Imaging of Egyptian Blue

Technical Details

Egyptian blue, a synthetic form of the rare mineral cuprorivaite (calcium copper tetrasilicate: $CaCuSi_4O_{10}$), was widely used as a pigment across the Mediterranean basin from early dynastic Egypt (*c.* 2500 BC) until after the end of the Roman period in Europe (its use declined around AD 800).

In most cases, the Egyptian blue pigment was mixed with an organic binding medium such as gum arabic, egg or animal glue and applied onto the surface of objects. While the blue pigment is extremely stable, even under adverse environmental conditions, the organic binder is susceptible to deterioration (especially after excavation) leaving the pigment particles loose and prone to fall off the surface. This results in the loss of the original polychromy, although in many cases a few grains of pigment survive.

A new, non-invasive and non-contact imaging technology, developed in the Department of Conservation and Scientific Research at the British Museum, can be used to detect the pigment particles [1].

When irradiated with visible light, Egyptian blue emits infrared radiation. This phenomenon is called photo-induced luminescence [2]. The absorption and excitation spectra of synthetic cuprorivaite show three different electronic transitions ($^2B_{1g} \rightarrow {}^2B_{2g}$, ^2E_g and $^2A_{1g}$) attributable to Cu^{2+} ions, which are expected to be the only photoluminescent centres in cuprorivaite. While the major excitation peak is centred in the red range of the electromagnetic spectrum (*c.* 630 nm), the emission spectrum is centred in the infrared range (*c.* 910 nm) and is related to the lowest energy electronic transition ($^2B_{2g} \rightarrow {}^2B_{1g}$). The infrared radiation emitted by the pigment can be recorded with a camera that has some sensitivity to infrared radiation.

The infrared emission by the pigment is exceptionally strong (Φ_{EM} = 10.5%) [3] and, for this reason, even single particles of pigment can be detected from a distance of a few metres. In the photo-induced luminescence images, the pigment appears as 'glowing white'. In addition, because of the strong response of the pigment, the images produced often allow the identification of otherwise lost decorative patterns and the detection of very small areas of paint.

The setup required for the measurement is relatively inexpensive and can easily be used either within a museum or for work *in situ*. Large objects that cannot be moved or rare works of art that cannot be sampled, can be investigated by this portable, inexpensive and non-invasive investigation technique, which, although not intended as a substitute for analytical investigations, offers a valuable complementary tool in the understanding of ancient polychromy.

It has also been determined that Egyptian blue is the strongest known infrared emitter in the infrared range for a molecule-level chromophore [3], with potential applications in the fields of biomedical analysis, telecommunications and lasers. The British Museum is currently collaborating with other researchers in furthering these studies.

[1] G. Verri, *Analytical and Bioanalytical Chemistry*, 2009, DOI 10.1007/s00216-009-2693-0
[2] G. Pozza, D. Ajò *et al.*, *Journal of Cultural Heritage*, 2000, **1**, 393
[3] Accorsi G., Verri G. *et al*., *Chem. Commun.*, 2009, DOI: 10.1039/b902563d