Yale Institute for the Preservation of Cultural Heritage

Noninvasive Detection of Chemical Changes in Aging Art Objects

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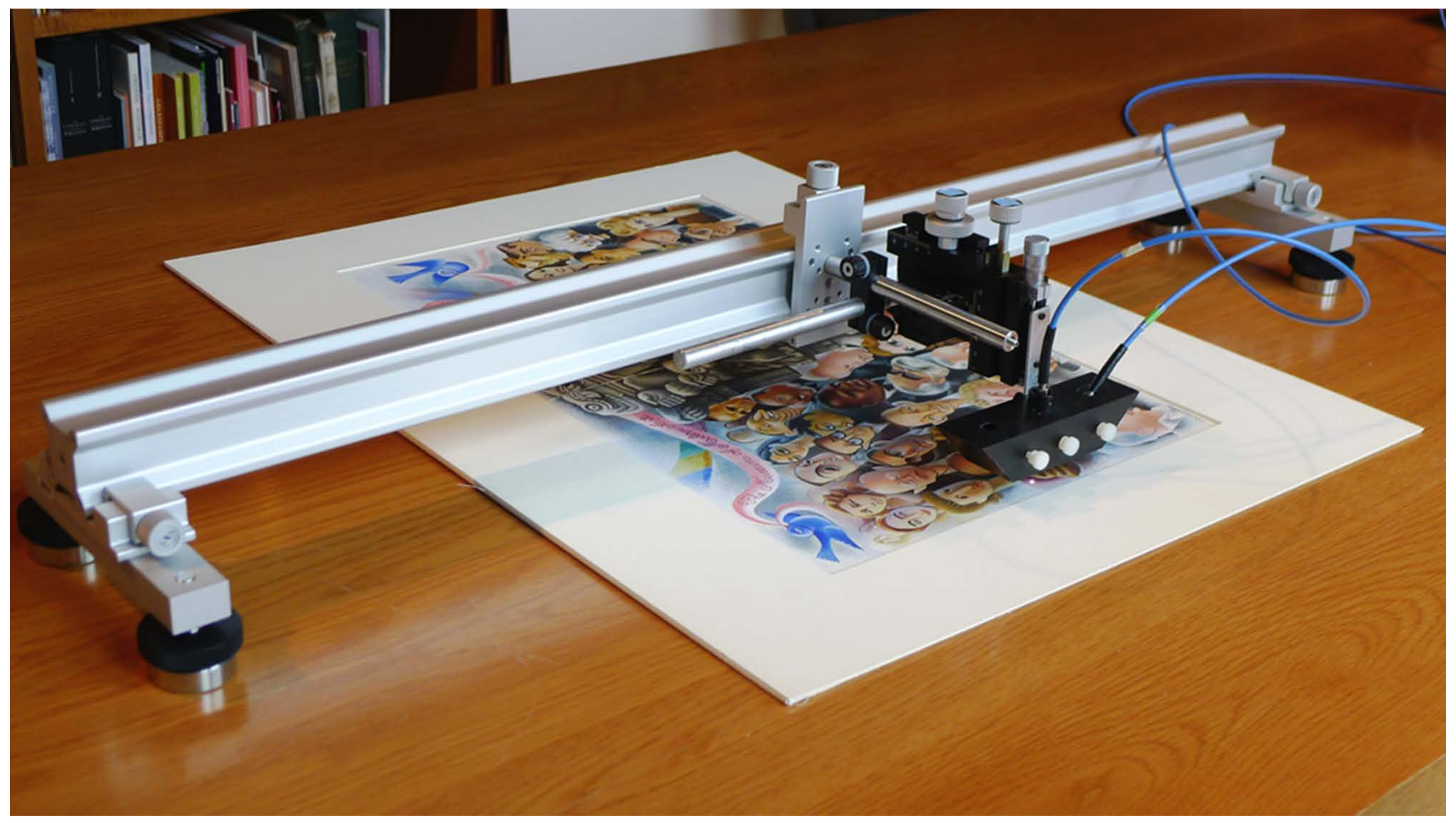
Microfading Tester Evaluates Colorant Fading Behavior

