Preventive conservation plan for a group of bronze sculptures from the Gori Art Collection

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Preventive conservation plan for a group of bronze sculptures from the Gori Art Collection

Sara Croci[1], Leila Es Sebar[1], Caterina Gori[2], Leonardo Iannucci[1], Emma Angelini[1], Sabrina Grassini[1]

[1] Department of Applied Science and Technology, Politecnico di Torino, Italy, sara.croci@polito.it, leila.essebar@polito.it, leonardo.iannucci@polito.it, emma.angelini@polito.it, sabrina.grassini@polito.it
[2]Collezione Gori, Fattoria di Celle, Santomato, Pistoia, Italy, caterina.gori.me@gmail.com

***Abstract* – This paper deals with a multi-analytical and long-term in-situ monitoring campaign for evaluating the state of conservation of some outdoor contemporary bronze sculptures of the environmental Gori Collection, at the Fattoria di Celle, located in the municipality of Santomato, Pistoia, Italy. Digital 3D models of the Cavaliere and of one of the thirty-three figures of Katharsis have been made by means of photogrammetry in order to characterize the artworks. On the same sculptures, the chemical composition of the corrosion patinas has been determined by Raman spectroscopy. Moreover, the protective effectiveness of the corrosion products layer has been assessed by means of electrochemical impedance spectroscopy (EIS). The analytical data obtained in the monitoring campaign, still in progress, are discussed as a function of the exposure time and conditions to outdoor environment of the works of art.**

I. INTRODUCTION

Nowadays, preventive conservation strategies play a key role in the long-term protection of Cultural Heritage, and the ultimate goal is to define the most suitable conditions to guarantee the safeguard of artworks as long as possible [1]. In order to reach this goal, an interdisciplinary multi-analytical approach may be adopted to evaluate the current state of conservation of the works of art and the effects of their interaction with the environment [2].

When metallic artefacts are considered, particular attention should be paid to the phenomena of atmospheric corrosion. In literature, several strategies and methodologies aimed to characterise the corrosion products and to study the degradation mechanisms in the cultural heritage field may be found [3-5]. They prioritize the non-invasiveness and the non-destructiveness of the proposed analytical techniques. Moreover, monitoring artworks over time, by planning long-term campaigns, is an important tool to help conservators in recognizing potential degradation risks. It has to be underlined that all these actions and measures should not modify the aesthetical appearance or interfere with the constituent materials of the artworks [6]. Each work of art has its own specific chemical composition and structure and consequently, the degradation mechanisms are peculiar to each artifact.

Fig. 1. Bronze sculptures of the Gori Collection located in the Fattoria di Celle, Santomato, Pistoia, Italy: a) Katharsis by Magdalena Abakanowicz, 1985; b) Cavaliere, by Marino Marini, 1980.

This paper presents a multi-analytical approach aimed at evaluating the conservation state of bronze sculptures and artistic installations exposed outdoors.

As well known, the degradation mechanisms of outdoor bronze artifacts are influenced by the alloy composition and microstructure as well as by the microclimatic and environmental parameters [7].

Raman spectroscopy (RS), three-dimensional (3D) photogrammetry, and electrochemical impedance spectroscopy (EIS) have been chosen to carry out the on-site monitoring campaign. These non-invasive analytical techniques are frequently employed in studies on preventive conservation in the Cultural Heritage field [8-10]. As a matter of facts, these techniques allow to collect a considerable amount of data, useful to identify the manufacturing technique and the conservation state of the works of art. Raman spectroscopy has been used for the identification of the different corrosion products and for the analysis of their microstructural and chemical features. EIS has been employed for the assessment of the protective effectiveness and of the electrochemical stability of the corrosion patina. Photogrammetry has been employed to obtain 3D models of the artifacts, in order to evidence their chromatic, geometric, and textural features, submitted to possible changes over time due to interaction with the environments.

The two bronze artifacts under investigation are: Katharsis (1985) by Magdalena Abakanowicz (Fig.1a) and Cavaliere (1957-58) by Marino Marini (Fig. 1b). They are part of the Gori Collection, a private contemporary environmental art collection located in Fattoria di Celle, in Santomato (Pistoia, Italy). They are both exhibited under similar exposure conditions in a rural environment and were produced in the same decade, during the 80s of the 20th century. Although these artworks have been produced in recent times, it was not easy to find information about their manufacturing technique and state of conservation.

Founded by Giuliano and Pina Gori in the late 1970s, the collection counts more than 80 artworks by national and international artists. The artifacts were designed to create installations in strict relation with the surroundings, thus allowing to define the Gori Collection as the first private collection of environmental artworks.

In 2018 a monitoring campaign started and is still in progress. The main task of the campaign is to establish a tailored multi-analytical strategy to ensure the preventive conservation of the collection. In this context, the close correlation of the artworks and the environment was assessed.

