

CONTEMPORARY ART MATERIALS TESTS

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Abstract

The present report is related to a running project on contemporary visual art conservation and is considering various case studies, involving different techniques. On one hand the research investigates by means of advanced optoelectronic methods a series of modern artworks, while on another approach is testing today's art materials stability by undergoing accelerated ageing. The multiannual research's main aim is to create a new scientific approach in contemporary visual art and start up an advance form of specialization in restoration/conservation based on rigorous organized information about new materials and techniques, all with full and deep respect for contemporary artists and their artwork. The general objective is absolutely thought not to constrain the artists' practice, but to inform them and to create necessary set-ups and comprehensive databases, as decisive information for the restorers' community of tomorrow.

Keywords: *Contemporary art; Photonic techniques; Accelerated ageing; Ultraviolet exposure; Materials stability; Photodegradation; Color*

Introduction

With the rise of the avant-garde in the early twentieth century, visual artists have used an extensive number of new materials and techniques that in a relatively short period generated the background for a new wave of problems in the art conservation and restoration field [1]. As for the vast majority array of this new developed pigments and binders little data exists when dealing with issues regarding material stability, ageing or conservation treatments, conservators are challenging complex and delicate situations [2]. Moreover, beyond the material science, awareness and care of the artist's intent amplifies problematic and even ethical situations when confronting key decisions on regard the proper way of preserving the artwork. Fortunately, the same unprecedented development of means one can find in the scientific fields, particularly research. Scientific equipment is developing at high speed, allowing the researcher to carry in-depth studies and thus to understand and foresee the possible weakness of one material or another. Most important, the ultra-modern investigation, diagnose and treatment techniques [3]

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have the capacity to reconstruct almost every kind of environment and literally play the time-machine by manipulating the aging process, so that they are able to tell how things will evolve in long term. This is a keystone in the process of developing the adequate restoration manner and treatment long before they are needed and also in the improvement of new materials preservation. Still, protocols based on high-tech scientific investigations [4, 5] which tend to become standard or routine on regard traditional art and archaeological artifacts [6] – even in the case of underwater or other extreme environments [7], may prove to be insufficient in the case of contemporary art as situations without precedent are being generated. Under these directions, a short selection of investigated artworks, part of a large thematic exhibition - "Contemporary histories in the studio: artistic and scientific perspectives" that took place on December 2012 at the Visual Arts Center Galley in Bucharest, highlights some of the possible demanding issues that may rise in future restoration work. Each example from the investigated and discussed cases (Figs. 1-3) has unique particularities retrieved within the chosen materials and none the less within the artist's technique. The evaluation of complex multilayer structures, reflective materials or rugged surfaces were few of the problematic situations carefully analyzed by advanced photonic methods. The artificial ageing tests, that will be further discussed, were seen as the best approach in order to evaluate modern materials behavior in time and establish the first steps of a future standardized protocol of testing.



Fig. 1. Multispectral analysis: 1A - case study: *Abandoned transformers on the Danube* by Nicolae Comănescu (2009) / ash, soil, dust, mustard powder and acrylic medium on canvas (80x120 cm); 1B - 1C - details in UV fluorescence mode, near infrared region respective, revealing the working technology, successive color layers, possible retouchings/overlappings and optical characteristics of some of the materials used (fluorescence of the acrylic emulsion)