Instrument Design

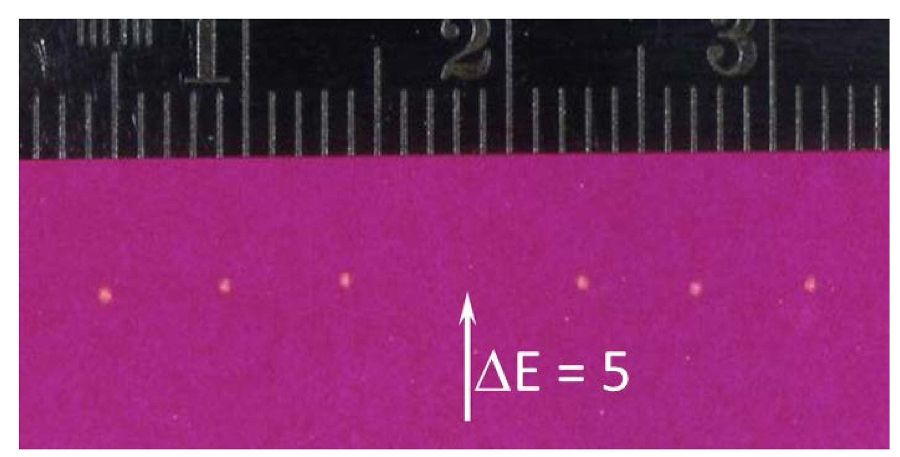
The microfading tester is a custom-built instrument using three basic components to measure color under high-intensity illumination: a light source (currently we are using an Apex portable xenon arc lamp from Newport Corp., with filters to eliminate UV and IR radiation); optics to deliver and focus the light onto and to collect reflected light from a very small area on an object surface; and a photodiode array spectrophotometer.



The microfading tester probe head and rig. (courtesy of Paul Whitmore)

Capabilities

The instrument delivers a light dose equivalent to a few years of gallery exposure during the test, which takes minutes to perform. Materials whose colors are sensitive to light will react during the test. Because the microfading test is essentially nondestructive (leaving no trace of altered color where the test is performed), presentation surfaces of objects can be quickly screened for their lightfastness in future exhibition conditions.

