must be suitable for museum and heritage environments.
Key aspects: precision, energy efficiency, long battery life, compatibility, versatility and environmental friendliness. [Led by UPV]

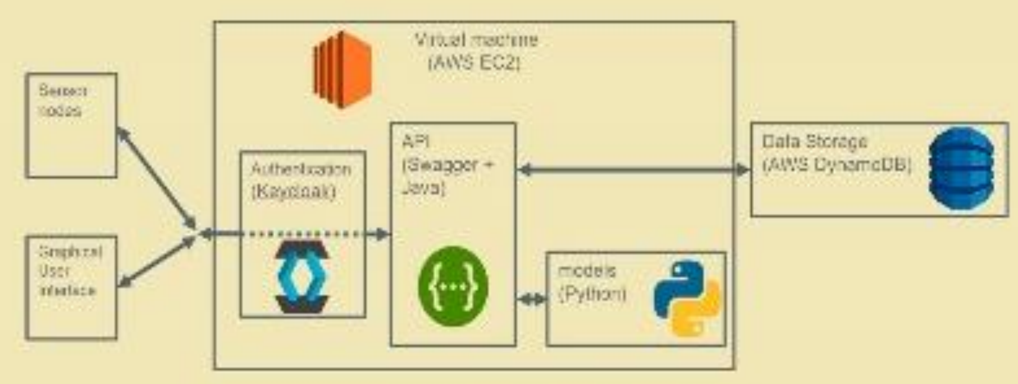
ITACA Institute, UPV

Optimized sensor node

Connectivity. Radio-mapping and connectivity annalysis (Sigfox and LoRaWAN technologies) have been carried out to ensure data transmission in worst-case scenarios, such as historical buildings with thick walls, vaults or long distances to cover. [Led by UPV & Sigfox]

The Royal Danish Collection (RDC)

Big data & Cloud computing. A cloud infrastructure based on Amazon Web Services (AWS) has been designed to store data, create the environment for running algorithmic models, support data analysis and connect to the user interface. [Led by Atos]

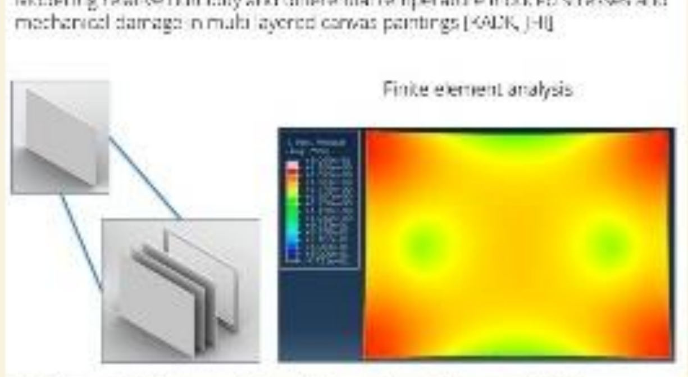


RESEARCH ON MATERIALS DEGRADATION

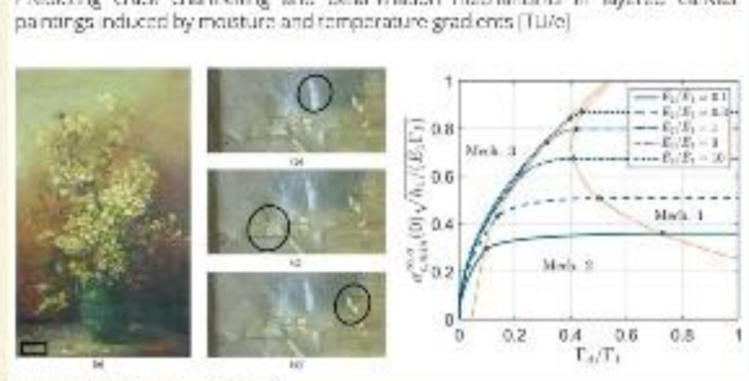
One of the key points of the project has been the progress in research on material degradation models (canvas painting, paper, wood and metal), such as mechanical damage to canvas paintings, chemo-mechanical degradation of paper or corrosion in metal, among others. These material degradation models have been translated into mathematical algorithms and uploaded to the cloud in order to analyse the data and predict the future degradation of cultural objects, taking into account their multimateriality.

