COALITION

CSIC Thematic Network on Cultural Heritage. Electronic Newsletter

Newsletter No. 8
July 2004

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RED STAINING AND HETEROTROPHIC BACTERIA

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Monumental stone surfaces are often covered with stained areas without any apparent biological presence. In the case studies illustrated here are shown some examples of red coloured patches whose origin may be attributed to a biological activity.

Exposed monuments support the dwelling of complex biocoenosis which can cover the surface with coloured patinas and black crusts (Figure 1) (Pietrini et al. 1985). Sometimes after the restoration and cleaning treatment the surface of the object appears stained with red colour patches (Figure 2). This effect is quite diffuse on different monuments mainly of calcareous composition (Figures 3-4). Diagnostic investigations to assess the nature and origin of these coloured patches have usually failed. The presence of lead, detected in a few cases, has been tentatively involved in the phenomenon (Realini and Sorlini, 1988).

Figure 1. Monumental Fountain placed in the Medici's Villa of Castello (Firenze, Italy) before its restoration
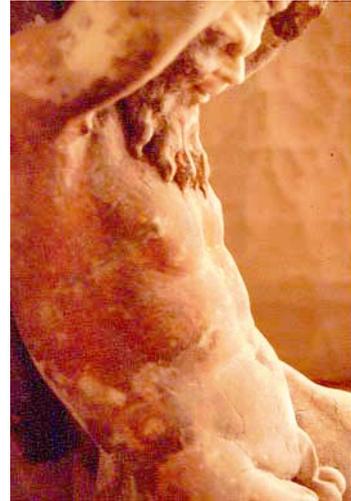

Figure 2. Detail of the Figure 1 after restoration. The breast of one of the satyr, holding the upper basin, shows a diffuse reddish staining

In the case of the Duomo of Siena (Figure 5), whose external walls were covered with diffuse red patches, it was possible to establish the biological nature of the staining of the white marble slabs (Tiano and Tomaselli, 1989).
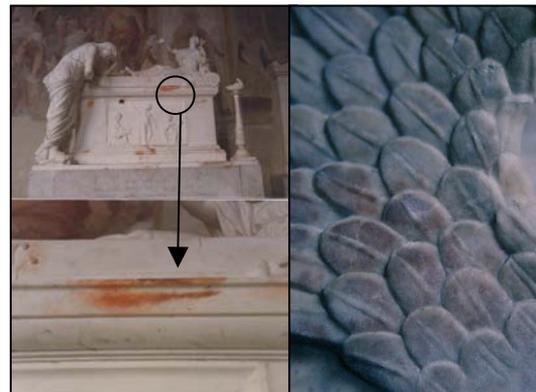

Figure 3 (left). Marble Cenotaph in the Monumental Cemetery of Pisa (Italy). Presence of red patches not removed by the restoration treatment. Figure 4 (right). Detail of a marble bas-relief on the facade of the Foligno Cathedral (Perugia, Italy) after restoration. Presence of undiscoloured red patinas after the restoration

To some of these red areas was also associated a green patina. This chasmolitic dwelling was found under a thin slice of white marble (Figure 6). The material collected from this sample, observed directly under optical microscope and after the development in organic and inorganic cultural media, showed the presence of a complex biocoenosis composed by bacteria, fungi and green algae (Figure 7).

The prevailing isolated bacteria were identified as coloured species of

Micrococcus. The colonies appear pink, yellow, orange and red owing to the production of different carotenoid pigments (Figure 8). These heterotrophic cocci (cell diameter 1-1.5 μm) probably derive organic nutrients from the association with the green micro-algae as observed *in situ.*

Figure 5. Siena Cathedral (Italy): various red areas on the marble slabs of the facade (south)

Figure 6. Detail of Fig 5, chasmolithic growth of green algae

Figure 7. Light micrograph of the complex biocoenosis (green algae, micro fungi and bacteria) occurring in the sample collected from the green area in Figure 6 (440x)

A liquid culture of one of the isolated red pigmented strains (Mr12) was inoculated in Petri dishes containing artificial media made with nutrient broth and powered $CaCO_3$ or $MgCO_3$ (Figure 9). The plates were incubated at 28°C and maintained wet with diluted nutrient broth.
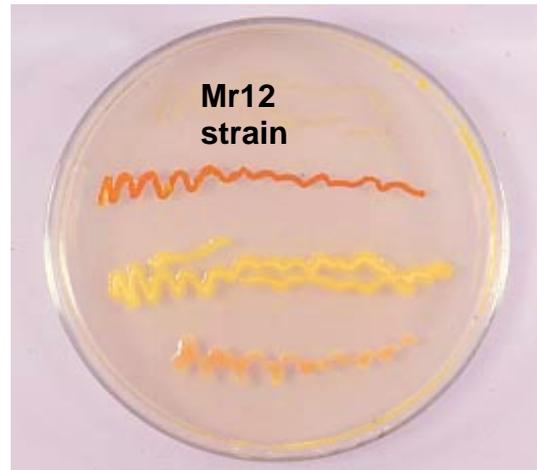

Figure 8. Three different isolated *Micrococcus* strains streaked on plate count agar

Figure 9. Mr12 strain developed on an artificial substrate made with powered $MgCO_3$. Note the formation of a red area very similar to those observed on the monument

After two weeks the Petri dishes were dried (120°C) and the red organic pigment produced by the cells was absorbed by the powered stone material inducing permanent red stained areas very similar to those on the monument.

