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Comparative study between IR and UV laser radiation applied to the removal of graffitis on urban buildings

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Abstract

The present article focuses on a comparison between cleaning process of graffitis on urban buildings by using laser radiation at 308 nm (XeCl excimer laser) and 1064 nm (Nd:YAG laser). Laser-induced breakdown spectroscopy (LIBS) elemental analysis was applied as real-time diagnostic technique, safeguarding against possible damage of the substrate during ablation rate studies. The morphological analysis of the etched surfaces by optical microscopy and environmental scanning electron microscopy reveals remarkable features of interest to understand the wavelength dependence of the ablation efficiency. The ablation threshold fluences of different paints sprayed on several substrates were determined applying a photoacoustic technique. To remove graffitis from urban buildings the laser radiation at 1064 nm was observed to be the most efficient wavelength, supporting the best result.

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Keywords: Laser cleaning; Excimer; Nd:YAG; Laser-induced breakdown spectroscopy; Photoacoustic technique; Graffitis

1. Introduction

Over the last years, the possibility of the use of laser ablation as an alternative method to the conventional techniques of mechanical cleaning (sandblasting) or chemical removal [1–7] has been considered. The laser cleaning technique allows some benefits: the different and characteristic absorption at the laser wavelength exhibited by each substance allows a selective removal of the material without damaging the substrate, which allows controlling, with high accuracy, the depth of the removed layer. This method is intrinsically fast and clean, and circumvents the use of toxic and polluting solvents, required with the more conventional cleaning procedures, thus preventing also damage to environment. The laser methods make possible the treatment of surfaces that with other techniques cannot be cleaned or where the conventional cleaning process is much more

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expensive. In addition, combination of the laser cleaning process with the use of analytical techniques, allows us to identify the substrate, carry out a layer analysis of the surface and control the cleaning process in real time [8–9]. The tendency is to extend the field of application of lasers from the cleaning of individual artworks to the cleaning of larger areas such as entire building façades. The high power of the lasers used in this application, the fast cleaning rates and diversification of substrates could result in some health hazards, as surface ablation can generate micro powder hazard and toxic substances [10–11]. To ensure safe laser cleaning conditions, critical requirements are the use of laser goggles, fume extraction equipment to avoid inhalation and adequate operator training [12–15].

The mechanism responsible for the laser cleaning process depends on the wavelength, duration and energy of the laser pulse as well as on material properties. In the particular case of laser cleaning of artwork, the sample's fragility, its unique nature and cultural value, make necessary to characterize the object extensively to guide the restoration process. For this task, the methods of analysis based on laser ablation are particularly suitable, although it is necessary to assess carefully their possibilities and limitations, the optimal conditions for their use, and the response of the materials [8].

The fundamental wavelength of a Q-switched Nd:YAG laser ($\lambda = 1064$ nm) is nowadays the most utilized wavelength to clean stone (including marble) surfaces [1,16–18]. The major advantage of using this wavelength is commonly described as self-limiting-phenomenon, since the gap between the ablation thresholds of incrustation and marble/stone reaches a maximum at this wavelength [18]. Nd:YAG lasers have also demonstrated their effectiveness in the cleaning of a great variety of substrate materials: paper, wood, metal, leather, parchment and carpets [19–21]. However, the efficient removal of thin layers of aged varnish in polichromies and canvas required pulsed excimer laser, due to the high absorption of polymers in the UV region, in a process which leaves intact the inner layers and reveals the original colors [9,22]. At the moment, these methods are in development, and numerous questions about their safe and efficient use have still to be answered. In addition, there is still some controversy about the efficiency and mechanism responsible for the ablation process, since photochemical and photothermal mechanisms, as well as a combination of both have been proposed [23–25]. In a photochemical process, the absorption of one or more photons results in an electronic excitation followed by decomposition of the compound caused by direct bond breaking in the solid, in competition with various relaxation processes. In a thermal mechanism, the initial electronic excitation produced by the absorption of the laser radiation is converted into vibrational excitation via fast relaxation processes, which causes thermal decomposition of the compound. Probably, in the ablation process both mechanisms are involved, and depending on the properties of the irradiated materials and the irradiation conditions, such as wavelength, one of them may be dominant.

In this study, we carry out a comparison between the performance of the fundamental radiation of the Nd:YAG laser ($\lambda = 1064$ nm) and the radiation of a XeCl excimer laser ($\lambda = 308$nm) in the removal of graffitis from construction materials. The goal of the present work has been to evaluate and compare in a systematic way the efficiency and quality of the painting removal by IR irradiation at 1064 nm, which acts essentially via a photothermal mechanism, and at 308 nm, where the UV photons are expected to induce photochemical processes. This comparative study can be of importance for both technical applications and fundamental understanding of the ablation behavior. When dealing with artworks, a careful control of the cleaning procedure is needed in order not to damage the original surface and preserve the artistic value of the work. Although in the case of removal of vandalic painting from public buildings such rigorous control is not needed, nevertheless it is important to avoid damage on the construction materials, mainly in historical buildings and monuments. Laser-induced breakdown spectroscopy (LIBS) technique was applied for spectroscopic analysis of the emission from the plasma generated when the laser radiation interacts with the material's surface [5,8,26]. In addition to the elemental composition, LIBS, if combined with traditional techniques such optical microscopy (OM) and scanning electron microscopy (SEM), provides information on structural composition facilitating in this way the choice of the appropriate parameters for the cleaning process. Finally, the monitorization of the acoustic signal generated by the material removal during the laser ablation [27], as registered with a microphone,