

Diagnostic campaign and innovative conservation treatments carried out on the statue “La Speranza” by Odoardo Fantacchiotti

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Abstract – This work is focused on the conservation-restoration work carried out on the Speranza, monumental sculpture of the 19th century placed inside the English Cemetery in Florence. The statue was covered by scattered greenish and black-grayish patinas mainly due to the biological growth. Optical microscopy, culture-based methods and CF-PAM imaging (Pulse Amplitude Modulated fluorometry of the Chlorophyll Fluorescence) were used to characterize the biodeteriogens, while the study of the stone material and of the decay layers was performed through microstratigraphic observations and X-ray diffraction analyses. Laser cleaning trials were carried out using different wavelengths (1064 nm and 532 nm) and pulse durations. The optimization of the laser parameters was performed taking into account the results obtained from the stratigraphic layers observations of the thin cross-sections of the stone material and real time CF-PAM imaging of the phototrophic presence. The study allowed improving, planning and accomplishing of the laser cleaning treatment of the whole statue.

I. INTRODUCTION

Exposed stone surfaces represent a substrate on which microorganisms can adhere and grow according to the material bioreceptivity [1]. This is indeed the intrinsic characteristic of a given material to be colonized by biodeteriogens and, besides the whole material properties (such as, for example, surface roughness, porosity, moisture content and chemical composition), the bioreceptivity is correlated with the surrounding microenvironment that contributes to the establishment, anchorage and development of colonizing organisms. Cyanobacteria and algae as first colonizers, followed by micro-fungi, lichens and bryophytes, are the natural inhabitants of the stone

substratum. They play a crucial role in developing aesthetic and physical-chemical alterations, exerting mechanical destructive forces and causing chemical modifications during their life cycle in the stone material. It was estimated that biological weathering can be even severer than the non biogenic degradation, representing a serious cause of deterioration of the outdoor stone cultural heritage all over the world.

During conservation-restoration works, biodeteriogens are usually removed using different methods, whose effectivity can be influenced by extrinsic causes such as previous conservation treatments on stone material and environmental factors. Furthermore, the majority of outdoor artworks have to be maintained in place, in most cases without covering structures or other physical protections. For such reasons, the long-term effectiveness of biocide applied on exposed stoneworks is usually scarce, being the future recolonization very difficult to be avoided. The re-growth can involve species which differ from those affecting the artwork before restoration, and it can be really rapid and enhanced by environmental conditions.

The periodical removal of biodeteriogens and the impairment of biological presence with the help of an eco-effective photochemical system (PS) represent fundamental needs for the preservation of outdoor stone cultural heritage.

Since conservative treatments are usually demanding, time consuming and costly, their long-term effectiveness, efficiency and usability must be considered. Moreover, the ethical aspect and the sustainability of the process should also be considered, as the treatments could be harmful to the integrity of the artifact and to the environment. Studies on these topics contributed to the improvement of a responsible management of the conservation of outdoor artworks and allowed to widen the range of suitable methodologies of restoration, as well as their reliability. Among them, laser ablation is a very

appealing solution. Although applications of laser cleaning were carried out in the past on stone masterpieces, some issues raised up and are still open. In particular, only few works dealing with the removal of biodeteriogens are reported [2-4] and none of these involved an extensive application.

In this work, intervention of restoration of the Speranza, marble sculpture placed inside the English Cemetery in Florence, is presented. The set-up of the preliminary trials and the optimized cleaning procedure are reported.

II. THE STATUE

The Florentine cemetery known as the *English cemetery* was built between 1827 and 1828 by the Swiss Evangelical Reformed Church outside the city walls, to give a burial to all non-Catholics. The renovation of the city following the proclamation of Florence capital (1865) of the newborn Kingdom of Italy and the implementation of new health regulations, caused the closing of the cemetery and its declaration as monumental site. Since then, the English cemetery became an open-air museum, rich of sculptural works of arts made by the greatest artists of the time, such as Lorenzo Bartolini (1777–1850), Hiram Powers (1805 – 1873), Giuseppe Lazzarini (1831-1895). They adorned the tombs of illustrious people such as Elizabeth Barrett Browning (1806-1861), Walter Savage Landor (1775-1864), Jean Pierre Vieusseux (1825-1865). The English cemetery is an evidence of the integration and intercultural exchange between Florence and foreign communities as well as the rediscovery of architectural styles of the past and, in particular, neoclassicism.