In fact, the carotenoid pigments react with the calcareous matrix and constitute a very strong chemical bound.

They become practically insoluble to all solvents (organic and inorganic) used in the attempt to extract them.

This can explain the reasons for which is quite often impossible to assess the chemical nature of such red stained patches in samples taken from monuments.

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LASER-INDUCED FLUORESCENCE

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Abstract

Laser-induced fluorescence (LIF) is a versatile, non-destructive analytical technique that can be performed in situ and in remote sensing, and provides information directly related to the molecular structure of the materials on the illuminated substrate. LIF is capable of detecting both organic and inorganic species which exhibit fluorescence upon irradiation with UV or visible excitation. The instrumentation required includes a laser and a detection system. Two different cases in which LIF has successfully served to identify the materials on Cultural Heritage artefacts are presented.

Basic Principles

Every material has its own characteristic electromagnetic absorption and emission spectrum. By selective excitation using specific light wavelengths, it is possible to identify materials with high certainty. Using a laser as the excitation light source, it is possible to select a controlled excitation wavelength; this results in very high-resolution measurements that allow the detection of even small traces of substances or chemical compounds.

Laser-induced fluorescence (LIF) is the optical emission from molecules or impurity centres, doped in small concentrations into solids, that have been excited to higher energy levels by absorption of laser radiation. These emitters can be the own constituents of the material, i.e. the molecules in a molecular substrate, or be present as impurities or crystal defects into solids. LIF emission from painting materials provides information that can be directly related to the molecular structure of pigments or other painting materials, both inorganic and organic, as binders or varnishes. Biological layers also display their own characteristic LIF spectra. The possibility of employing different laser wavelengths for excitation adds versatility and selectivity to the technique.

In its application to Cultural Heritage, LIF is useful to identify the materials of an artifact, either original, as products of deterioration processes, or added in the course of restoration activities during the lifetime of the object. Analytical schemes have been proposed for performing LIF analyses of artworks and Cultural Heritage substrates. Excitation of the sample surface with a pulsed laser beam produces the emission of fluorescence, or more generally luminescence, that, for instance, can be characteristic of a pigment, provide information on the aging of a binder or varnish, identify the presence of a protective coating or biological grow on a stone surface, etc. Due to the versatility of the technique, LIF can be performed in situ (Miyoshi et al. 1982; Anglos et al. 1996; Borgia et al. 1998; Kautek et al. 1998; Athanassiou et al. 2000; Castillejo et al. 2001) and in a remote sensing system, using light detection and ranging (LIDAR) (Weibring et al. 2001).

Instrumentation

The excitation source for LIF is typically a pulsed laser operating in the UV, like an excimer laser, or the harmonics of a Q-switched Nd:YAG laser, or eventually a tunable dye laser in the visible spectral region. Studies in the near UV and near IR are becoming more common as near IR lasers and frequency-doubling methods improve. High-resolution studies require cooling of the substrate, using cryogenic methods or crystalline matrices, to remove spectral congestion and to reduce the Doppler width of the transitions.

A typical experimental arrangement used for LIF is schematically depicted in Figure 1. The main components of the set-up are a laser excitation source and a spectrum analyser.

A laser system typically used for LIF is a nanosecond Q-switched Nd:YAG laser operating at its fundamental (1064 nm) or harmonic frequencies (532 nm, 355 nm). The laser beam is directed to the sample surface by the use of mirrors or prisms or by using an optical fibre. The laser output is usually attenuated to illuminate the sample with low fluence values (given in Joules/ cm^2). The light emitted is collected with an optical fibre that directs the fluorescence emission to the entrance port of the spectrum analyser.

For spectral analysis, various possibilities are available including a monochromator-photomultiplier assembly or a spectrograph with an ICCD (intensified charged coupled device) camera. The advantage of the latter is that the whole spectrum can be acquired in only one laser pulse, whereas the former requires one pulse per wavelength. In an advanced fluorescence system, together with the spectral information, the emission lifetime is measured providing superior discriminating power. In those systems, the ICCD camera is furnished with fast gating with adjustable delay and gate width. This allows the collection of the signal at adjustable time intervals.
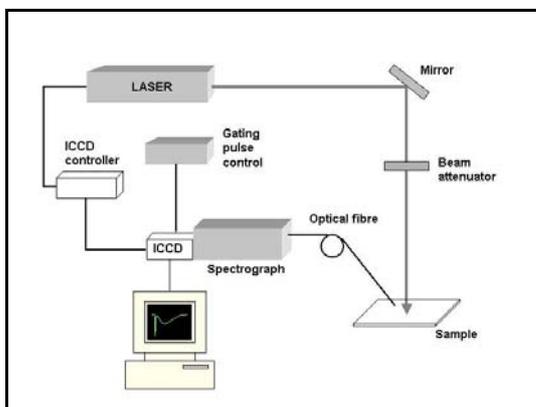

Figure 1. Schematic diagram of an experimental set-up used for LIF measurements

Examples of application

Two examples of the use of the LIF technique for analysis of Cultural Heritage objects are presented. In the first one, LIF spectral information is used for analysis of painting materials (Miyoshi et al. 1982; Anglos et al. 1996; Borgia et al. 1998; Kautek et al. 1998; Athanassiou et al. 2000; Castillejo et al. 2001); secondly, remote sensing by LIBS is employed to assess the conservation state of architectural historical façades (Weibring et al. 2001).

