Rothko Restoration: Advancing the Science of

Art conservation scientists and art conservators often possess similar skill sets that include an extensive understanding of analytical methods and physical characterization techniques, knowledge of the chemistry of numerous types of art media, extreme patience, and a real passion for art. However, how they attain these skills and their backgrounds can vary. In the United States, the title "conservation scientist" is not defined by a formal university or licensing regimen; most scientists hold degrees in chemistry or related fields. On the other hand, the terminal degree for art conservators is a Master of Science in art conservation. A recent collaboration brought these two disciplines together for the benefit of art lovers everywhere.

A once-declared art major turned coatings scientist, Dr. Melinda Keefe, with support from her employer Dow, has been fortunate to combine those two interests via an ongoing collaboration between Dow Coating Materials (DCM), the Tate Modern art museum in London, and the Getty Conservation Institute. The collaboration is focused on improving wet cleaning systems for the conservation of modern acrylic paintings and other unvarnished works of art. This collaboration provides opportunities for Keefe to present new solutions to conservators for evaluation. More recently, she and colleagues Felipe Donate, of Dow's Oxygenated Solvents business, and Chris Tucker, of Dow's core R&D business, were able to provide support to the art conservation team at Tate Modern when they faced the challenge of restoring the Mark Rothko painting *Black on Maroon* (1958), which was damaged by graffiti in 2012.

Photo showing graffiti-damaged Rothko painting.

DEVELOPING SOLVENT SOLUTIONS

"DCM, as part of Dow, is well-positioned to provide support to the art conservation community because the company has, in addition to extensive knowledge regarding acrylic coatings technology, significant expertise with solvent and cleaner chemistries through its industrial solvents and cleaners businesses. We are leveraging that combined knowledge and applying it to specific challenges in the art conservation field," says Keefe.

For example, using Dow's high throughput technology, she has developed a robotic system for more rapid analysis of the cleaning solutions she develops. After careful consideration of the physical properties of the cotton swabs typically used by conservators, Keefe used a rigid foam and cotton batting to mimic the swabs, and attached this device to a robot that then cleaned artificially soiled dried acrylic paint films. A high-resolution imaging system provided detailed data that she used to determine the "percent clean" value for each sample, which in turn enabled comparison of multiple samples. Importantly, the results using the robot have been compared to the results obtained at Tate for more traditional manual cleaning of artificially soiled acrylic paint films with good agreement, according to Keefe. "With this system, we are able to explore many different possible aqueous and aliphatic hydrocarbon-based systems, including a broad range of surfactants, solvents, microemulsions, etc., that might have potential for use in the restoration of acrylic paintings," she observes.

Promising cleaning solutions are sent to Tate's senior conservation scientist, Dr. Bronwyn Ormsby, for systematic evaluation. Those that the Tate staff find interesting are then shared with attendees at workshops


The painting is returned to its display space at Tate Modern following the successful collaborative conservation effort.

Tate Modern art museum

for art conservators hosted by the Getty Conservation Institute, where the conservators use them in hands-on sessions. The feedback from these workshops is then used to improve the systems at Dow.

"This development cycle is ongoing and leads to continuous advances in cleaning technology for use in art conservation," Keefe asserts. "Specifically, our goal is to develop a range of effective cleaning solutions, because every conservation project has unique challenges and no one cleaning system will be applicable for all of them. Conservators need a 'toolbox' of different cleaning solutions that have a range of performance characteristics," she adds. This work, along with other emerging scientific research, is adding to that toolbox.

An advantage of working for Dow is that Keefe has access to the company's proprietary solvent database and software program (CHEMCOMP℠ Solvent Property Modeling Service) designed to determine solvent candidates for a given material. The database contains many hundreds of solvents, along with their physical properties information, and uses the Hansen Solubility Parameter (HSP) of the material to be dissolved as the key input. In fact, Keefe used this database and software program to help generate a potential list of solvents for cleaning the damaged Rothko painting.

THE CHALLENGE OF *BLACK ON MAROON* (1958)

Mark Rothko's painting *Untitled, Black on Maroon* (1958, Tate T01170) was extensively damaged by black ink in October 2012, with a total of 45 marks/letters applied to the painting surface over a large area of the lower right corner. The challenges for the conservation treatment were both complex and numerous, according to Ormsby.