The content of the paper is structured as follows. In section 2, the Katharsis and Cavaliere artefacts and the sculptors are presented. In section 3 there is a description of the applied analytical methodologies. In section 4, the experimental findings are reported and discussed. In section 5, the most remarkable results are highlighted and the conclusions are reported.

II. TWO BRONZE SCULPTURES OF THE GORI COLLECTION

Since its establishment in the 1970s, the Gori Collection has continued to grow by following a site-specific art program [11] consisting in the creation by different artists of multi-material installations and sculptures in iron, Corten steel, bronze, and aluminium, in such close dialogue with the environment that it becomes part of the work itself. As a matter of facts, several artworks are located in an outdoor environment, unprotected from weathering, often directly in contact with soil or water. As a result, atmospheric corrosion phenomena affected to a different extent the works of art of the collection.

Two bronze sculptures of the Gori Collection have been investigated in the frame of the present study.

The first artwork examined is Katharsis created by the Polish sculptress Magdalena Abakanowicz (1930-2017) in 1985, shown in Fig. 1a. It consists of 33 bronze elements installed outdoors in a delimited area sized about 60 x 40 m^2 of the Fattoria di Celle. The elements are about 3 meter-high and made of bronze sheets anchored to the ground. The sheets are also assembled into different shapes: 9 for the concave side and 8 for the convex side, in order to create several variations of the same figures. Each of the elements represents a human figure without heads and arms, back views from the viewers. This subject has been taken up by the artist in many of her works, done in different materials.

The second artwork under study is the bronze sculpture Cavaliere by the Italian artist Marino Marini (1901-1980), shown in Fig. 1b. It is located in the villa's garden, near a fountain and surrounded by trees. Throughout his artistic career, Marino Marini owes much to the Etruscan and Northern European sculptural tradition, whose influence persists into the several themes he worked on, including the series of Cavalli and Cavalieri, Giocolieri, Guerrieri and finally Miracoli. Although Marini is well-known for his sculptures, he made countless paintings too [12]. The purpose of his artistic production is to evoke from the viewer mythological images arising from a modern interpretation of classical themes.

III. MULTI-ANALYTICAL APPROACH

A. *Raman Spectroscopy (RS)*

The identification of the corrosion products was performed by Raman spectroscopy, without any preliminary cleaning of the artefacts, in areas with different exposure to atmospheric corrosion.

The instrument was a portable iRaman plus (BWTeK) outfitted by a spectrometer (BWS465-532S) operating at a maximum resolution of 7.3 cm^{-1} in a measuring range from 150 cm^{-1} to 4200 cm^{-1}. The cooling system involved the use of a CCD sensor. A green excitation laser (532 nm) was used to analyse the corrosion patinas of the investigated artifacts. A portable BAC151® microscope was used in combination with the Raman spectrometer. Thanks to it, the beam was focused into a spot size defined by the magnification used in the optical microscope.

Measurement parameters were optimised in order to limit the energy absorbed by the analysed compounds and thus prevent any chemical alteration of the investigated areas.

B. *Electrochemical Impedance Spectroscopy (EIS)*

Electrochemical impedance spectroscopy (EIS) allows the assessment of the protective effectiveness of the corrosion products layer [13]. Moreover, EIS measurements can be employed to investigate the ongoing corrosion phenomena and their kinetics.

EIS measurements were carried out by means of a portable instrumentation, consisting of a combination of an electrochemical interface and a measuring probe. The latter ensures the non-invasiveness of the measurement as it was realised by 3D printing in polylactic acid (PLA) in the laboratories of the Politecnico di Torino, and attached to the artifact surface by double-sided neoprene adhesive [14]. The working electrode was the artifact under investigation and the counter electrode was a platinum wire. A 10 mV alternating voltage was applied in the frequency range from 0.01 Hz to 100 kHz for data acquisition.

C. *Photogrammetric survey*

Photogrammetry is a technique for creating a virtual digital model of existing three-dimensional objects. It is useful to document the conservation state of the artworks investigated; in this way, the combination of the diagnostic data with morphological, geometric, and surface texture information is allowed. Compared to a bi-dimensional acquisition, the 3D model is not affected by perspective distortion and allows the object to be observed on its real scale [15]. The restorer can also actively look at the model, and make magnifications of the most interesting areas, which can be seen from different viewpoints. Photogrammetry simplifies the comparison with the current state of conservation of the artworks and the detection of potential damage progression.

In this study, the 3D models of the Cavaliere and of one of the thirty-three elements of Katharsis were acquired. Acquisitions were both achieved through the same instrumentation and operating conditions.