Analysis of painting materials

LIF was employed to examine semiconductor cadmium sulphide- and calcium selenide- based pigments in oil painting test samples using laser excitation wavelengths of 532, 355 (Nd:YAG) and 248 nm (KrF excimer) (Anglos et al. 1996). This technique was suitable to differentiate between selected pigments having the same colour appearance, to differentiate among the various cadmium pigments and also to identify individual components in mixtures of these pigments on the basis of their characteristic fluorescence emission

In another study (Borgia et al. 1998), laser induced luminescence of common natural and synthetic pigments and resins was excited by Nd:YAG laser at 355 nm. The emission time decay was also measured. Results obtained are collected in Table 1. These results prove that luminescence induced by laser excitation can be used to identify pigments and to detect forgeries in oil paintings. The pigments may be identified by their luminescence emission bands and corresponding decay time. The LIF technique allows the identification of the original colours in the artwork or retouching with modern pigments.

LIF has been also used as a diagnosis technique, sometimes applied on line, to assess the procedure and the effects of laser cleaning on several types of substrates such as paintings or paper documents (Kautek et al. 1998; Athanassiou et al. 2000; Castillejo et al. 2001).

Fluorescence LIDAR imaging of historical monuments

A scanning fluorescence LIDAR system was used in this application for the non-destructive monitoring of the façades of the Lund cathedral in Sweden (Weibring et al. 2001). A mobile system, containing the optical and electronic systems (Figure 2, left), was placed at about 60 m from the building and a 355 nm pulsed laser was swept over the façade.

Pigments	Natural colour	Luminescence		Lifetime (ns)
		Wavelength (nm) at the maximum	Colour	
Zinc white	white	385	violet	0.3
Titanium white	white	473	turquoise–green	0.2
Lead white	white	547	yellow	100×10^3
Cadmium yellow	yellow	483	blue	0.05
Naples yellow	yellow light	538	green	100×10^3
Cadmium red	red	568	yellow–green	0.04
Red lead	orange–red	586–600	brown	3.7×10^3
Resins[a]				
Turpentine		450		16
Dammar		437		7
Copal		456		11
Colophonia		435		17

[a]Resins emit approximately in the same region. A better characterization may be obtained by the intensity ratio at different wavelengths.

Table 1. Luminescence characteristics of a few typical natural and synthetic pigments and resins. Taken from Borgia et al. (1998)
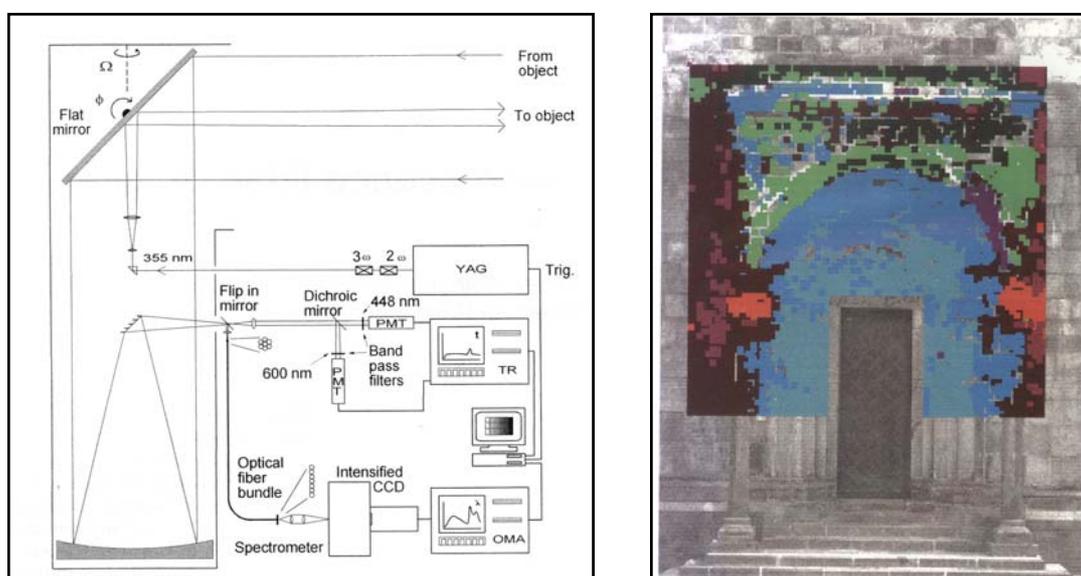
Figure 2. Left: Optical and electronic arrangement of the LIDAR system employed in the measurements of the historic building. PMTs photomultiplier tubes; OMA, optical multichannel analyzer; TR, transient digitizer. Right: False-colored image superimposed upon a photograph of northern portal of Lund cathedral. Different coloured pixels correspond to areas of biodeteriogen (red) and different stone types (blue, green). Taken from Weibring et al. (2001)

The spectrally resolved fluorescence emissions from each point revealed different spectral signatures. Classification of the gathered spectra allowed the identification of different stone types with natural surface aging or crust and pollution deposited layers and biodeteriogens like green algae, lichens, etc, (Figure 2, right).

