Nanotechnology – Materials and Techniques for Safeguarding Cultural Heritage

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Abstract. The presented project aims to provide practical solutions for ceramic and paper artifacts, based on new antifungal recipes, in order to reduce the impact of biodegradation of cultural heritage artifacts. The developed recipes, specific for each type of support material (ceramic and paper), will be based on the use of soft nanomaterials, applicable in the form of xerogels or spraying. The recipes will take into consideration the interaction between the developed materials and the support materials.

Keywords: Nanomaterials, Ceramic Artifacts, Paper Artifacts, Antimicrobial Recipes.

1 Introduction

The cultural heritage and architectural monuments are exposed to environmental pollutants, climatic factors (temperature, humidity, rain and other precipitations, sun exposure) and chemical treatments (biocides, surfactants and hydrophobic compounds) that facilitate microbial growth, resulting in physical, chemical, but also aesthetic effects. An adequate assessment of biodegradation and material disintegration requires a combination of microbiological, surface and material characterization techniques.

Several research papers, including those published by our group, presents the application of alternative methods in the area of restoration/conservation of cultural heritage artifacts, including the use of natural extracts (Barresi et al., 2017; Fierascu, R.C., et

al., 2017) and synthesised nanomaterials (Valentini, et al., 2012; Chelazzi et al., 2013; Fierascu, I., et al., 2014; Elhaddad et al., 2018; Fierascu, I., et al., 2018; Quagliarini et al., 2018; Sassoni, 2018).

2 Complex Project Description

The presented project (*Nanotechnology - Innovative Approach with the Development of Materials and Techniques for the Safeguarding of Cultural Heritage*) represents Research Project No. 2 of the Complex Project "Multidisciplinary complex project for monitoring, preserving, protecting and promoting the Romanian cultural heritage" (RO-CHER). The complex project (implementation period 2018-2020), financed in the 2017 national competition "Complex projects realised in RDI consortia" organized by the Executive Unit for Financing Higher Education, Research, Development and Innovation (UEFISCDI) consists of four separate research projects, each having its own partners, implementation methodologies, activities and results. The complex project (coordinator Romanian Space Agency) includes the following research projects:

- Research project 1: Monitoring of cultural heritage objectives using space technologies; coordinator: Romanian Space Agency; partners: University of Agronomic Sciences and Veterinary Medicine of Bucharest and Museum of Dacian and Roman Civilization Deva;
- *Research project 2: Nanotechnology - Innovative approach with the development of materials and techniques for safeguarding cultural heritage; coordinator: ICECHIM; partners: Museum of Dacian and Roman Civilization Deva, National Museum of the Union Alba Iulia and University of Agronomic Sciences and Veterinary Medicine of Bucharest;*
- Research project 3: Integrated management (conservation, restoration, protection) of cultural heritage objectives; coordinator: National Museum of the Union Alba Iulia; partners: Romanian Space Agency and ICECHIM;
- Research project 4: Promoting cultural heritage using current digital reconstruction technologies; coordinator: University of Agronomic Sciences and Veterinary Medicine of Bucharest; partners: Romanian Space Agency, ICECHIM, Museum of Dacian and Roman Civilization Deva and National Museum of the Union Alba Iulia.

The specific result indicators of the complex project that will support the further development of project activities in the post-implementation phase are:

- Newly created R&D jobs - by implementing the project, 7 new positions will be created for young researchers;
- Patent applications - following the implementation of the proposed project, 6 patent applications will be filed;
- Validating technologies and systems and integrating them into the developers' portfolio;
- Reciprocal access of partners to the equipment and technology needed to implement the project;

- Strengthening the capacity of partner institutions, through development of human resources and research infrastructure;
- A common RDI program correlated with the institutional development plan of each partner (ensuring the sustainability of the collaboration after the completion of the project) - thus developing a cluster of knowledge capable of accessing national and international funds.

3 Research Project: Nanotechnology - Innovative Approach with the Development of Materials and Techniques for Safeguarding Cultural Heritage

The main objective of the project is to provide practical solutions based on new anti-fungal prescriptions, to reduce the impact of biodegradation of cultural heritage artifacts. The developed, specific for each type of support material (ceramic and paper) will be based on the use of soft nanomaterials and will be applied in the form of xerogels or by spraying. Recipes will be based on mixtures of alkoxide materials, alkaline-earth metal hydroxides and apatite compounds with properties (rigidity, porosity, thermal, expansion coefficient and colour) and controlled dimensions.