This task has been led by partners specialised in each of these fields: KADK, JHI and UPV (canvas painting), TU/e (paper and canvas painting), LSWIC (wood) and UW (metal).

Modeling relative humidity and differential temperature induced stresses and mechanical damage in multi-layered canvas paintings [KADK, JHI]

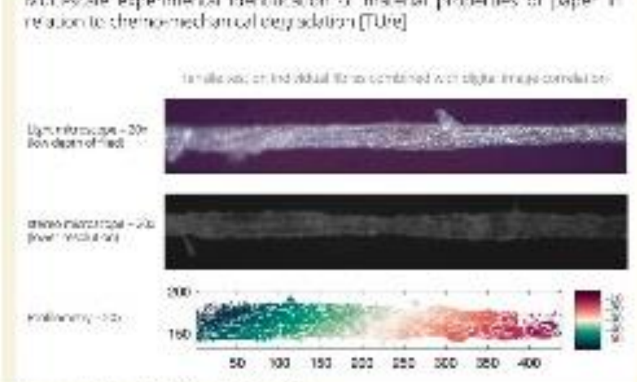


Predicting crack channelling and delamination mechanisms in layered canvas paintings induced by moisture and temperature gradients [TU/e]

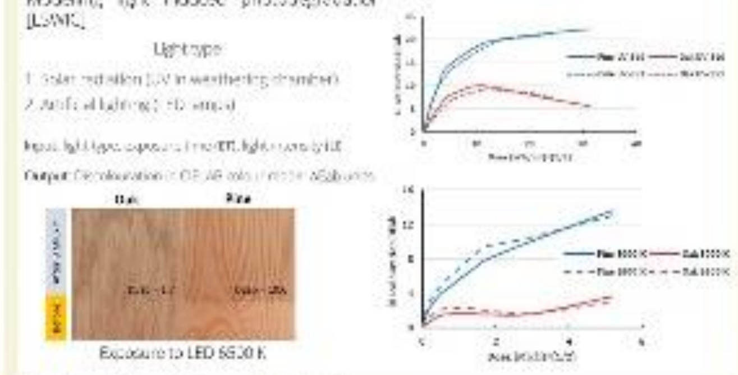


Bosco et al. (2020). Int J Fract 225, 1-30

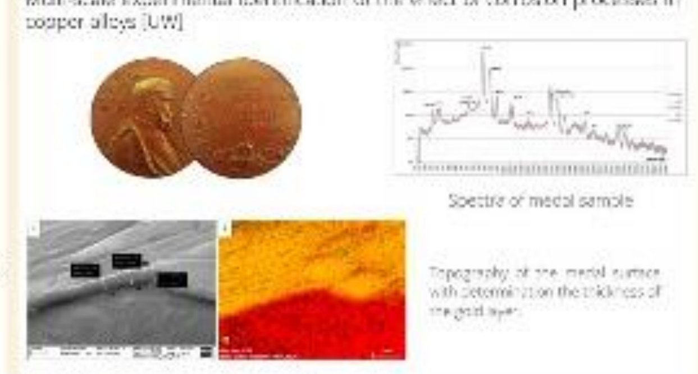
Multi-scale experimental identification of material properties of paper in relation to chemo-mechanical degradation [TU/e]



Modeling light induced photodegradation [LSWIC]