Conclusion

In summary LIF is a non-destructive analytical technique of high simplicity of use, able to provide fast analysis of both organic and inorganic compounds with high sensitivity. The technique is limited by the impossibility of detection of materials (pigments or substances) with low fluorescence quantum yield, due to non-radiative relaxation mechanisms in the material. The fact that fluorescence bands are broad in comparison with atomic fluorescence bands results in a decrease of selectivity

Future developments aim at the integration of LIF systems into transportable units involving a compact laser source and a spectrum acquisition module.

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RAMAN SPECTROSCOPIC DETERMINATION OF ORGANIC RED DYES BY INCORPORATION IN Zr-ORMOSIL MATERIALS

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Introduction

The ability of natural dyes to colour has been known since ancient times. Colouring materials were used by man for personal adornment, decorating tools, making pictures and dye textiles. Most easily procurable were vegetable or animal colours like the materials obtained from the madder root (alizarin) or from the lac insect (carmin from Cochineal and Kermes).

The earliest written record of the use of natural dyes was found in China dated 2600 BC. In more modern times, Alexander the Great mentions having found purple robes dating to 541BC and in medieval times the red robes of kings, cardinals, judges and executioners announced their power over life and death (Scheweppe and Winter, 1998).

Although purple was the most precious red tinctorial material (12000 molluscs for 1.4 g of pigment), since medieval times cochineal replaced purple (150 female insects for 1 g of pigment). Moreover, as their colour was less intense than purple, it was used with metallic salt mordanting (lakes) and consecutive baths of dye with madder. Madder was the cheaper red material. Therefore, it is usual to find alizarin and carmin dyes mixed on some red coloured materials.

In our days, identification of dyes in a mixture is essential for dating, restoring and conserving artworks, but it is difficult to detect whether red dye is from alizarin or carmin by chemical analysis. Spectroscopic techniques have demonstrated to be the most indicated. In particular, Raman spectroscopy gives important molecular structure information of natural organic dyes (Guineau, 1989). Unfortunately, these compounds show a high fluorescence that prevents the identification of most of the dye bands.

SERS (Surface Enhanced Raman Scattering) is a useful tool to avoid the dye fluorescence spectra. In a previous work we have shown the ability of this technique in the study of alizarin (Cañamares et al. 2004). Now, we report a new method to reduce fluorescence and to selective analysis of dye mixtures. This method uses the ability of dyes to be included on an Organic Modified Silicates (Ormosil) matrix.

Ormosil was obtained by sol-gel technique on 80´s (Popper and Mackenzie, 1987). Some years later, dyes were incorporated on these materials leading to important applications in laser optic, sensors, solar concentration, etc. (Avnir et al. 1984). Organic dyes interact with Ormosil matrix leading to a change in its photoactivity. In particular, Zr-Ormosil are good candidates for optical applications because transparent, mechanically stable and photodegradation resistance materials are easily obtained (Giorgetti et al. 1999).

In this work we reported the results obtained by the incorporation of red dyes

into Zr-Ormosil. Two red dyes were selected for their described importance on arts: alizarin and carminic acid.

Carmine is a natural organic dye made from the dried bodies of the female insect *Coccus cacti* (Cochineal). It is an Al/Ca salt of carminic acid (Scheme 1). Alizarin is a natural dye from *Rubia tinctorum* (Madder) plant's root (Scheme 2).
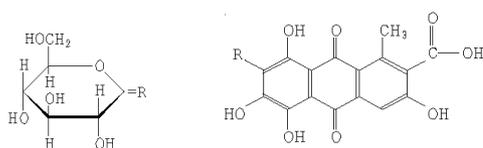
Scheme 1. 7-C-a-glucopyranosyl-3,5,6,8-tetrahydroxy-1-methyl-2-anthraquinone carboxylic acid (hereinafter called CA)
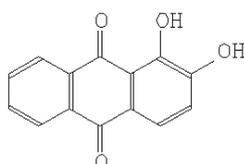
Scheme 2. 1,2-dihydroxyanthraquinone (hereinafter called Az)

Experimental Details

Zr-ormosil composites (Murcia-Mascarós et al. 2004) contain 0, 5, 10 and 15 wt% of Zr. The sols were gelled at 60ºC during 24 to 480 h, depending on the Zr contain. Small pieces (0.8x1.0x0.1mm) of transparent Zr-Ormosil were immersed at different pH (from 3 to 12), concentration (10^{-1}-10^{-6} M), solvents [DMSO, DMSO:H_2O (1:1) and NaOH 0.5 M] and time (1 to 360 h), on pure and mixed alizarin and carminic acid solutions (1 mL).

The Raman spectrum was measured directly on the dye-Zr-Ormosil composites at 785 nm in a Renishaw RM2000 micro-Raman (objective 50x, laser power = 20 mW, spatial resolution = 4 cm^{-1}). UV-Vis absorption spectra were recorded with a Cintra 5 spectrometer. The liquid samples were put in 1 cm optical path cuvettes. Coloured gels were measured directly.

