IRUG12
Infrared & Raman Users Group

Book of Abstracts

ORMYLIA FOUNDATION

Art Diagnosis Centre

Ormylia, Greece

The twelfth Biennial Infrared & Raman Users Group Conference

www.irug12-ormylia.gr

Organised by

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Ormylia, Greece

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Thermal quasi-reflectography (TQR), handheld Raman spectroscopy, and optical profilometry: multi-technique mapping of decay in wall paintings

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The combination of full-field imaging techniques with techniques that can analyze only a very limited portion of the artwork is very important to guarantee an effective sampling over the surface and hence collect reliable information about the work of art. Besides such guided sampling, the integration of imaging and spectroscopy, if properly based on ground-truth data and information processing, enables non-destructive identification and mapping of materials over the target surface. The effective use of a multi-technique analysis and its integration level is related to the knowledge of the performance of the employed methods as well as of their complementarity.

In this work, Thermal Quasi-Reflectography (TQR), handheld Raman spectroscopy, and optical laser micro-profilometry have been tested. These three techniques have been chosen to overcome specific limitations related to them, allowing a more accurate characterization of the sample under investigation directly in-situ. TQR is a recent imaging technique [1] based on the acquisition of the thermal mid-IR (3-5 μm) in (quasi-)reflectance modality, which has been shown to gain information where other optical methods are not effective. TQR response is determined by factors related to the material composition, to the density and microstructure, and to the surface roughness. As such, TQR has the potential to detect the presence of different materials and binders, and to discriminate the response of different surface layers. Combination of TQR with the above techniques is unexplored.

Multi-technique analysis has been applied on mock-up samples of fresco plaster. The high sensitivity of TQR permits to detect and to map changes in the composition of the surface materials, handheld Raman spectroscopy is then used to understand the composition of the areas mapped with the TQR, optical micro-profilometry is used to model the surface morphology and to understand any changes induced in the roughness structure at micron scale, [2].

The results are discussed and the pro and cons of the above techniques are evaluated, with the aim of assessing their complementarity and thus performing an effective integration. Finally, the joint use of TQR imaging and Raman spectroscopy has been tested as a potential tool for mapping in-situ, full-field and non-destructively, the areas affected by sulphate decay in wall paintings (Fig. 1)

[1] C. Daffara, D. Ambrosini, L. Pezzati, D. Paoletti, *Optics Express* 20(13), 2012, 14746-14753.
[2] C. Colombo, C. Daffara, R. Fontana, M.C. Gambino et al, *Lasers in the Conservation of Artworks: LACONA VI*, 2005, 522-526.

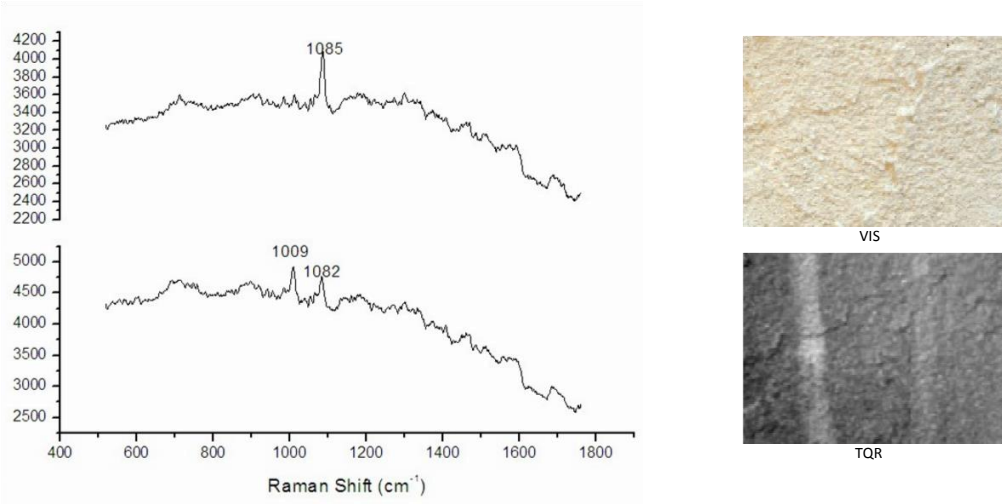

Fig. 1: Analysis of plaster decay in fresco test-beds (example). Left: Raman spectrum of sound (top) area and sulphate decay (botton); Right: VIS image and TQR response (sulphated areas are the vertical lines).