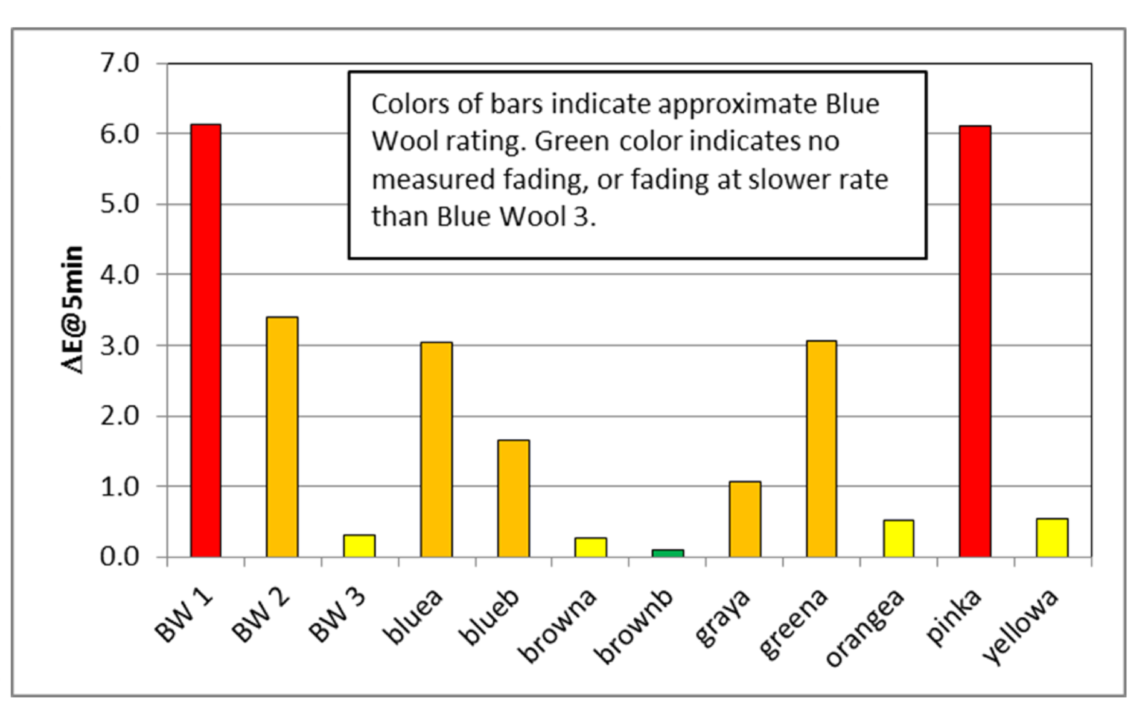


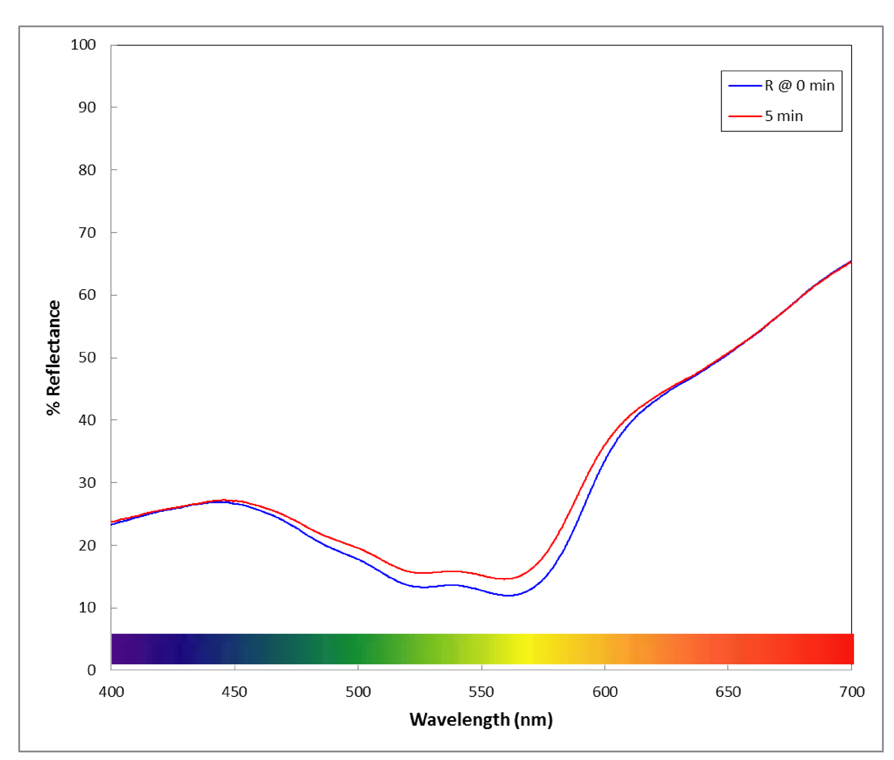
Spots deliberately faded into a colored surface to show test area size of the microfading tester. The spot faded to ΔE =5, the maximum change in color allowed during a test, is not visible even when magnified. (image credit: Paul Whitmore)

Practical Use

These tests can identify at-risk colors on objects, paintings, prints – essentially any colored material – and the information can inform how an object might be displayed responsibly: lighting conditions, rotation schedules, or perhaps deciding not to exhibit or loan an object at all. It can also target sensitive colors that should be monitored to track changes from exhibition use. In addition to identifying colors that are vulnerable to light exposure, the tests can also indicate that an object, which might have been suspected of having sensitive colors, is in fact reasonably robust and not in need of extraordinary protection measures.