Results and Discursion

In aqueous medium and pH interval from 3.0 to 12.0, carminic acid and alizarin anthraquinone dyes (Miliani et al. 2000) can exist under different protonated

forms, corresponding to the UV-Vis spectra of Figure 1 a and b.
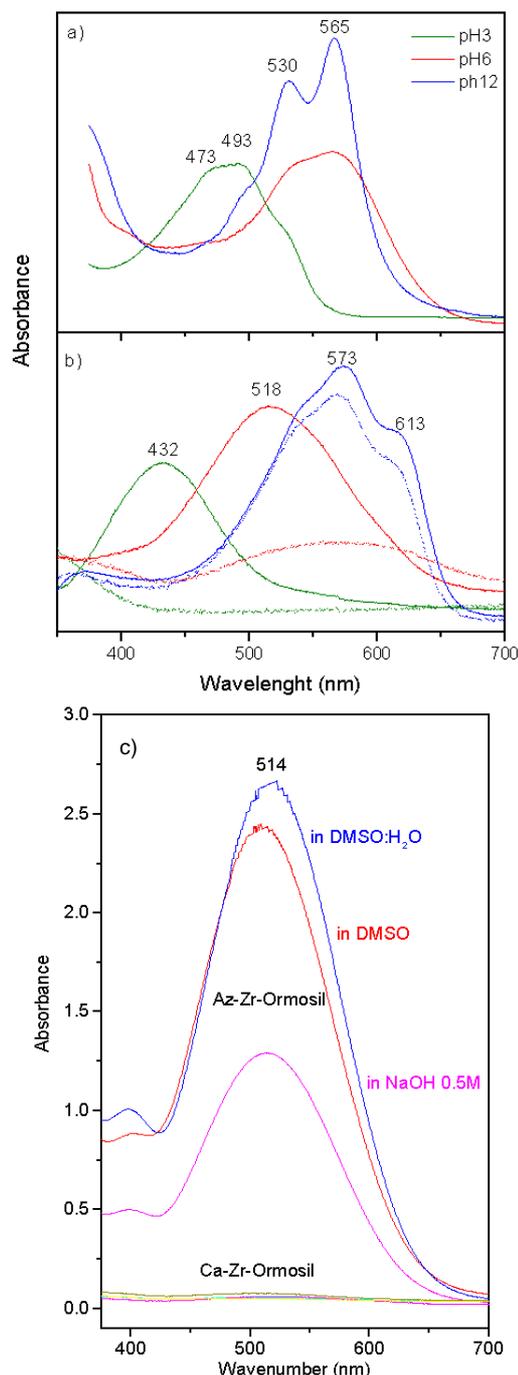
Figure 1. a) UV-vis spectra of a) Ca and b) Az solutions (10^{-3} M DMSO-H2O) at the different pHs. Dashed lines in b) correspond to the solutions after the contact with 10 % Zr-Ormosil composites; c) UV-vis spectra of dye doped Zr-Ormosil solids.

Figure 1b shows also the UV-Vis spectra of Az solution after (dashed lines) the contact with Zr-Ormosil polymer. No changes were observed on the carminic acid concentration after long contact time. As shown, the absorption of all the Az forms diminishes on the final solutions

indicating the inclusion on the solids. The same result was obtained when dye mixture solution were used.

Figure 1b shows the UV-Vis spectra of the resultant dye doped Zr-Ormosil solids. In accordance with the results obtained for the solutions, only Az Zr-Ormosil spectra show an absorption peak at 514 nm. Absorption intensities change with contact time and pH but in all cases no changes in peak position were observed. This position is related with the existence of Az⁻ form inside the gel.

In the case of carminic acid no changes in the colour of the solids were observed, even at different pH. When mixtures of the red dyes were in contact with the polymer UV-Vis spectra show the Az peak at 514 nm, thus indicating that only Az is included by the Zr-Ormosil.

Raman spectra of dye composites are shown in Figure 2. In agreement with UV-Vis spectra, intense signals corresponding only to the Az-Zr-Ormosil were observed. In solids obtained at pH = 6-7 more intense bands were registered even at short contact time. The same Az signals are also seen at acidic and alkaline pHs although a longer time is needed. This result indicates that the Az is incorporated in the gel under the Az⁻ form. At acidic and alkaline pHs an equilibrium shift is induced to the Az⁻ form to the prevalently incorporated by the gel.
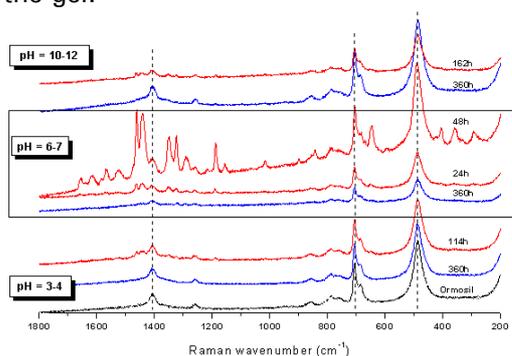
Figure 2. Raman spectrum of dyes doped Zr-Ormosil obtained at different pHs and contact times. Blue lines correspond to the carminic acid solutions while red lines are from alizarin solutions. Raman spectra of dyes mixture correspond with alizarin ones

When pure carminic acid solutions were used no CA bands were detected in the solid. However, Az bands appear when Az-CA mixtures solutions were contacted with polymer matrix, indicating again that only Az is incorporated.