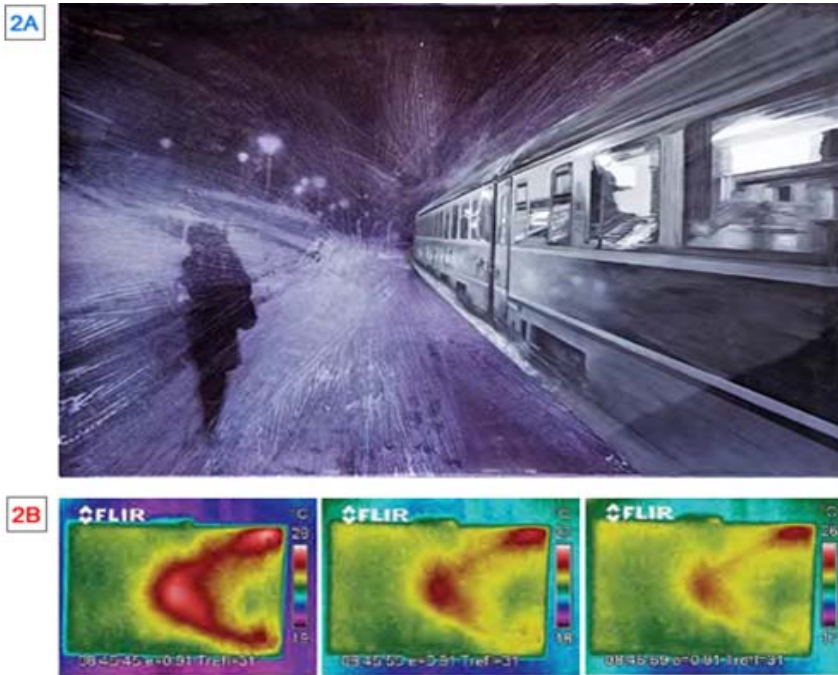


Fig. 2. Thermovision images: 2A - case study: Time on wheels by Francisc Chiuariu (2009) / oil on backlit / 80x120cm; 2B - the results of the thermo investigation tests (relaxing process with negative thermo gradient) emphasized a certain sensitivity of the backlit material to changes in environmental temperature as large areas of the painting's support immediately answered to the applied stress factors; these analyses are relevant for proper evaluation of possible regions with a higher risk factor for establishing appropriate handling, storage and display conditions



Fig. 3. Digital documentation by 3D Laser Scanning 3A - case study: Face without a face by Florica Prevenda (1998) / mixed media on paper / 65x50cm; 3B - maximum digitization of the surface was rendered impossible by the roughness and the relief of the surface under investigation as well as by the materials of which it consists (the resolution obtained reached millimeter size only); the central area of the work posed the greatest difficulties as the successive layers of super-fine porous paper (tea sachets) attached to the area and covered with a fine layer of wax could not be scanned due to the transparency of wax at the laser scan's specific wave radiation (690 nm)

Materials and Methods

Paint Samples

Taking into consideration our previous studies on modern and contemporary artists' paints, for this stage of the project the range of acrylic tested materials was extended, and for a comparative study on regard traditional media and techniques, corresponding tempera and oil based colors were included. Due to the large variety of products offered on the market, paint selection was done towards the basic color palette with professional grade products within the Liquitex[®], Lefranc & Bourgeois[®] and Maimeri[®] paint brands; the complete list of tested materials and their characteristics are summarized in Table 1. In the case of acrylic colors varnished samples were also tested, Lefranc & Bourgeois[®] Extra-fine Retouching Varnish. A number of over 150 samples were obtained as thin paint film layers cast on small glass slides (76x26mm) that were further stored in dark ambient conditions and let dry prior to analysis.

Table 1. List of commercial paints investigated

Manufacturer/ product type	Color name
Liquitex / Basics Acrylic Color	Titanium white, Naphthol crimson, Ivory black, Naples yellow hue, Primary yellow, Dioxazine purple, Deep green, permanent, Ultramarine blue
Lefranc & Bourgeois, Fine Gouache	Permanent white, Red vermilion, Ivory black, Raw sienna, Primary yellow, Persian violet deep, Light green deep, Ultramarine deep
Maimeri, Classico Oil Colors	Zinc white, Cadmium red light, Ivory black, Burnt Sienna, Primary yellow, Permanent violet reddish, Phthalo green, Ultramarine deep

Accelerated Ageing

Even though current practice along accelerated testing highlights the need of proper light source selection, with Xenon arc radiation filtered to resemble sunlight or daylight through window glass as the most widely accepted source [8], for the present paper extreme UV exposure tests were considered by a number of reasons, already mentioned [9]. In-line, multiple types of accelerated light - ageing regime were used up to 300 hours of exposure with variations on regard the spectral source (fluorescent lamps covering different levels of ultraviolet radiation: 315-380 nm, 305-315 nm, 253.7 nm) and up against the geometry of exposure. On another approach, a sub-set of samples undertook thermal and humidity ageing during 30 days in a dedicated climate chamber, with a microclimate dynamics of temperature variations from 10° to 65°C, and relative humidity between 40% and 65% at each 24 hours.

Color Measurements

The color of each sample was recorded prior to exposure and periodically during the experiment by means of a GretagMacbeth portable spectrophotometer. For a good statistics a template was used to position the spectrophotometer at the same spot on the surface of the sample each time a measurement was taken. Recorded data, expressed as the CIE L*a*b* coordinates registered under the standard illuminant D65 and using the 10° supplementary standard observer, were obtained as an average value of two successive readings. In order to have a relative evaluation of the induced damage degree on respect color changes, the overall color differences (ΔE) between reference and aged samples were calculated using the CIE 1976 L*a*b* equation [10], with resulting values reported to those found in literature [11].