Sample results for a microfading test. Color changes (ΔE) induced by light exposure of areas on object are compared to response of ISO standards for lightfastness (Blue Wools, or BW, #1, 2 and 3). BW 1 is the most light sensitive and BW 3 is the slowest to fade of the three standards. Results like these show the likely impact of exhibition.





Sample microfading data showing the initial reflectance spectrum of the colorant spot and its reflectance spectrum after a 5 minute test.

Selected Publications

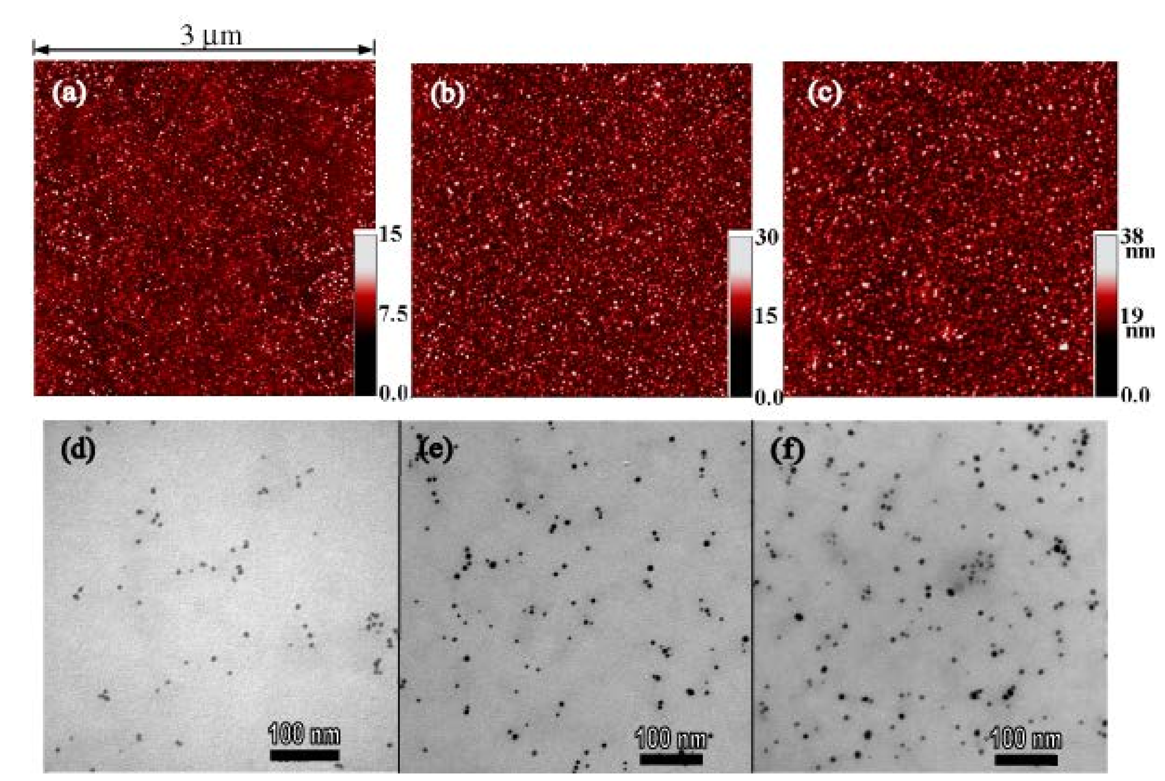
- Whitmore, P.M., C. Bailie, and S. Connors. 2000. Micro-fading to predict the result of exhibition: progress and prospects. in *Tradition and Innovation: Advances in Conservation*, ed. A. Roy and P. Smith. London: IIC: 200-205.
- Whitmore, P.M. 2002. Pursuing the fugitive: direct measurement of light sensitivity with micro-fading tests, in: H.K. Stratis, B. Salvesen (Eds.), *The Broad Spectrum: Studies in the Materials, Techniques and Conservation of Color on Paper*. Chicago, 5–9 October 1999, Archetype, London, 2002: 241–244.
- Whitmore, P.M. and C. Tao. 2011. Development of a micro-fading tester with near-UV Capability. Final report to the National Center For Preservation Technology And Training.