A selected Raman spectrum was studied to determine the possible conformation of the dye molecule into the polymer. Figure 3a shows the Raman spectrum of Az-Zr-Ormosil composite. SERS at pH 5-6 (Figure 3b), Raman and FT-Raman spectra of pure solid Az (Figure 3c-d) and FT-Raman spectrum of the original Az in DMSO solution Figure 3e) are also shown for comparison.

The main wavenumbers of pure Az and Az-DMSO solution FT-Raman spectra, as well as the assignments, are derived from calculation already reported (Cañamares et al. 2004). The Raman of Az corresponds to the neutral form. However the Raman of Az inside the Zr-Ormosil shows many differences in relation to the neutral form. On the contrary, Az-Zr-Ormosil spectrum shows similarities with SERS spectrum of Az on Ag nanoparticles where Az interact with Ag under the Az⁻ form. This again demonstrates that Az is incorporated in gel under the monoanionic form.

In particular, the Raman of Az-Zr-Ormosil shows intense bands at 1465, 1446, 1350, 1324 and 1290 cm⁻¹ attributed to C-OH moieties coupled to ring stretching vibrations, which are enhanced due to the higher electronic delocalisation induced by the interaction with Zr. Moreover, the bands at 1659, 1632, 1587 and 1570 cm⁻¹ corresponding to C=O stretching modes are less intense due to this interaction. This tendency is typical of the isolated molecules that interact with a surface (Cañamares et al. 2004).
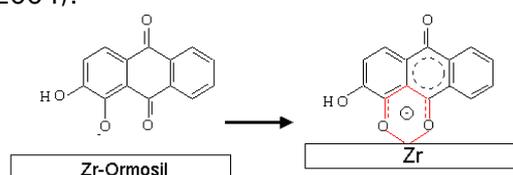
Scheme 3. **Az⁻ and Az-Zr-Ormosil structure**

The interaction between Az and Zr-Ormosil leading to the formation of the metallic chelate ring structure (Scheme 3 in red) previously reported (Huber et al. 2000) on the formation of alizarin/Al³⁺
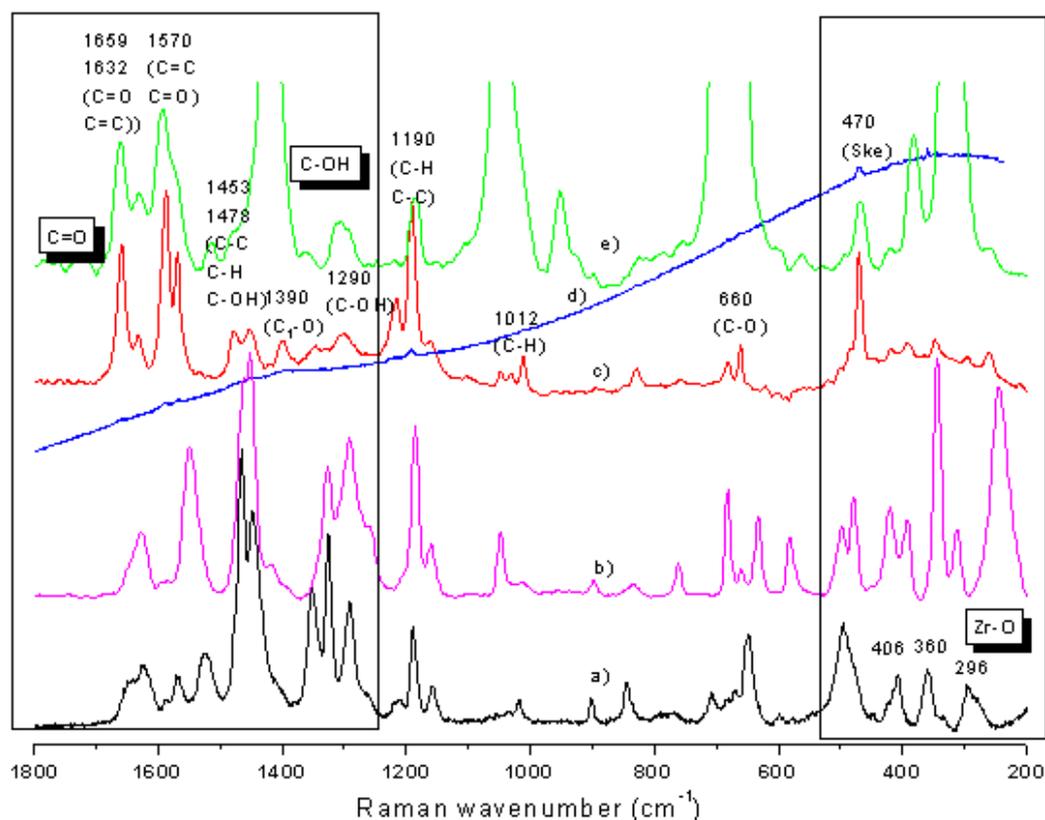
Figure 3. a) Raman spectrum of Az Zr-Ormosil obtained with Az 10^{-4} M DMSO:H_2O solution for 160 h at 785 nm; b) SERS of Az on Ag nanoparticles at 785 nm; c) FT-Raman spectrum of Az powder at 1064 nm; d) Raman spectrum of Az powder at 785 nm; e) FT-Raman spectrum of Az 10^{-1} M DMSO at 1064 nm, intense band are due to DMSO