The three-dimensional model of each of the artifacts was obtained by the acquisition of several shots. The images have been taken at 3 different heights, circling the artifacts. Where needed, more detailed images have been added.

Finally, the digital 3D model processing (image alignment, dense cloud, point cloud, meshing, and texturing) was carried out with Meshroom® (2023.1.0), a free and opensource three-dimensional reconstruction software [16,17].

IV. RESULTS AND DISCUSSION

A. *Raman spectroscopy (RS)*

The on-site monitoring campaign aimed to evaluate the preservation state of the artworks, and it started with the simple visual examination of the artefacts, that allowed to detect surface deposits of coherent particulate material, corrosion products, and water stagnation areas, on both

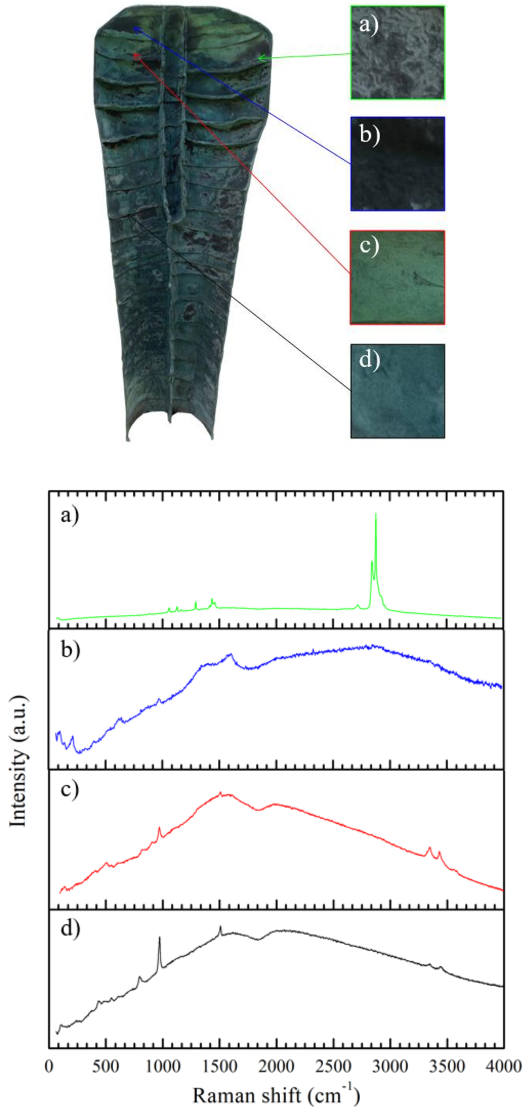

Fig. 2. Raman spectra recorded on different areas of one of the bronze elements of Katharsis: a) beeswax; b) cuprite, brochantite and amorphous carbon; c) brochantite and atacamite; d) brochantite and clinoatacamite.

sculptures.

Successively the chemical analysis of corrosion patinas was carried out by means of a portable Raman spectrometer [18].

Both sculptures showed the presence of patinas typical of bronze alloys after long-lasting interaction with the atmosphere, whose Raman spectra are shown in Fig. 2 and Fig.3. In the case of the Cavaliere, the acquired spectra identified the darker green patinas as antlerite, and the lighter ones as brochantite. The same corrosion products were identified on the bronze sculpture of Katharsis in combination with an early stage of the bronze corrosion

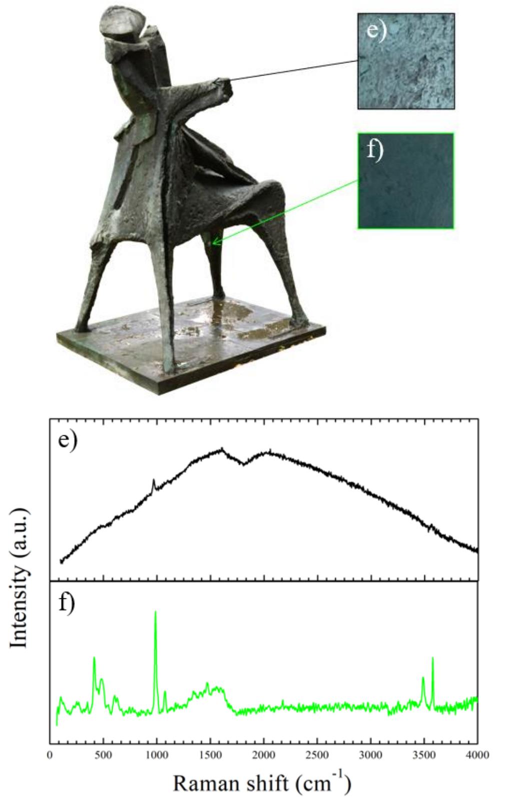

Fig. 3. Raman spectra recorded on different areas of the Cavaliere: e) brochantite; f) antlerite.

process leading to the formation of cuprite, atacamite, and clinoatacamite in the areas of water stagnation. Raman analysis allowed to confirm the presence of beeswax used as a protective coating during the restoration performed in 2009. Some representative Raman spectra are shown in Fig. 2 for one of the elements of Katharsis and in Fig. 3 for the Cavaliere. Moreover, it is interesting to observed that in the case of Katharsis, all the 33 elements are characterised by corrosion patinas of similar chemical compositions.