Results and Discussions

In a primary analysis focused towards the evaluation of the photodegradation processes, correlation between recorded colorimetric data and UV exposure time outlines the particular material response when undergoing light ageing. Overall, in the first stages of the light-ageing tests the acrylic paints showed the highest photo-stability maintaining their brightness and texture. A resembling behavior was observed in the case of the acrylics' varnished samples, excepting the blue, green and black paint layers where the gloss film faded. Perceptible discolorations extended on the entire surface as well as structure brittleness were characteristic effects of the aged tempera, while in the case of the oil paints degradation mechanism followed exfoliations and shriveling of the paint layers along with the color changes. The intensity of the deterioration mechanisms and the dynamic of the related physico-chemical processes were seen to vary upon the local characteristics and formulation of each material, with UV exposure time inducing cumulative effects. More exactly, with the increase number of exposure hours the degradation effects observed in the previous stages emphasized, and for the samples that showed a good stability till then deterioration mechanisms appeared: at high exposure rates acrylics' lose their brightness; varnish layers disappear and become tacky; colors in the vast majority of cases are pale, dull and don't show the same saturation and brightness.

In terms of color stability chromatic changes exceeded a level of $\Delta E = 1.5$, considered to correspond to a color change that is visually perceptible [11], in the vast majority of the cases after the first 50h of exposure under short wavelength radiation, 100h respectively under the near-UV range (315-380nm). Despite particular paint formulation and characteristics, within all types of tested materials colorimetric results pointed out an unexpected increased sensitivity on a similar range of pigments; specific, the monoazo yellow pigments - PY74, PY97, PY175; the dioxazine purple – PV23 and the synthetic ultramarine – PB29 – a complex silicate of sodium and aluminum with sulfur, were among the ones with the highest registered photosensitivity. At high exposure rates for tested samples containing the above mentioned dyes, the corresponding general color variation (ΔE) and/or the variation of the colorimetric parameters (ΔL^* , Δa^* , Δb^*) reached high numerical values ($\Delta E > 20$), fact that may indicate the unstable color behavior of these materials in time. To a greater or lesser extent, depending upon the binding medium and the degree of light exposure, the red dyes – monoazo PR170, cadmium red PR108, natural vermilion, and the green pigments respectively – PG7, PG36 corresponding to the phtalocyanine chemical class, recorded noticeable changes in the visual appearance also.

As expected, the natural earth and mineral pigments – titanium and zinc white PW6/PW4, black ivory PBk9 and iron oxides – PBr7, PY42, showed the most stable color behavior, with the general color variations bellow an average value of 10 even at high UV exposure hours. Unlike the tested dyes with less light-fade resistance that generally highlighted an increased sensitivity under shorter wavelength radiation, for the natural pigments the highest photosensitivity was recorded in UVA range.

With similar degradations effects generated by a variety of photo-oxidations mechanism and reactions, understanding the ageing chemistry processes behind these type of materials reveals as an ambiguous demand. As stated in previous studies [12] the drying and ageing processes of modern paint formulations depend to a great extent not only on the type of pigment and binding medium, but also on a series of additives added during manufacture; as regard their general physical properties, under controlled accelerated ageing it was observed, as in our study, in most of the cases a nonlinear response that sets a subsistent complexity when trying to understand the chemical kinetics and the influence of the microclimate conditions. Moreover, in acrylic emulsions it was reported [12] that the rate and induction time of photo-oxidation reactions tend to be notably affected by the type of colorant that seems to act as catalytic agent.

In view of these recent results, it appears that the colorimetric data registered in our study highlights a non-random fading tendency that could be further considered on issues regarding preventive conservation. The graphical representations (Fig. 4) in the case of the blue tested paints for example emphasize a linear ageing behavior with a sensitivity that exists even at lower thresholds of exposure. The high numerical ΔE values (a maximum of 27) recorded for the blue acrylic samples (pigment ultramarine blue PB29) under all types of light-ageing regimes indicates a particular photo-sensitivity that may be due to the acrylic resin binder. The assumption seems to be confirmed as for the blue oil samples (containing the same pigment – PB29) much lower ΔE values are registered, at least in the first 100h of exposure.

