Nanotechnology cleans up

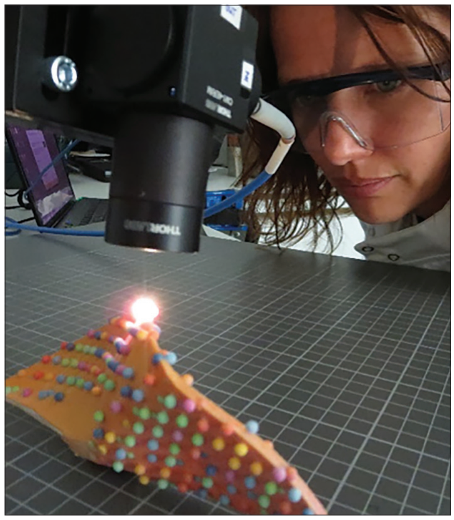
A European project called Nanorestart is turning to nanotechnology to find novel ways to preserve modern works of art, explains **Carolien Coon**

Despite the best intentions of conservators in preserving works of art, the treatments they apply could turn out to have damaging effects in the future. Back in the 17th and 18th centuries, for example, people used to rub Michelangelo's famous frescoes in the Sistine Chapel with bread or linen dipped in wine. Thankfully, we now have more sophisticated tools such as laser cleaning or selective cleaning using hydrogels or micro-emulsions, which can be fine-tuned to remove unwanted deposits without affecting the underlying painted substrate.

In principle, any intervention must be reversible such that a work of art can be restored to its previous untreated condition. In practice, this is extremely difficult or even impossible to achieve, and it is often more realistic to adopt a principle called "re-treatability and compatibility". Conservators therefore continuously have to balance the risks of doing nothing to doing something. Indeed, the fear of being responsible for devaluing a piece of cultural heritage has forced some conservators to lay down their swabs and spatulas, and to go in search of better tools.

This challenge is particularly relevant for the preservation of modern art, where few established conservation protocols exist. Traditional conservation ethics are difficult to apply when artists have used ephemeral materials in their work, such as plastics. Once degradation has been initiated in plastics via thermal, photo-oxidative or hydrolytic means, the process proceeds auto-catalytically and very little can be done to prevent the artwork's imminent demise. In some cases replication is the only alternative for preserving heritage, which is reminiscent of conservation efforts in the dark ages.

Collectors and auction houses are increasingly seeking advice from conservators on how to prevent their treasured pieces from decaying or on how to restore a modern artwork. Unfortunately, they are too often met with a bad prognosis as pieces lose their vibrancy, start cracking and yellowing or lose an inherent material property such as flexibility that could be intrinsic to the meaning of the work. The scale of the problem can perhaps be better appreciated in a financial context: in 2014 the global art market was worth a little over €50bn ($56bn), of which post-war and contemporary art accounted for 48% and modern-art sales 28% of all auction sales, respectively.



Spot on Carolien Coon using ultra-accelerated photodegradation testing, or microfadometry, to explore the fading of a rapid prototype artwork in a tiny, virtually invisible spot.

Nanotechnology to the rescue

Thanks to a multi-partner European Commission (EC) project called Nanorestart, which kicked off last year, nanotechnology could soon provide conservators with novel ways to future-proof modern works of art. Nanotechnology is certainly not new to the art world. Since the Bronze Age, artisans have used the "magical" properties of nanoparticles in their wares, which seem to defy the laws of physics. The dichroic properties of the fourth-century Roman Lycurgus Cup, which is currently on display in the British Museum, were a mystery until as recently as 1990, when scientists used transmission electron microscopy to discover that clusters of silver and gold nanoparticles measuring 50–100 nm across changed the optical appearance of the glass from a deep red to opaque green, depending on whether viewed in transmitted or reflected light.

> Characterizing materials at the microscopic scale in a non-destructive manner is a mantra in heritage science.