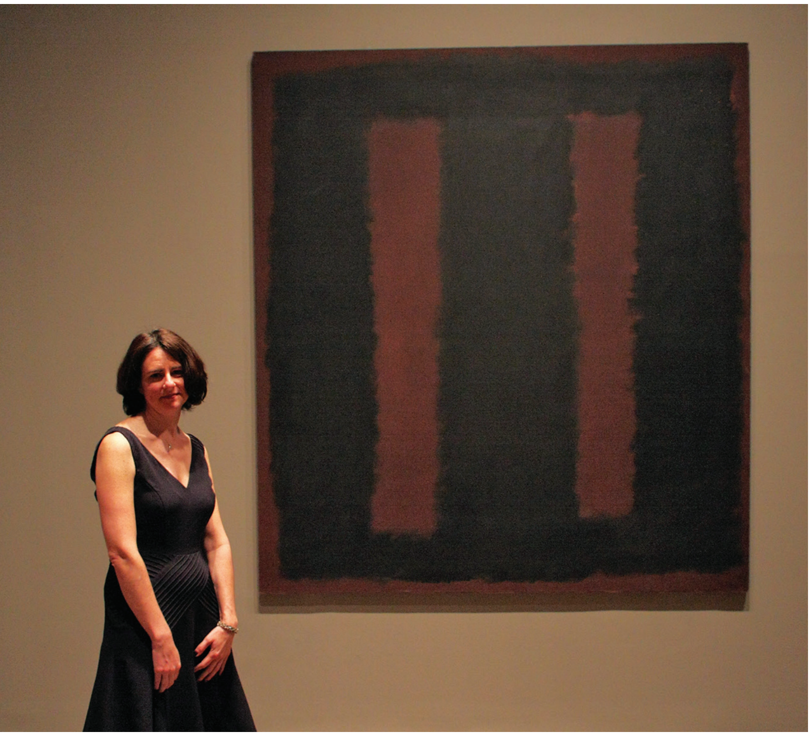
The ink was a fast-drying, highly colored, "permanent," highly penetrating, solvent-based proprietary graffiti product that is designed to stain. In addition, Ormsby notes that Rothko's paintings are difficult to conserve due to his choice of painting materials and technique. In this case, that involved sophisticated tonal variation and subtle surface effects created by multiple thin applications of paints and coatings of different media (both natural and synthetic polymers) and pigment mixtures, some of which are light-fugitive and several of which are soluble in the same range of solvents as the graffiti ink. Furthermore, the effects of natural aging, particularly of the localized dammar resin and egg glazes thinly applied over black paint, contributed to the complexity of the treatment. These glazes did block penetration of the ink into the black paint; however, with no glaze over the porous maroon paint with its network of fine micro-cracks, the flow of the graffiti ink through the painting structure was facilitated.

"The overall complexity of the chemistry, physical properties, and appearance of the painting; the differences in graffiti ink thickness and penetration; and the fact that this unique problem had never been encountered before necessitated a most thorough, ethically sound, collaborative, and responsible approach," Ormsby observes.

To manage the restoration project, a Treatment Team and Rothko Project Advisory Group were established and operated in tandem to ensure that the approach, research, support, ethical considerations, and conservation treatment were explored and carried out to the highest possible standards. The stages of the project included initial research and testing, ink removal, and surface reintegration.

The R&D stage involved testing of artificially aged painted samples prepared using information about the materials and structure Rothko used in *Black on Maroon*. Samples of the ink were also analyzed at Tate and by external collaborators and contracted scientists. For example, the ink solvent content was determined by gas chromatography with a flame ionization detector, and the polymeric and colorant constituents were characterized and properties explored via an extensive suite of techniques and found to be based on a modified polyaromatic hydrocarbon resin of low molecular weight. "The main aim was to explore the solubility of the ink so that an appropriate, low-risk solvent system could be designed to remove the ink from the painting," Ormsby says.