B. Electrochemical Impedance Spectroscopy (EIS)

For artworks located outdoor, it is mandatory to take into account the possible effect of atmospheric agents when choosing the areas to be analysed. As an example, rainwater is responsible for the formation of stagnant water areas and consequently of the dissolution of corrosion patinas located in unsheltered areas. These local environmental conditions influence both the chemical composition of the corrosion products and the thickness of the patinas.

Fig. 4 shows the EIS spectra, reported as Bode plots, recorded on the bronze sculptures under study in areas with different exposure to atmospheric corrosion.

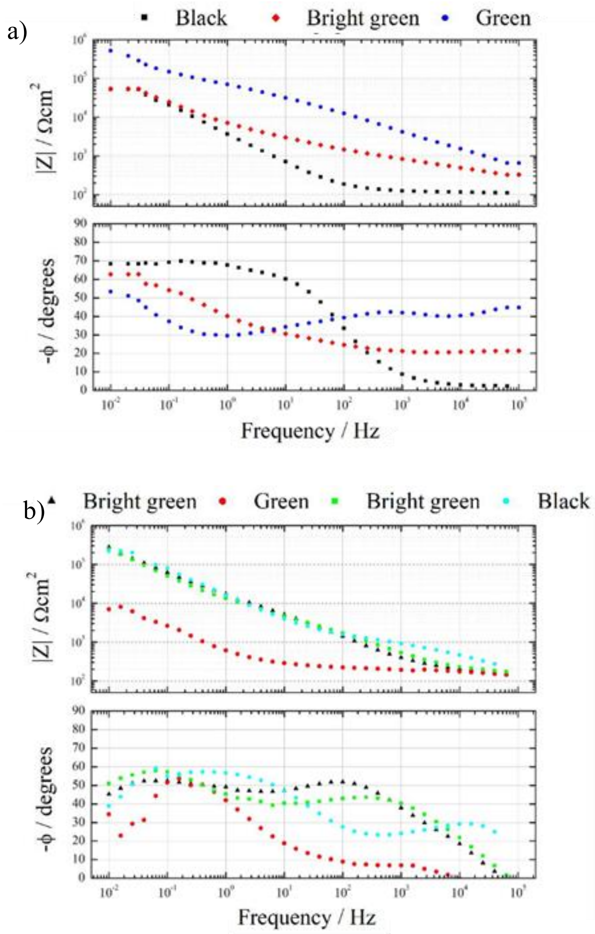

Fig. 4. EIS measurements as Bode plots, recorded on different areas of: a) one of the 33 elements of Katharsis; b) Cavaliere.

The patinas grown in sheltered areas of the artworks, whose chemical composition is identified by Raman spectra as antlerite, have a higher thickness and good protective effectiveness. On the contrary, the EIS measurements reveal that the patinas grown on areas exposed to the atmospheric corrosion, in which brochantite was identified, show higher porosity, lower thickness and poorer protective effectiveness.

Notwithstanding the different thickness, the patinas of both sculptures have an overall satisfactory protective effectiveness against further corrosion.

C. Photogrammetric survey

Fig. 5 shows the results from the 3D reconstruction obtained by means of photogrammetry.

In this study photogrammetry was used to support the diagnostic campaign, in addition to the aim of increasing the fruition. The points of analysis were integrated with the virtual model thus simplifying its interpretation, both during the acquisition process and in the overall evaluation a)

b)

Fig. 5. 3D models of two bronze sculptures under study, shown in Fig. 1: a) one of the 33 bronze elements of Katharsis; b) Cavaliere.

procedure.

Photogrammetry confirms to be a useful tool for a better fruition of artworks both for public and for curators, due to the higher attractiveness of three-dimensional images with respect to bi-dimensional images.

V. CONCLUSIONS

The multi-analytical approach adopted in the on-site monitoring campaign of the artworks of the Gori Collection has proved to be an efficient method to assess the conservation state of the artworks.

The corrosion products grown on the bronze sculptures have been identified by means of Raman spectroscopy, meanwhile their protective effectiveness has been characterised by EIS. Finally, photogrammetry has been applied to visually evaluate the current state of conservation of the artworks.

The monitoring campaign will go on in the next years in order to track any further modification of the surface of the sculptures occurring over time.

VI. ACKNOWLEDGMENTS

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