lakes where also an interaction between O atoms in positions 1 and 9 with the metal is proposed (Kiel and Heertjes, 1963). The differences shown with respect to the SERS of Az-Ag are due to the different metals involved in the interaction. Moreover, this interaction is the responsible of the observed bands at 406, 360 and 296 cm^{-1} induced by the Zr-O-C bonds, which supports the chelate configuration.

A more detailed Raman confocal study along the z-axis of the doped polymer reveals that Az-Zr-chelate configuration is homogeneously distributed into all the polymer bulk where Zr is present (Murcia-Mascarós et al. 2004).

Conclusions
A new method to identify organic alizarin and carminic acid red dyes is presented. Alizarin dye is notably preferred by the Zr-Ormosil, giving to a red dyes separation. The alizarin-Zr-Ormosil composites present a very intense Raman spectrum, without fluorescence, that allows the dye detection even at very low concentration. These results confirm that other metals and organic siloxanes could be used on the Ormosil synthesis to adapt it to a given dye.

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Book announcements
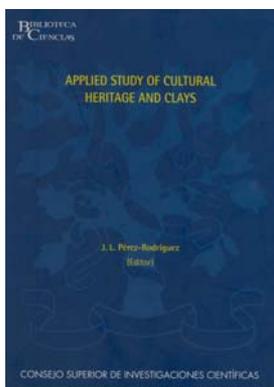
J.L. Pérez Rodríguez (ed):
Applied Study of Cultural Heritage and Clays
CSIC, Madrid, 2003

The book *Applied Study of Cultural Heritage and Clays*, was edited by Dr. José Luis Pérez-Rodríguez and published in December 2003 by the CSIC as a homage to Dr. Angeles Vicente Hernández, who unexpectedly died on April 28, 2000.

The first part of the book contains chapters on characterization, weathering and conservation studies of stones, ceramics and mortars of some of the main Spanish monuments such as the Cathedrals of Almería, Ávila, Cádiz, Granada, Jaén, Málaga, Salamanca, Santiago de Compostela, Sevilla and Zamora, the Alhambra Palace of Granada, the Mosque of Cordoba, the Roman Bridge of Salamanca, the Golden Tower of Sevilla and other buildings of historical and cultural interest. Some chapters deal with damages due to the presence of soluble salts and efflorescences on monuments. Finally, two chapters on non-destructive techniques and clays in Greek pottery are also included. The second part of the book contains papers on the genesis, properties and applications of clays.

Dr. M. Angeles Vicente Hernández, researcher at the Instituto de Recursos Naturales y Agrobiología de Salamanca (CSIC) initiated in 1982 a research topic on the decay processes and conservation of ornamental rocks. This was a consequence on her broad knowledge of clays as she was one of the Spanish pioneers working on the subject until her premature and much regretted death.
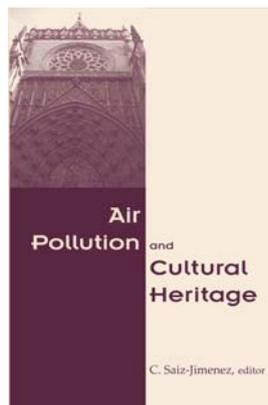
C. Saiz-Jimenez (ed):
Air Pollution and Cultural Heritage
A.A. Balkema Pub., Leiden, 2004

This book contains thirty six reviewed papers divided into five sections: aerosols, particulate matter and black crust characterization; effects of air pollution and monument weathering; soiling and cleaning; and cultural heritage policies.

Thirty papers were delivered at the International Workshop on *Air Pollution and Cultural Heritage*, held in Seville, December 2003. Another six invited papers complement the content. The papers are authored by a comprehensive team of international contributors.

More information at:
http://www.rtphc.csic.es/novedades.htm

Vacant positions

MARIE CURIE ACTIONS: EARLY STAGE TRAINING FELLOWSHIPS (EST)

The RTPHC is negotiating with the European Commission the project "Advanced Research Training on the Conservation of Cultural Heritage". This EST action is a multidisciplinary approach to the study of conservation of cultural assets and materials. If the negotiation is successful 9 long-term (36 months) fellowships towards obtaining a EURO PHD and 3 short-term (6 months) research and training stages will be awarded.

The topics and places will be the following:

BIODETERIORATION OF ROCK ART PAINTINGS (36 months). Instituto de Recursos Naturales y Agrobiologia (IRNAS), Consejo Superior de Investigaciones Cientificas, Avenida Reina Mercedes, 10, 41012 Sevilla, Spain.

MORTARS AND CONCRETE IN MONUMENTS (36 months). Instituto Eduardo Torroja de Ciencias de la Construccion (IETCC), Consejo Superior de Investigaciones Cientificas, Serrano Galvache s/n, 28033 Madrid, Spain.

