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FE-SEM with integrated Raman at the DINAMICO Laboratory

Photo Angelo de Simone Troncone
Courtesy CNR-ISMN

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"WE TREAT THE CULTURAL OBJECT AS IF IT WERE A PATIENT"

Dr Gabriella Di Carlo, a PhD in Chemistry and researcher at the Institute for the Study of Nanostructured Materials of the Italian National Research Council (CNR-ISMN), leads the CNR-ISMN team in developing innovative and sustainable protective materials as part of the European GREENART project.

After obtaining her PhD in Chemical Sciences from the University of Palermo in 2006, Dr Di Carlo became the lead researcher at CNR-ISMN, Rome 1. Her scientific career began at the University of Palermo, focusing on new materials for removing atmospheric pollutants. In 2010, she moved to Rome, shifting her research to the reuse and enhancement of waste such as polysaccharides, cellulose, and plastics, and their application in the field of cultural heritage. She is involved in numerous national and international projects, either coordinating activities like Plasmare and ECOforCONCRETE or leading the CNR-ISMN research unit in European initiatives such as NANORESTART, InnovaConcrete, APACHE, and GREENART. Launched by the European Union in October 2022, GREENART is an international project bringing together scientists, conservators, and cultural institutions engaged in the conservation-restoration of artworks. Together, they collaborate to develop new, green, and sustainable restoration products such as cleaners, protective varnishes, consolidants, and monitoring technologies.

Furthermore, Dr Di Carlo teaches Chemistry for the restoration and conservation of metals in the Master's program "Science and Technology for the Conservation of Cultural Heritage" at La Sapienza University in Rome. She is a member of the doctoral council for Earth Sciences at the same university and heads the Laboratory of Nanometric and Micrometric Diagnostics for the Knowledge and Conservation of Advanced Materials and Cultural Heritage (Lab DINAMICO) at CNR-ISMN. This lab is part of the ERIHS infrastructure in the Lazio region.

What is your current role within the National Research Council (CNR) and the GREENART project?

CNR is a partner in the GREENART project alongside the Institute for the Study of Nanostructured Materials (CNR-ISMN) and the Institute of Polymers, Composites, and Biomaterials (CNR-IPCB). Our team has been involved in several EU-funded projects, including the NANORESTART project (2015-2018), coordinated by the Center for Colloid and Surface Science (CSGI) in Italy. In this project, alongside CNR-IPCB, we developed new stimulus-responsive materials for corrosion inhibition. This innovative approach focused on the targeted release of protective molecules when needed. Building on this success, the current GREENART project focuses on creating durable protective materials with stimulus-responsive properties, derived from natural waste and renewable resources. Our aim is to produce materials that are not only effective but also more durable and safer than those currently on the market. In GREENART, the CNR team leads the development of eco-friendly

— Antonio Mirabile

protective coatings for metal objects and other potential targets like ceramics and canvas. The main focus of the CNR-ISMN team is on producing new biopolymer-based coatings to prevent the degradation of artefacts. Our goal is to create long-lasting, safe products that can be applied and removed with non-toxic, water-based solvents, primarily aimed at preventing metal corrosion.

You have plans to develop multifunctional coatings for the long-term protection of cultural assets. Could you tell us more about this?

Indeed. In order to reduce the frequency of conservation interventions on cultural artefacts, we are focusing on creating active and intelligent protective coatings that offer long-term efficacy. Our main challenge is to prevent the degradation processes in metallic objects. The formation of corrosion products can not only alter the surface appearance but also compromise their chemical and physical stability, leading to irreversible damage or even the loss of unique and irreplaceable pieces. Our approach to long-term protection involves targeted actions, similar to how targeted drug delivery works. We treat the cultural object as if it were a patient, intervening selectively and only when necessary, which enhances the effectiveness of the protective materials while reducing the use of active substances. Previously, in the NANORESTART project, we explored the impact of stimulus-responsive protective materials on improving the effectiveness of coatings on bronzes. Currently, within GREENART, we are developing biopolymer-based coatings that include new green additives to enhance the material's stability over time. We are incorporating graphene-related materials supplied by the Foundation for Research and Technology-Hellas (FORTH) in Greece or lignocellulosic materials from the University of Campinas (UNICAMP) in Brazil to improve barrier properties. The coating acts as a shield, slowing the diffusion of atmospheric degradation towards the artefact's surface. We are also exploring the use of new stimulus-responsive nanocontainers to make the materials smarter, more durable, and more effective in the long term compared to past solutions. A thorough understanding of these materials is crucial for fully grasping their functions and enhancing their properties when necessary. Through GREENART, we study these new materials using sophisticated methods, such as small-angle and wide-angle grazing incidence X-ray scattering, in collaboration with CSGI in Italy and NIKKO in Japan.