Additional analyses and examinations focused on the painting surface and interactions between the paint and the graffiti ink. The Dow scientists determined the HSP of the ink and generated a list of potential solvents using the company's proprietary database and software, considering the ink properties and the properties of an aged alkyd as a surrogate for the actual painting. Keefe and Donate first eliminated solvents with undesirable health, safety, and environmental profiles, and then investigated the remaining leading candidates by applying the solvents to an acrylic-primed canvas. They ultimately provided the Tate staff a list of 16 solvents, solvent blends, and microemulsions, including ethyl lactate, several glycol ethers and glycols, n- and iso-butyl alcohol, and dimethyl sulfoxide. "The information provided by Dow saved valuable



Dr. Melinda Keefe alongside the restored *Black on Maroon.*

time at this early stage of the project and was very useful in guiding the ink removal process," notes Ormsby.

The list of 16 solvents was ultimately expanded to approximately 80 options/permutations, and solvent gelling options, suction techniques, solvent application methods, and the use of various tissues for the removal of the softened ink were also evaluated over a four-month period. "Solvents were assessed for their speed of ink removal, evaporation rate (which affects working time), toxicity, clearance, blanching effect, tendency to bleed or spread beyond boundaries, and the most vital aspect—their effect on the underlying paint layers," Ormsby explains.

The solvents were systematically tested on ink applied to a white acrylic primed canvas (where it was easy to see the effects), the aged representative sample, and an archival primed canvas kindly provided by the Rothko family, who were very supportive of the project throughout, according to Ormsby. Finally, a group of six solvents was chosen to evaluate on the painting, and ultimately a blend of benzyl alcohol and ethyl lactate was selected that offered a slow swelling action facilitating a controllable ink removal process with minimal impact on the underlying paint films. "Fortunately, the aromatic hydrocarbon-based ink was different enough from the painting to be slowly dissolved while minimizing the risk to the underlying painting materials which (at least) include egg, dammar, oil, alkyd resin, animal glue, and a range of pigments," Ormsby adds.

Extensive analysis of *Black on Maroon* itself was also necessary. Analysis of the interactions between the painting and the applied graffiti ink was achieved through examination of the painting under light microscopes, in ultraviolet light, and with high-resolution digital microscopes. Samples of paint in the ink-affected area were also taken (with permission), mounted, and investigated as cross-sections using light microscopy, UV microscopy, scanning electron microscopy, Fourier transform infrared imaging, and other mass spectrometry techniques. Canvas samples were also extensively analyzed.

"This extensive analytical effort was necessarily collaborative, as it is rare that any one museum laboratory can offer all of these techniques," Ormsby comments. The analytical team consisted of scientists from Tate; the National Gallery of Art, Washington D.C.; Jaap Boon Enterprises, Amsterdam; HIROX, France; The Yale Center for British Art, New Haven; and the University of Delaware, Delaware.

The ink removal phase lasted approximately seven months. The process involved application of the solvent blend (with occasional amendments) using a small brush, swelling of the ink for a few seconds, and then careful blotting of the softened ink with a highly absorbent tissue. "Each letter was removed slowly and meticulously, working on an area of approximately 4 mm^2 at any one time and evaluating the results in-situ with various forms of microscopy," Ormsby says.

The final stage of the process involved the reintegration of the surface, or the retouching phase. Here, reversible materials were used to recreate the lost glazes and to disguise remnants of the ink left in the paint. These materials included water-based watercolors and water-resoluble acrylic media with the addition of stable pigments and minerals, such as mica, to amend gloss and mimic the velvet-like surface of the painting. The aim of the treatment, according to Ormsby, was to eliminate all visual evidence of the damage in gallery conditions and to return the work back into the display space at Tate Modern. This was achieved on May 13, 2014.

THE IMPORTANCE OF COLLABORATION

Apart from enabling the return of the painting to Tate Modern, one of the highlights of this project for Ormsby was witnessing the collaborative effort of many people and institutions in support of this unique conservation treatment—including within Tate, within the project advisory committee, within the international art and heritage science communities, and beyond into the coatings industry. "Every small and large contribution proved vital to the success of the project, which has also allowed us the rare opportunity to educate the world about the vital behind-the-scenes work of dedicated museum professionals," she asserts.