Silver Nanoparticle Films as Gas Sensors

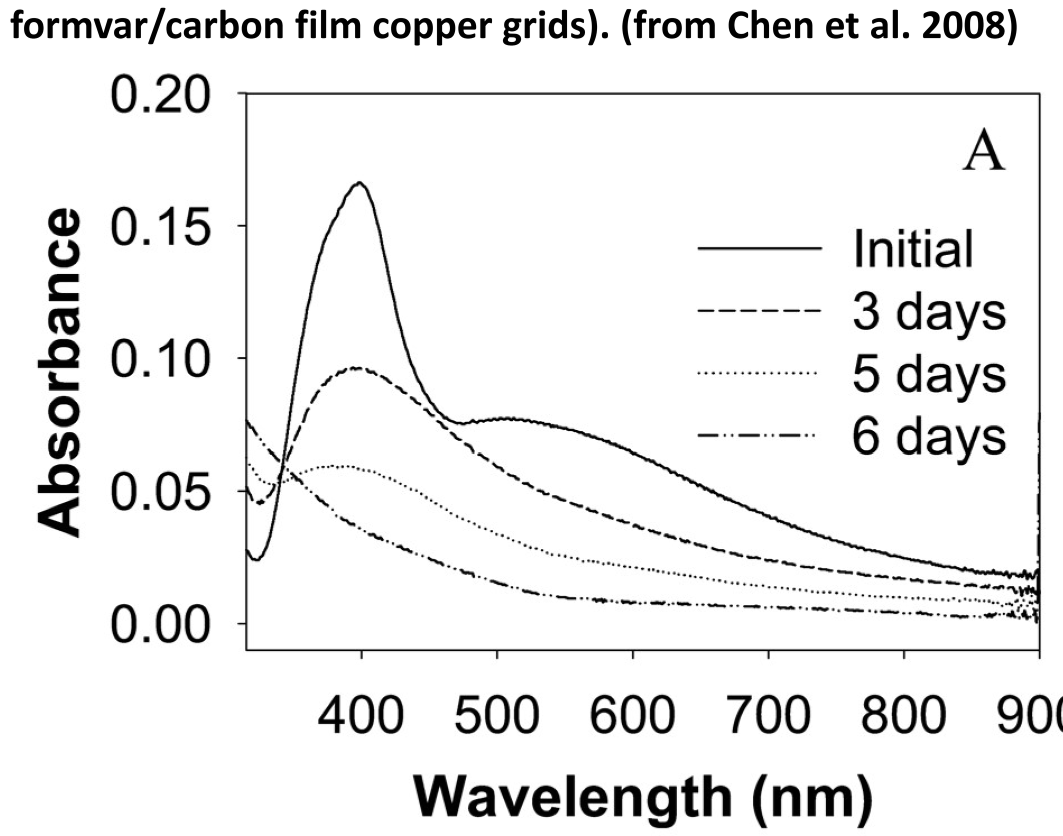
Elena Torok (Yale University Art Gallery) and Rui Chen in the Wurtele Collections Study Center, where silver nanoparticle sensors were deployed in 2016 to identify and resolve an air quality issue in the cases, some of which hold silver objects. (photo credit: Jon Atherton)

Detecting Unsafe Storage Environments

The Yale University Art Gallery's Wurtele Collection Study Center is a uniquely accessible storage space that provides unparalleled access to the Gallery's collections for hands-on scholarship. The new ventilation system was designed to provide pure, low humidity air for the silver objects stored in the cases. A worrying odor started to emanate from the cases, and silver nanoparticle film sensors uncovered a serious air quality problem, traced to a malfunctioning water purifier in the humidification system. In this instance, the silver nanoparticles sensed the risk before the YUAG silver collection was moved into the cases, where the objects would have signaled the air quality problem by becoming tarnished.