What is the origin of these materials?

At GREENART, we focus on materials derived from natural waste and renewable sources. This strategy not only allows us to create sustainable products but also reduces waste production, providing both economic and environmental benefits. Our products are based on biopolymers such as chitosan and cellulose derivatives. Chitosan is a biopolymer obtained from crustacean shells, typically produced from the waste of the fishing industry. Besides its non-toxicity and water solubility, this polymer offers excellent transparency, film-forming ability, and ease of disposal. Its applications are increasingly gaining interest in various fields, including food packaging and biomedicine. We are also exploring other biopolymers, with cellulose derivatives being particularly promising due to their aesthetic qualities and the possibility of deriving them from plant waste. In developing additives and corrosion inhibitors, we follow a similar philosophy. We have enhanced our chitosan-based formulations with new additives that provide greater stability to the coatings over time. Additionally, we are studying natural and non-toxic corrosion inhibitors as alternatives to benzotriazole, seeking effective and safe solutions. Our choice of nanocarriers also reflects our commitment to sustainability, drawing inspiration from materials used in the cosmetic and pharmaceutical industries. Indeed, chitosan and its composites have generated considerable interest within the scientific community due to their applications across various fields, particularly in the food packaging industry where these materials have been greatly beneficial. Edible chitosan-based coatings are widely recognised for their ability to extend the shelf life of perishables such as fruits and vegetables. Moreover, the versatility of chitosan has led to its use in other areas such as wound healing and water purification. Given recent trends, it is expected that new uses for these biomaterials will be discovered, potentially extending their application to the preservation of cultural artefacts.

Do these materials work on all types of cultural heritage materials?

At GREENART, we are developing eco-friendly protective coatings primarily for metallic objects composed of copper and silver alloys. During the optimisation phase, we use mock-ups with varying compositions and surface finishes as disposable substrates to validate our new materials. These mock-ups have been selected in collaboration with conservators from institutions such as the Italian Ministry of Culture, the Peggy Guggenheim Museum, the Hungarian National Museum, and the Museum of Fine Arts in Houston, aiming to replicate the compositional and metallurgical characteristics typical of contemporary and archaeological artefacts. After validation, the coatings we have developed could potentially be applied to other substrates. The results obtained so far indicate high transparency, great stability, and ease of application and removal. Validations conducted in our laboratories, which involved very aggressive environments and natural ageing, show promising results.

How are they innovative compared to existing materials?

The main innovation lies in the way of thinking and designing new materials based on intelligent systems. Practically, cultural objects affected by a pathology are treated like patients and are protected with materials that, like a medicine, are capable of providing targeted and effective

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Photo Angelo de Simone Troncone. Courtesy CNR-ISMN