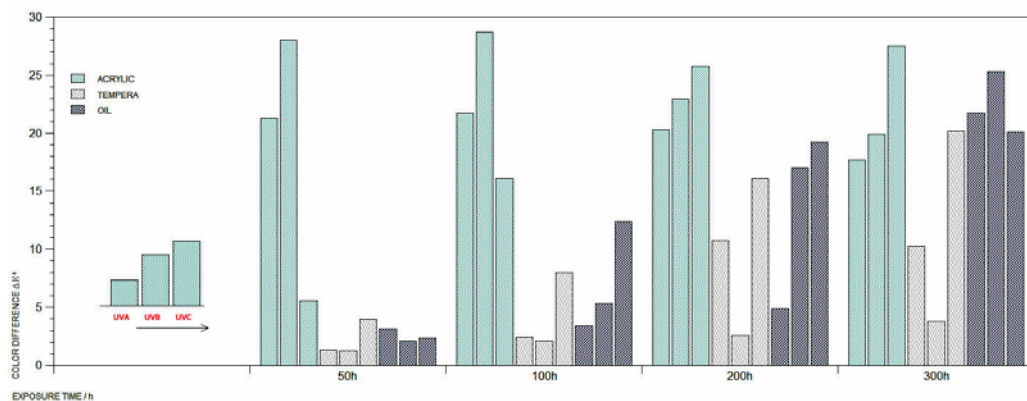


Fig. 4. Plotted data in the case of the blue tested paints showing the general color variation against UV exposure hours

Reaching a saturation threshold beyond which samples even if further tested don't suffer any more degradations, as well as reversible reactions where after a certain point materials display a declining rate mechanism, are also possible situations for specific type of materials (eg. the plateau region reached by the green PG7 pigment after 100h of exposure). Still, for a better understanding of material behavior under specific wavelength radiation a more elaborate analysis has to be carried as a profound lack of information remains unfilled on regard the photodegradation processes of these new pigments and binders. In the past decades there have been a series of studies attempting to determine whether the shorter wavelengths of the ultraviolet regions induce significantly different reactions than those in the visible spectrum. On regard, Hirt and Searle published numerous examples of activation spectra pointing that below 400nm there's a general rise in degradation that gradually reaches a peak of activity that is then followed by a decline [8]. The effects at relatively specific wavelength regions and the corresponding photochemical activity were also described by Martin and Tilley, their study on polymeric materials using narrow-band-pass filters allowing the measurement of the photo-oxidation rate as a change in the absorption of the carbonyl group [13]. Later, Gardette and Lemaire were able to show using various light-exposure devices that 254nm radiation generates within poly(vinylchloride) significantly different mechanisms and types of reactions than under near-ultraviolet radiation [14]. Nevertheless, materials photodegradation behavior is very peculiar as for example we have to take into account that when a dyed or pigmented material fades, the main cause beyond deterioration may not be the absorption of light by the most obvious absorber, but instead the chromophoric groups absorption within a trace of impurity that subsequently activates the vehicle in such a manner that at a certain point will lead to the degradation of the colorant [8]; yet, not all the wavelengths absorbed by the material compounds will generate changes as the excited molecules may release its absorbed energy by re-emitting it at longer wavelengths by different photophysical processes.

Photodegradation reactions will initiate thus only when the absorbed energy is not dissipated but instead transferred within the material molecules, the intermolecular energy exchange processes between electronically excited impurity groups and another group or weak link in polymer materials for example, being considered as the first steps of photodegradation during weathering [15]. Polymeric materials design, with its molecular and structural features [16], plays a specific role thus as the light-absorbing entities in trace contaminants may be part of the polymer itself (carbonyl (C=O) and carboxyl (COOH) groups; peroxy (-O-O-) links; metallic impurities; catalyst residues) or substances introduced later, at any stage of the material life cycle [15]. Also, it was shown that in the case of common polymers the quantum energy of the bond strength has the same magnitude (99 to 70 kcal/mol) as UV light of wavelengths between 290 and 410nm, and therefore may cause chemical instability.

Furthermore, issues regarding degradation and materials stability become even more ambiguous when the moisture and thermal effects are taken into account. With counter processes (eg. cross-linking and chain breaking) that can take place concurrently as they affect different compounds within the material, predicting materials behavior in time becomes a difficult task. As shown by the colorimetric results of our microclimate test, with the exception of the blue acrylic, and some of the oil samples (yellow, purple and blue), the general color variations are small when compared to those resulted by UV exposure; at mechanical level though, samples are much more affected, situation due to the specific thermo-hydrolytic mechanisms that took place during weathering. The variable, non-uniform induced effects observed in some of the cases were probably generated by the gradients in moisture content and temperature within the material, with cyclic dimensional changes occurring irregularly onto the surface. Complementary information gathered by further analysis will allow an in-depth characterization of the samples with a focus on the identification of the degradation mechanisms and reactions, as well as on the evaluation of the degradation products.