AFM images at top (size: 3 µm × 3 µm) of (a) the polyethylenimine (PEI)-treated glass coverslip, (b) Ag nanoparticle assembled film on the glass, and (c) Ag_2S nanoparticle assembled film obtained from the gas–solid reaction. The Z range units are on the nanometer (nm) scale. TEM images at bottom of (d) PEI nanosize domains, (e) Ag NP assembly, and (f) Ag_2S nanoparticle assembly obtained from the gas–solid reaction (all deposited on formvar/carbon film copper grids). (from Chen et al. 2008)



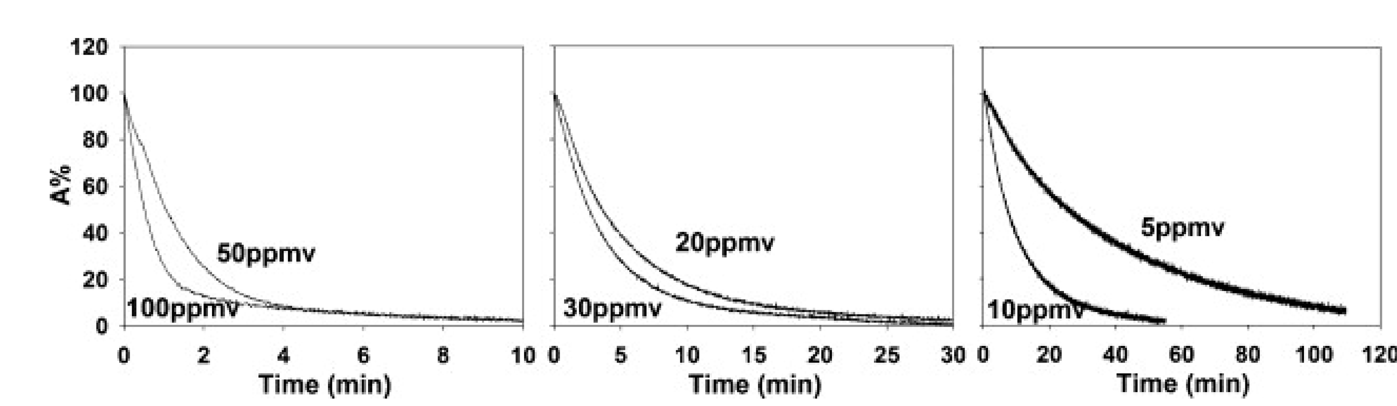
UV-vis spectra of Ag nanoparticle film during the exposure to sulfide gas in the Oddy test of a wool fabric sample. (from Chen and Whitmore 2014)

Nanoparticles for Traditional Material Compatibility Testing

The Oddy test was created at the British Museum in 1973 as a standardized way of determining whether a material intended to be in contact or in a closed environment with art objects was compatible with the art material. The Oddy test uses copper, lead, and silver coupons as proxies for art materials, and involves enclosing the proposed material with these coupons in a hot and humid environment for 28 days.

The enhanced reactivity of nanoparticles is a welcome alternative that promises to speed the tests and allow quantitation of the results.

Example Oddy test setup. (Image credit: CAMEO)



The decreasing absorption intensity of the Ag NP films with reaction time at different gas concentrations. *A%* is the percentage of remaining absorbance of the Ag NP films (related to the amount of unreacted Ag on the surfaces of the nanoparticles). (from Chen et al. 2013)

Selected Publications

- R. Chen et al., "Silver sulfide nanoparticle assembly obtained by reacting an assembled silver nanoparticle template with hydrogen sulfide gas." *Nanotechnology* **2008**, *19*, 455604.
- R. Chen, H. R. Morris, and P. M. Whitmore. "Fast detection of hydrogen sulfide gas in the ppmv range with silver nanoparticle films at ambient conditions." *Sensors and Actuators B: Chemical* **2013**, *186*, 431-438.
- R. Chen and P. M. Whitmore. Silver Nanoparticle Films as Hydrogen Sulfide Gas Sensors with Applications in Art Conservation in *The Science and Function of Nanomaterials: From Synthesis to Applications*, Harper-Leatherman and Solbrig; American Chemical Society: Washington, DC, 2014; chapter 6.