Even throughout the Dark Ages and into the Renaissance, the optical and reflective properties of metal nanoclusters were exploited to create the beautiful iridescent quality of medieval and renaissance lusterware, whereby their colour changes depending on the viewing angle. Thankfully, many of these artefacts have already withstood the test of time. But many other cultural heritage objects, particularly those made from organic materials, risk being lost to future generations if not treated carefully.

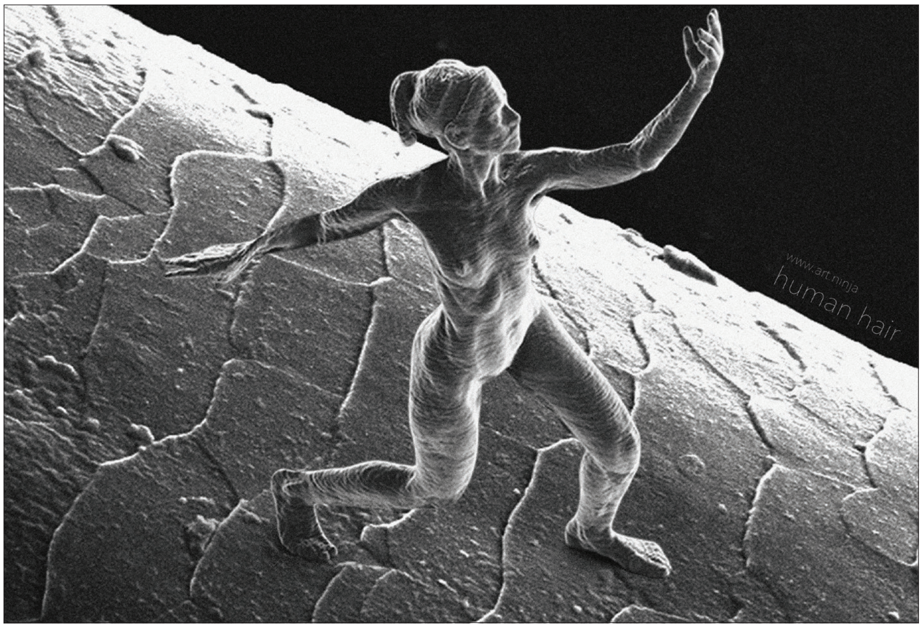
Today, heritage science is a cross-disciplinary field that aims to conserve cultural artefacts and improve access to them. While there has been a steady growth in our understanding of preservation techniques for classical artworks, preserving modern art is much more challenging. These works are often made from novel materials, some of which are intentionally transient. Indeed, artists may unintentionally use materials that have an inherent vice such as polyurethane foam, cellulose nitrate, cellulose acetate and polyvinyl chloride. These are known as "malignant" plastics, not just because they are intrinsically unstable, but also because the degradation mechanisms they suffer produce harmful products, such as corrosive volatile organic compounds (VOCs) that could damage other plastics or objects in their surroundings.

The idea of using nanotechnology to protect heritage artefacts was pioneered by Piero Baglioni and colleagues at the Centre for Colloid and Surface Science (CSGI) at the University of Florence, Italy. It was built on groundbreaking conservation work by Enzo Ferroni, who – following the Florence floods in 1966 – helped develop a method to remove salts threatening frescoes that had been immersed in flood water. The method is a two-step process, using ammonium-carbonate and barium-hydroxide solutions to remove sulphur from – and thus consolidate – the contaminated frescoes. Unfortunately, the

Heritage science

penetration depth of the consolidant was limited by the particle size and, in some cases, risked the formation of a white bloom on the surface of the painted layer.

The team at the CSGI therefore developed more efficient methods based on inorganic particles with smaller sizes. "Nano-lime", which is based on dispersions of calcium-hydroxide nanoparticles in non-aqueous solvents, has similar physical and chemical properties to the original lime plaster used in frescoes and so behaves and ages in a similar fashion, without introducing stresses. Through the European Commission FP7 "Nanoforart" project, which ended in 2014, inorganic nanotechnology-based consolidation alternatives for frescoes were refined, as were systems that could remove past treatments, such as polymer-based consolidation treatments used in wall paintings. Nano-systems were also developed for the consolidation, de-acidification and controlled removal of unwanted deposits from organic materials such as paper, wood and canvas.



www.jontyhurwitz.com

Nano-art "Trust", a nano-sculpture by artist Jonty Hurwitz created using two-photon lithography, is the smallest ever reproduction of the human form. But for how long will it last?