3.1 The degree of novelty and complexity

The exploitation of the synergic action of the materials used and the establishment of an optimal relationship between them constitutes the scientific / technical novelty of the project, as well as the use of the same type of recipe (material) for several types of artefacts - artefacts on ceramic support and papers artefacts. The project can be summarized in relation to the current state of knowledge, as follows:

- The main purpose of conservation science is to develop more sustainable practices and policies in the field of cultural heritage conservation in order to achieve sustainable conservation. The proposed recipe will not only provide scientific and technological growth, but will also provide a significant socio-economic and cultural advantage, given the possible application of proposed materials in the field of cultural heritage preservation;
- The main elements of difficulty of the proposed topic are: obtaining materials with controlled properties and dimensions and offering practical solutions for preventing biodegradation.

3.2 Specific objectives

In order to fulfil the general goal of the project, several specific objectives were considered:

- Optimizing nanomaterial synthesis by controlling properties and dimensions for better antifungal effect and material characterization;

- Establishing an optimal ratio of materials in the proposed innovative recipe and exploiting synergistic action;
- Determining the method of application depending on the support material of the artifact;
- Study of the interaction between proposed prescriptions and support materials (archaeometry studies before and after treatment);
- Determining the effectiveness of the proposed recipes, depending on the morphology and properties of the organisms identified in the biodegradation process and the applied procedures;

3.3 Phases of the project

In the implementation of the project, three phases (one per year) were considered, that are detailed in the following paragraphs.

Phase 1. Elaboration of the integrated research strategy in order to obtain innovative materials for conservation / restoration (March 2018 – December 2018). The activities will include:

- The elaboration of working protocols for the preliminary assessment of artifacts and development of improved methods for obtaining soft nanomaterials; the development of improved methods for obtaining soft nanomaterials (alkoxides, alkaline-metal hydroxides and calcium phosphate compounds) and their characterization by various methods (FTIR, DLS, UV-Vis, XRD, EDXRF, ICP-AES, SEM, TEM, etc.)
- Identifying the best methods of application of soft nanomaterials on ceramic support material; development of ceramic laboratory models - simulated artifacts;
- Identifying the best methods of applying soft nanomaterials to paper support material; development of laboratory models of paper stationery - simulated artifacts;
- Identification of vegetation conditions favourable for the development of biodeteriogens - classification of microorganisms that attack the support materials used in the study.

Phase 2. Applying the integrated strategy for obtaining soft nanomaterials; establishing the recipe containing innovative nanomaterials and exploiting their synergistic action (January 2019 – December 2019), with the following activities:

- Optimizing the recipes for obtaining soft nanomaterials to control particle size; development of the innovative recipes;
- Evaluation of antimicrobial activity of proposed recipes;
- Evaluation of the physico-chemical interactions of the recipes obtained with the ceramic support material (simulated artifacts);
- Evaluation of the physico-chemical interactions of the recipes obtained with the paper support material (simulated artifacts);

Phase 3. Demonstration of the functionality of the proposed solutions for the restoration / preservation of ceramic and paper artifacts (January 20202 – October 2020), with the following activities:

- Demonstration of the effectiveness of applying the proposed recipes on ceramic support materials and demonstrating the effectiveness of the treatment; study of the aesthetic, chromatic, etc. effects on the ceramic support material and of the physico-chemical interactions with the real artifacts;
- Demonstration of the effectiveness of applying the proposed recipes on paper support materials and demonstrating the effectiveness of the treatment; study of the aesthetic, chromatic, etc. effects on the paper support material and of the physico-chemical interactions with the real artifacts;
- Demonstration of the effectiveness and functionality of the proposed application methods of the proposed recipes by assessing the antimicrobial activity on the two types of support materials;
- Elaboration of technical documentation for the obtained products.

3.4 Expected results

At the research project level, the following results are expected:

- Two recipes able to reduce the impact of biodegradation of cultural heritage artifacts (one for each type of support materials – ceramic and paper), protected by patent application;
- Protocols for obtaining the innovative recipes;
- Archaeometry protocols;
- Publication of the obtained results (at least three papers in ISI journals);

3.5 Dissemination

The dissemination of the project and of the results will be realised through:

- The continuous update of the project web site;
- The use of modern communication media (such as the social web-sites);
- Direct meetings with potential stakeholders;
- The dissemination of the project and of the obtained results through paper publication, as well as by presenting papers/poster in at least ten international scientific meetings.

4 Conclusions

The project *Nanotechnology - Innovative approach with the development of materials and techniques for safeguarding cultural heritage* represents one of the four research projects contained in the complex project *Multidisciplinary complex project for monitoring, preserving, protecting and promoting the Romanian cultural heritage* (RO-CHER). The research project proposes the development of innovative recipes, adapted for two types of support materials (ceramic and paper), recipes based on synthesised nanomaterials for reducing the impact of cultural heritage artifacts biodegradation. A very important aspect of the project will be the archaeometry studies performed on the two types of artifacts. Supplementary information can be found at http://ro-cher.rosa.ro.

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