The Speranza statue was sculpted in 1863 by the Florentine artist Odoardo Fantacchiotti (1811-1877) for the burial of Reginald Samuel Routh. This is one of the most imposing tombs in the English cemetery, though almost nothing is known about the deceased. The monumental statue, carved in white marble, represents an allegorical figure (about 2 m high) placed on a basement with burial inscription and overturned torches on each edge, representing a symbolic reminder of death. The Speranza, as well as the whole artistic work of Fantacchiotti, is characterized by an extreme softness of the drapery and sweetness of the traits, revealing his basic culture deeply founded on classical art.

Nowadays the statue was almost completely covered by widespread greenish and black-grayish patinas, due to the synergic action of biological growths, urban pollution, and microclimatic factors. To address the critical situation, the restoration of the whole statue was planned in the framework of the project TEMART.

III. EXPERIMENTAL METHODOLOGY

In order to characterize the marble and the state of conservation of the statue, five samples (microfragments and powders) were collected from different parts of the artifact. After examination of the specimens under the stereomicroscope, thin cross-sections were prepared and analyzed by means of a polarizing microscope equipped for observations in transmitted and reflected light. Optical microscopy was supported by X-ray diffraction analyses (XRD), using a Philips X'Pert PRO PW 3040 diffractometer (Bragg-Brentano geometry) with a CuK α source operating at 40 kV and 40 mA and equipped with a PW3015 X'Celerator detector.

The characterization of biological colonizers was performed through on site observations and laboratory analyses. The stone surface was firstly examined by means of eyepiece and a portable stereomicroscope. Then, samples of biological material were collected in several areas of the statue in order to characterize the phototrophic biological presence. This was done by means of macrophotography and optical microscopy, and by using microbial culture techniques. Then, the morphology characterization of the isolated phototrophic colonies and the morphotype identification were carried out under the optical microscope.

The phototrophic species were therefore analyzed in terms of pigment absorbance, in order to understand the possible interactions with the laser treatment. The presence of phototrophic pigments were analyzed using a spectrophotometer after one month of biological development in continuous low light at 28°C. Finally, laser cleaning trials were carried out on selected areas of the statue using different wavelengths (1064 nm and 532 nm) and pulse durations (from tens of ns to hundreds of μ s). Three Nd:YAG temporal regimes have been tested: (i) SFR Nd:YAG laser at 1064 nm (pulse duration = 40-120 μ s), (ii) LQS Nd:YAG laser at 1064 nm (pulse duration = 120 ns) and (iii) QS Nd:YAG laser at 532 nm (pulse duration = 8 ns). Tests were performed with and without the demineralized water assist, applied on the surface using a suitable nebulizer. The evaluation of the irradiation effects and the optimization of the laser parameters were performed by analyzing the stratigraphic layers of embedded stone samples and real time CF-PAM imaging[5]. Kinetic chlorophyll fluorescence imaging is a well-recognized method to gain information on the spatial distribution of photosynthetic activity and to study the stress effect on phototrophic organisms.

IV. RESULTS

In order to understand the possible origin of the stone used for the artifact, microstructural analyses of the

marble substrate were carried out. Figures 1 shows thin sections of samples taken from the statue (Figure 1a) and from the basement (Figure 1b). The different nature of the marbles used to sculpt the two parts is evident. The microstructures observed, both in the statue and in the basement, are compatible with those of marbles affected by a green-schist facies metamorphism, such as those found, in Tuscany, in the mining district of the Apuan Alps. In support of the hypothesis of an Apuan origin, the natural cavities with irregular morphology observed in the basement, named *taròli* and *tarme* by the Apuan Alps quarrymen [6], are typical defects of Apuan marbles deriving from particular structural positions.