Conclusions

Even with the significant number of research studies carried in the last decades within the conservation area, issues addressing materials stability and specific chemical aspects involved under the various deterioration mechanisms that may be induced over time, still face a major backdrop. In addition, the development and introduction on the art market of a revolutionary new range of products generated a new series of problems for current restorers and conservation scientists that are now challenged by unencountered complex situations. Under these perspectives, the use of controlled accelerated ageing offers a certain potential for relatively fast results, with an overall pattern of deterioration for selected tested materials summarized in this study by colorimetric measurements expressed as a function of color stability. Nevertheless, for more relevant results that could easily be correlated with real time scenarios, there's an extensive need for development and improvements of current standard test procedures and techniques that can accurately monitor and measure the degree of change and thereby foresee proper intervention and conservation strategies.

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References

- [1] O. Chiantore, A. Rava, **Conserving Contemporary Art: Issues, Methods, Materials, and Research** (first edition), Getty Conservation Institute, Santa Monica, 2013.
- [2] O. Chiantone, D. Scalarone, *The macro- and microassessment of physical and ageing properties in modern paints*, **Proceedings from the Modern Paints Uncovered Symposium**, 16th-19th May 2006, London, United Kingdom, p. 96.
- [3] M. Simileanu, W. Maracineanu, J. Striber, et al., *Advanced research technology for art and archaeology - ART4ART mobile laboratory*, **Journal of Optoelectronics and Advanced Materials**, **10**(2), 2008, pp. 470-473.
- [4] J. Striber, R. Radvan, L.M. Angheluta, *Laser spectroscopy methods for an 18(th) century grisaille painting investigation*, **Journal of Optoelectronics and Advanced Materials**, **11**(11), 2009, pp. 1815-1820.
- [5] H. Sadek, M. Simileanu, R. Radvan, et al., *Identification of porcelain pigments by Laser Induced Breakdown Spectroscopy*, **Journal of Optoelectronics and Advanced Materials**, **14**(9-10), 2012, pp. 858-862.
- [6] O. Mircea, I. Sandu, I. Sârghie, A.V. Sandu, *The identified effects of degradation in archaeological artifacts with overlapped metals used in authentication*, **International Journal of Conservation Science**, **1**(1), 2010, pp. 27-40.
- [7] M. Simileanu, R. Radvan, *Remote method and set-up for the characterization of the submerged archaeological remnants*, **Journal of Optoelectronics and Advanced Materials**, **13**(5-6), 2011, pp. 528-531.
- [8] R.L. Feller, **Accelerated Aging: Photochemical and Thermal Aspects** (Research in Conservation 4), Getty Conservation Institute, Marina del Rey, 1994.
- [9] P.M. Whitmore, V.G. Colaluca, *The natural and accelerated aging of an acrylic artists' medium*, **Studies in Conservation**, **40**, 1995, pp. 51-64.
- [10] K. McLaren, *The development of the CIE 1976 ($L^*a^*b^*$) uniform color-space and color-difference formula*, **Journal of the Society of Dyers and Colorists**, **92**, 1976, pp. 38-341.
- [11] C. Korenberg, *The photo-ageing behavior of selected watercolor paints under anoxic conditions*, **British Museum Technical Research Bulletin**, **2**, 2008, pp. 49-57.
- [12] M.T. Doménech-Carbó, *Study of behaviour on simulated daylight ageing of artists' acrylic and poly(vinyl acetate) paint films*, **Anal Bioanal Chem**, **399**, 2011, pp. 2921-2937.
- [13] K.C. Martin, K.I. Tilley, *Influence of radiation wavelengths on photooxidation of unstabilized PVC*, **British Polymer Journal**, **3**, 1971, pp. 36-40.
- [14] J.L. Gardette, J. Lemaire, *Wavelength effects on the photochemistry of poly(vinylchloride)*, **Polymer Degradation and Stability**, **16**, 1986, pp. 147-58.
- [15] A. Blaga, *Deterioration Mechanisms in Weathering of Plastic Materials, Durability of Building Materials and Components*, **ASTM STP 691** (Editors: P.J. Sereda and G.G. Litvan), American Society for Testing and Materials, 1980, 827-837.
- [16] F. Sava, R. Cristescu, G. Socol, R. Radvan, R. Savastru, D. Savastru, *Structure of bulk and thin films of poly-methyl-methacrylate (PMMA) polymer prepared by pulsed laser deposition*, **Journal of Optoelectronics and Advanced Materials**, **4**(4), 2002, pp. 965-970.

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