Application of the green protective coating on a bronze bell

Photo Angelo de Simone Troncone. Courtesy CNR-ISMN

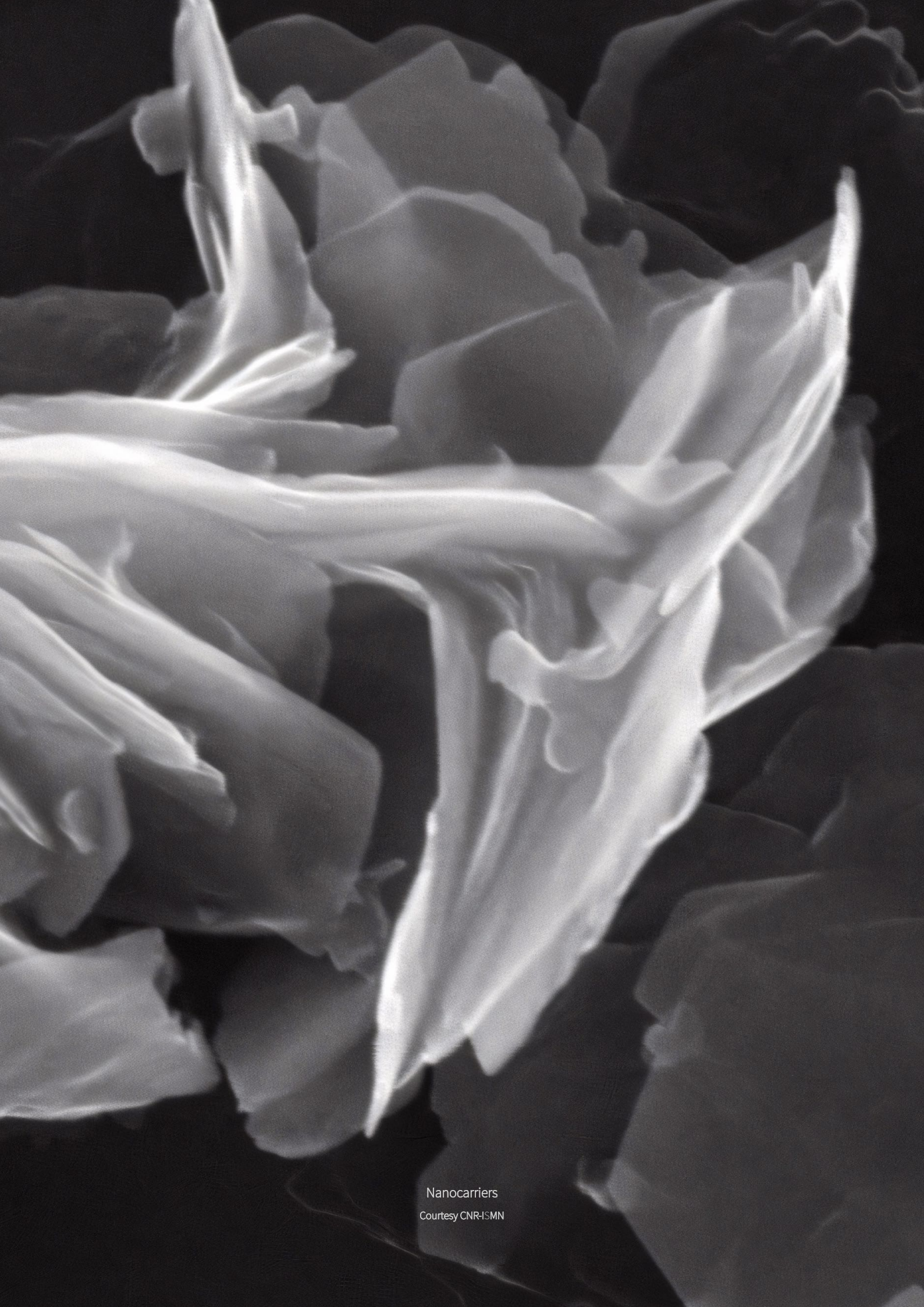
protective action. Compared to commercially available products, the new materials benefit from their multifunctional properties, offering enhanced protection against external agents of degradation and releasing protective agents in response to degradation *stimuli*, thus ensuring long-term efficacy. Additionally, the use of non-toxic solvents for their application and removal leads to safe conservation treatments. As I mentioned earlier, the innovation also lies in the use of sustainable materials, particularly focusing on those derived from natural waste and renewable resources.

Against which agents of deterioration do they offer protection? How do they work? How are they more environmentally durable?

Within the project, a partner, the University of Venice, is tasked with performing the safety and life cycle durability assessment for all new products. In our quest to develop innovative green materials, we focus on various aspects, including the selection of environmentally friendly reactants, solvents, and preparation methods. We have provided all this information to the University of Venice, which in turn gives us continuous feedback to properly guide the material development process. This is extremely beneficial for quickly eliminating any compound or process that would not be acceptable. There is a dynamic synergy and an exchange of information among the GREENART partners, who possess multidisciplinary expertise, facilitating the achievement of the project's objectives.

How do you work with cultural heritage institutions?

We work with conservators from the GREENART project. They provide essential feedback on primary conservation needs, the limitations of current products, and the specifications necessary for new materials. They also contributed to the identification of the most representative references and mock-ups. Additionally, some conservators participate in validating the new materials, with experiments already underway.



Nanocarriers

Courtesy CNR-ISMN

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