The artifact was almost completely covered by widespread greenish and black-grayish films, mainly due to the presence of biological development. The lower part of the statue, corresponding to the folds of the garment, was less subjected to the direct action of meteoric leaching. Here, thicker dark deposits and brownish stains with distinctive cracked appearance were observed. In the back of the neck a black crust with microscopic clumps aspect was observed.

In exposed areas, the marble surface was variously eroded, showing moderate intercrystalline decohesion phenomena and scattered presence of biodeteriogens in the spaces between the crystals. The marble of the basement showed cracks and red-pinkish stains. Furthermore, differential erosion phenomena, with nodular portions in relief with respect to the marble surface, were observed. Finally, the marble showed several natural cavities (*taròli* and *tarme*), which constituted preferential zones of accumulation of deposits and of cracks propagation.

The petrographic examinations of the thin sections and the XRD analyses, helped to deeply characterize the state of conservation of the Speranza statue.

The micro-stratigraphic observations were in agreement with the macroscopic ones. The main cause of degradation was represented by a widespread colonization of biodeteriogens (Figure 1c), which constituted a superficial layer of variable thickness (up to 200 μm) and lead to chemically and mechanically attack of the stone substrata.

In the most hidden parts, black crusts characterized by heterogeneous thickness, were observed. Such crusts were constituted by a gypsum binder, showing microcrystalline, acicular or columnar microstructure, which included several carbonaceous particulate matter and silicate grains. The grains were mainly concentrated in the upper part of the black crust, while, at the contact with the stone substrate, a thin layer of sulfation affecting the marble was observed (Figure 1d).

Diffraction analysis performed on the brownish patinas observed in the lower part of the statue showed

the presence of weddellite (calcium oxalate dihydrate), together with gypsum and silicates. The anthropogenic origin, connected to a treatment with organic substances applied for aesthetic purposes, no more visible for intense sulfation phenomena, was hypothesized. The intercrystalline decohesion phenomena, surface erosion and differential degradation processes that were observed in the case of Speranza statue, were a direct consequence of the physical decay processes (thermal stresses, crystallization of soluble salts, cryoclastism) acting with different intensities in marbles with different microstructure, such those coming from the Apuan Alps.

On the marble surface of the statue, laser cleaning tests for the controlled removal of biological films were performed. Laser cleaning trials were carried out using different wavelengths (1064 nm and 532 nm) and pulse durations (from tens of ns to hundreds of μs). Several tests using different parameters (increasing operating fluence and repetition rate) were carried out. The combined use of different temporal regimes was tested too.

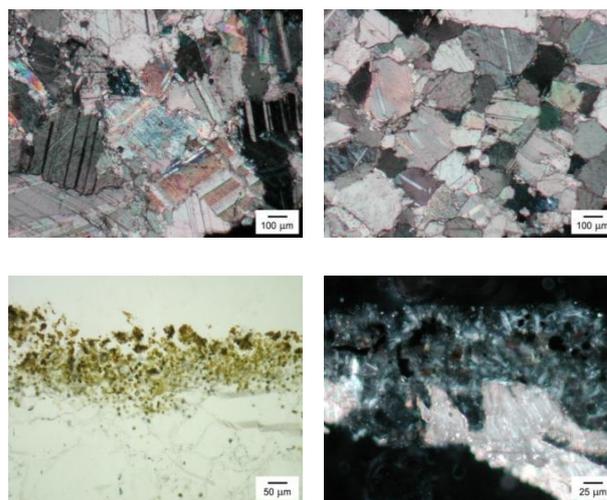


Figure 1 - The marble microstructure of the statue observed with polarized light (a) and the one of the basement (b), observed in thin section under transmitted polarized light with XPL the distribution of biological colonizers on the marble surface observed in reflected light darkfield with bright background (c) and the aspect of the non-biogenic black crust on the marble observed in transmitted polarized light with XPL (d).