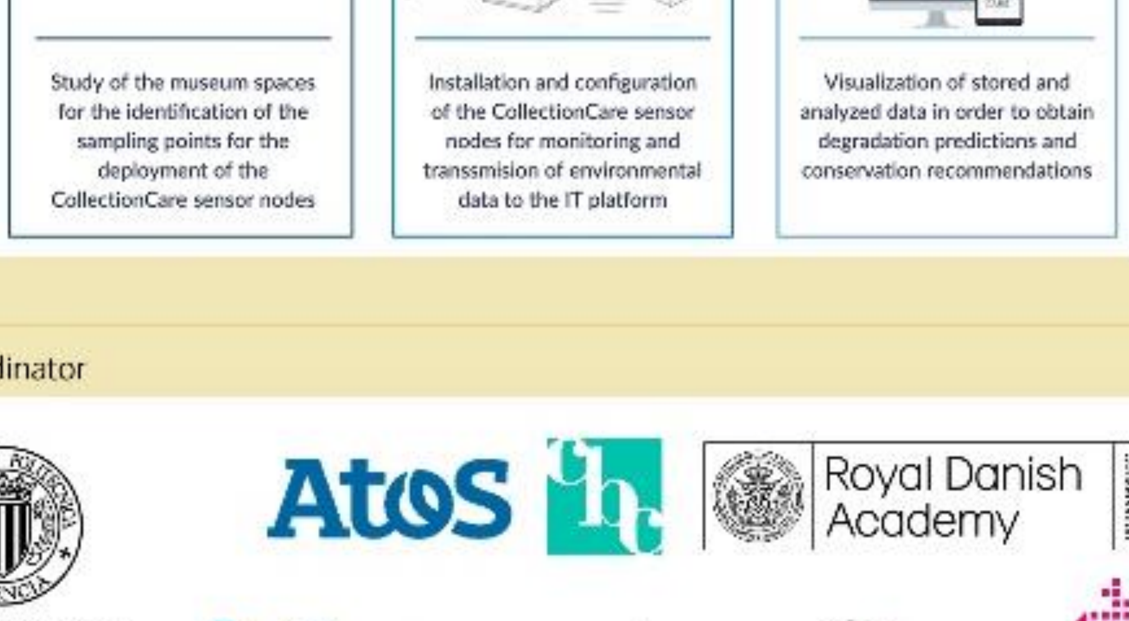
Multi-scale experimental identification of the effect of corrosion processes in copper alloys [UW]



PRODUCT

CollectionCare system. A highly accurate system with an energy-efficient, easy-to-install device that monitors each object and predicts its possible long-term degradation, helping conservators and museum staff to make more informed decisions and more accurate conservation strategies.

Front view elements	Back view elements
1 Location of the T (°C) & RH (%) sensor	8 Li-SOCL2Battery, voltage 3.6V & nominal energy 9.36Wh
2 Location of the light sensor (lx) & LED indicator	9 The slide. Part of the fixing system of the sensor housing
3 Location of the UV sensor (µW/lm)	10 The cover. Back housing part
4 The box. Front housing part	11 On & Off switch
5 Aux sensor hook	12 Reset button
6 Aux sensor connector for external probes	
7 User buttom	



CollectionCare system in operation in MUSEUMS

The validation and demonstration of the CollectionCare system has been carried out in the partner MUSEUMS of the project: The Royal Danish Collection. Rosenborg (RDC); Alava Arms Museum and Alava Fine Arts Museum, Diputación Foral de Álava (DFA); National Historical Museum, Historical and Ethnological Society of Greece (IEEE); Musical Instruments Museum, Art & History Museum (KMKG); La Filmoteca, Institut Valencià de Cultura (IVC); The Ethnographic Open Air Museum of Latvia (OAML).

Each museum has made a selection of cultural objects, from which their data and conservation status have been collected. For the demonstration tasks, several of these objects were chosen for monitoring, either because of their fragility, their strategic location or the particular interest of the museum conservators.

Before deploying the device, each museum was studied to avoid any connectivity problems and to establish the deployment protocols to be followed. Finally, the installation of the sensor nodes was carried out by the staff of each museum.

Several sensors are currently in operation in most of the partner museums. It has been verified that the data are correctly collected in the cloud and can be visualised on the platform adapted for this purpose. The Collectioncare device is working properly and has been tested for its easy installation and its versatility for different museum scenarios.

IIn the last phase of the project, demonstration activities of the complete system are planned for cultural objects on display, in storage and/or during handling and transport.

Cultural heritage is the legacy of our ancestors and it is our responsibility to preserve it for future generations. CollectionCare is intended to be a useful and accessible tool to help make the right decisions to properly preserve cultural heritage. **PRESERVING THE PAST, LOOKING TO THE FUTURE!**

Coordinator

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Consortium

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