Plastic concerns

Today, one of conservation's biggest challenges concerns contemporary artworks made from plastics. Plastic's reputation as an everlasting material has disappointed, with devastating degradation processes now observed in plastic collections dating from the 1920s to the 1960s. Iconic pieces from the Bauhaus and Pop Art movements are ticking time bombs. Russian sculptor Naum Gabo's early and now disintegrating pieces made from cellulose nitrate (another malignant plastic releasing acidic nitrogen-dioxide gasses) are another prominent example. The situation is complicated because plastics vary enormously in their make up. They span a range of synthetic/semi-synthetic polymers with many different chemical compositions, all of which follow different degradation pathways such as hydrolytic, thermal and photochemical processes, including thermal and photo-oxidation.

Fortunately for these materials, Nanorestart – launched under the EC's Horizon 2020 programme – is by far the biggest international research effort to develop nanotechnology-based solutions to the conservation of modern and contemporary materials. The project pools the expertise of enterprise and academic leaders across 27 partner institutions in nanoscience and conservation, and is divided into four distinct themes: cleaning of contemporary painted and plastic surfaces; stabilization of modern canvases and painted layers in contemporary art; removal of unwanted modern materials; and advanced protection of modern artworks in museums and outdoors.

The Institute for Sustainable Heritage at University College London (UCL), where I am based, is investigating whether polyfunctional active and passive coatings, developed by Nanorestart partners, would extend the lifetime of polymer-based rapid prototype (RP) artworks, which are starting to enter museum collections. Since RP objects are not end products and so are not designed to last, they present a bigger conservation challenge than that of the early industrial plastics of the 1950s and 1960s. Indeed, RP artefacts are extremely complex materials with unpredictable chemical and physical properties caused by unknown formulations and non-standard processing parameters. Some RP materials, particularly photopolymers, have already been shown to be chemically unstable and could benefit the most from nanotechnology-based coatings, particularly if applied at the point of creation.

Once again, the "magical" properties of metal nanoparticles could hold the key to preserving RP artworks. Nanorestart partners are working on active coatings that act as radical scavengers that deactivate radicals formed during oxidation and thereby stop the autocatalytic process, for example. Passive coatings are another target, offering gas barrier and ultraviolet (UV) blocking properties to protect works from oxygen, humidity and ultraviolet, which are the main agents of polymer degradation.

A crucial test of such treatments, and another focus of the UCL team's work, is to compare the stability of artworks pre- and post-application to help conservators make decisions. Microfadeometry, which involves measuring the colour change on a tiny spot while a sample is continuously irradiated with high-intensity light, is one way to achieve this. The technique is fast, making it a promising tool with which to test the effectiveness of coatings on polymeric surfaces, and the spot is so small that it cannot be noticed after the test is complete.

Breathalyser test

Characterizing materials at the microscopic scale in a non-destructive manner is a mantra in heritage science. Ultimately, we would hope to develop nanotechnology-based sensors that can detect VOCs emitted by polymers *in situ* during degradation. These "heritage breathalysers" would provide an alert when harmful VOCs such as the nitrogen dioxide produced by cellulose nitrate are emitted and action is needed, such as changing the display or storage conditions to slow down the process before it damages nearby objects.

These are just a few examples of the rapid technological progress occurring in modern heritage science, which often feels like a game of cat and mouse when trying to keep up with artists constantly at the forefront of experimentation. Some artists are even creating nano-art directly. Jonty Hurwitz, for example, uses two-photon lithography to print sculptures on the nanoscale. These sculptures perfectly illustrate what conservators might have to deal with in the future as art and science enjoy increasingly close connections.

Carolien Coon *is at the Institute for Sustainable Heritage, University College London, e-mail carolien.coon.12@ucl.ac.uk*