MOLECULAR BIOLOGY TOOLS FOR THE STUDY OF MICROBIAL COMMUNITIES IN MONUMENTS (36 months). Instituto de Recursos Naturales y Agrobiologia (IRNAS), Consejo Superior de Investigaciones Cientificas, Avenida Reina Mercedes, 10, 41012 Sevilla, Spain.

STUDY OF PIGMENTS, SUPPORTS AND BINDERS USED IN CULTURAL HERITAGE (36 months). Instituto de Ciencia de Materiales (ICMSE), Consejo Superior de Investigaciones Cientificas, Americo Vespucio s/n, 41092 Sevilla, Spain.

PROTECTIVE AND SENSING STRATEGIES FOR CONSERVATION OF HISTORIC GLASSES (36 months). Centro Nacional de Investigaciones Metalurgicas (CENIM), Consejo Superior de Investigaciones Cientificas, Gregorio del Amo 8, 28040 Madrid, Spain.

LASER ABLATION FOR CLEANING AND MICROANALYSIS OF CULTURAL HERITAGE SURFACES (36 months). Instituto de Quimica Fisica Rocasolano (IQFR), Consejo Superior de Investigaciones Cientificas, Serrano 119, 28006 Madrid, Spain.

ASSESSMENT OF THE CONSERVATION OF CULTURAL HERITAGE BY IR AND RAMAN SPECTROSCOPY (36 months). Instituto de Estructura de la Materia (IEM), Consejo Superior de Investigaciones Cientificas, Serrano 121, 28006 Madrid, Spain.

GEOLOGY, HYDROCHEMISTRY AND MICROCLIMATE OF HYPOGEAN MONUMENTS (36 months). Museo Nacional de Ciencias Naturales (MNCN), Consejo Superior de Investigaciones Cientificas, Jose Gutierrez Abascal 2, 28006 Madrid, Spain.

CONSERVATION OF ARCHAEOLOGICAL HERITAGE BY PALEOENVIRONMENTAL METHODOLOGIES (36 months). Instituto de Estudios Gallegos Padre Sarmiento (IEGPS), Consejo Superior de Investigaciones Cientificas, Rua San Roque 2, 15704 Santiago de Compostela, Spain.

CHROMATIC DETERIORATION OF NATURAL AND ARTIFICIAL MATERIALS IN FAÇADES (6 months). Instituto Eduardo Torroja de Ciencias de la Construccion (IETCC), Consejo Superior de Investigaciones Cientificas, Serrano Galvache s/n, 28033 Madrid, Spain.

ATOMIC FORCE MICROSCOPY FOR THE STUDY OF CULTURAL HERITAGE ASSET SURFACES (6 months). Instituto de Ciencia de Materiales (ICMSE), Consejo Superior de Investigaciones Cientificas, Americo Vespucio s/n, 41092 Sevilla, Spain.

DEGRADATION AND CONSERVATION TECHNIQUES OF ARCHITECTURAL HERITAGE (6 months). Instituto de Geologia Economica (IGE), Consejo Superior de Investigaciones Cientificas, Facultad de Ciencias Geologicas, Universidad Complutense, 28040 Madrid, Spain.

Candidates are invited to send an expression of interest indicating the topic, place and type of fellowship. For 36 month fellowships the starting period will be between January-June 2005). Fellowship periods of 6 months are expected to start in January 2007.

The candidates should have a strong background either in archaeology, chemistry, physics, material science, geology or biological sciences, and currently undertaking studies in a subject area similar to that of the RTPHC training site.

Eligibility criteria
The target candidates for RTPHC are scientists at the beginning of their research careers with less than four years of seniority after their Master's degree. Eligibility conditions for Marie Curie fellowship are restricted according to citizenship and geographic origin. Applicants may check their eligibility by consulting the handbook of Marie Curie Program at http://europa.eu.int/comm/research/fp6/ mariecurie-actions/action/level_en.html or by direct inquire to the project coordinator.

How to send an expression of interest
An expression of interest should be sent to the project coordinator, Prof. C. Saiz-Jimenez, Instituto de Recursos Naturales y Agrobiologia, Apartado 1052, 41080

Seville, Spain. e-mail: saiz@irnase.csic.es. The applications should include experience in the field of research, aptitude of the EST candidate to carry out an individual training/mobility project, capability for integration in a research team, potential for excellence, impact and the benefit of the proposed training to the individual fellow's research career and their origin country, academic degree obtained, list of scientific publications and participation in congresses, willingness to carry out an intense research training programme, and potential interest in a multidisciplinary research based on Cultural Heritage. The candidates for 36 months positions should have an internationally recognised diploma giving access to doctoral studies.

The RTPHC encourages all interested persons to apply, regardless of age, gender, religious affiliation or ethnic background.

Contract Type: Temporary Position Early Stage researcher (max. 4 years experience). Number of Positions: 9 long-term and 3 short-term.

Deadline for submission of expression of interest: 30th September 2004. When completed the negotiation process, the candidates who submitted an expression of interest will be invited to apply for the temporary position. Their applications will joint those applicants that directly applied in response to other advertisements in the Internet and Marie Curie web page.

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Conference announcement