In Figure 2 the comparisons of LQS (1064 nm) and QS (532 nm) laser tests performed on the basement and on the back of the statue are reported.

The treatment carried out with LQS laser (Figure 2c-d, subarea A, and Figure 2g-h, subareas C, E) did not

provide promising results. On the selected areas multiple pulses irradiation was used, testing single-pulse (LQS1), double-pulses (LQS2) and triple-pulses (LQS3) laser emission regimes (1.5 J/cm^2 , 2.5 J/cm^2 and 3.5 J/cm^2 respectively, 10-15 Hz). Ablation provided by the LQS regimes revealed low efficiency. Although in one case a satisfactory degree of biodeteriogens removal and PSII impairment was obtained (Figure 2g, subarea C), the low efficiency of this laser makes its productivity not competitive.

Varying QS set-up parameters, different results were achieved. Lower fluences of 0.5 J/cm^2 (subareas B in Figure 2c-d and Figure 2g-h) provided only a partial removal of the biological patina as well as a low PSII impairment effect. Using higher fluences, deeper degree of ablation and a more evident effect on the photosynthetic efficiency of the residual biodeteriogens was obtained without damaging the substrate material. In particular, when the fluence was higher than 0.8 J/cm^2 (subarea E2 and F in Figure 2c-d and subarea F in Figure 2g-h), no fluorescence emission was detected.

In situ observations and analysis carried out after laser treatment (Figure 2) confirmed that LQS irradiation is not able to remove the whole thickness of the patina. For this purpose high power densities obtainable with the QS laser are required.

More effective removal and impairment of the photosynthetic activities of biodeteriogens were achieved using 532 nm, because of the major absorption of these species at this wavelength.

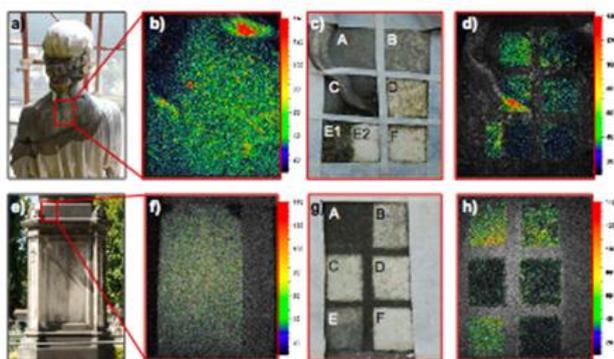


Figure 2 – Statue (a-d) and basement (e-h) areas before and after irradiation. Images of the tested areas: a, e) tested zones; b, f) F_{max} yield map before laser trials; c, g) tested areas after laser trials; d, h) F_{max} yield map after laser trials.

V. CONCLUSIONS

The effectiveness of laser cleaning in the case of Speranza statue was assessed through *in situ* observations (by means CF-PAM analysis) and through

specific/detailed laboratory investigations such as stratigraphic analysis on collected samples and epifluorescence microscopy.

The presence of biodeteriogens (phototrophic microorganisms and meristematic fungi) containing photosynthetic pigments and melanin facilitated the absorption of the 532 nm radiation, and consequently the laser removal of biofilm.

The possibility of exploiting different types of absorbers significantly broadens the application range of this wavelength. De facto, the real applicability of the laser treatment depends on the reactive chromophores concentration, which drive the ablative process playing the role of absorption centers of the radiation.

The promising results obtained during the preliminary trials allowed to schedule the laser cleaning of the whole statue. In order to evaluate the long-term effects on the biological colonization, CF-PAM measurements were performed one year after laser cleaning, on the basement and on the lower part of the statue. The areas analyzed showed fluorescence values close to zero proving a minimal vitality of photosynthetic organisms on the stone surface, and therefore the long term effectiveness of the treatment carried out.

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