Finding the Point of No Return

The Irreversible Effect of Ultraviolet Radiation Exposure

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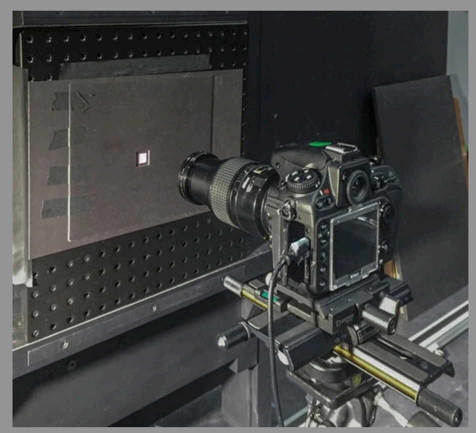
Synopsis: This poster presents the first stage of a project to survey a selection of different materials and their fluorescent responses after irradiated with UVA, the possible fluorescence reversion of these materials over time, and our attempt to find the chemical change that contributes to reduction in fluorescence.

Test 1: Finding the Changing Points

Exposure and Capture Setup:

1. Each Sample was held flat in a magnetic folder, with an opening of 1 ¼ x 1 ¼ inches square (see in Figure 1).
2. The same spot on each sample was exposed to 400 µW/cm² longwave ultraviolet radiation(UVA) produced by 2 Wildfire Long-Throw 250 watts UVA lamps.
3. Camera package: A Nikon D800E camera + a 105mm macro lens + Kodak Wratten 2E and Peca 918 filter set.
4. The camera was positioned for 1:1 magnification capture for every sample.
5. The capture was programmed with a time lapse mode to shoot at 15 seconds intervals for 40 captures as the sample continued to be irradiated with UVA.



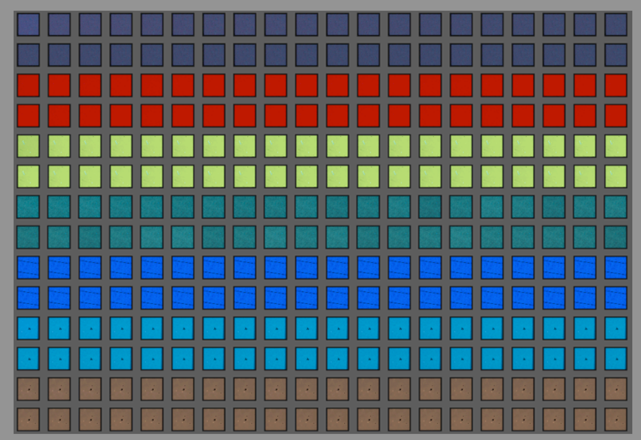


Figure 1 (left): the camera was setup for 1:1 capture.
Figure 2 (right): A screen shot of the view on Adobe Bridge showing all the UV/vis fluorescence photographs taken (see Table 1 for the samples tested). The screen shot shows the sequence of the captures starting from left to right and continuing to the next row.

Result and Evaluation:

Slight reduction in fluorescence intensity can be observed visually on samples 1, 4, and 6 by comparing the 2nd image to the last image.

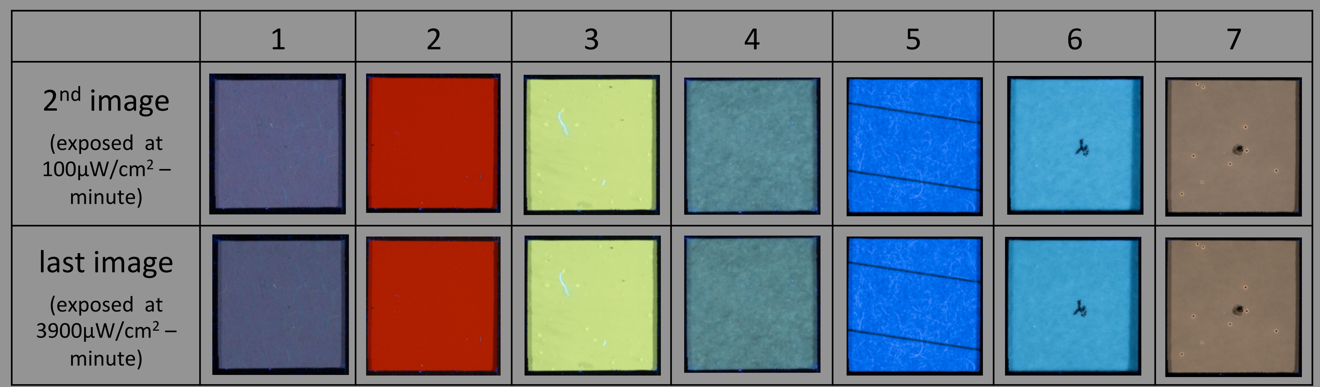


Figure 3: Selected UV/visible fluorescence photographs of seven samples.

Brightness difference was calculated from the RGB Blue values of the images, seen in the following table. The value is based on 8-bit, 0 to 255 scale.

	Samples	Brightness difference
1	Light blue wrapping paper	-6.97
2	Rose madder watercolor	0.29
3	Zinc white	0.49
4	Whatman filter paper	-6.93
5	Notepad paper	0.80
6	Whatman watercolor paper, 1954	-5.41
7	Shellac light	-1.40

Table 1: Brightness difference = average brightness of the second, third, and fourth images subtracted by the average brightness of the last 3 images in the series. Brightness = (R+G+B)/3

The difference in brightness between the exposed and the non-exposed areas on both sample 1 and 4 was no longer apparent after 2 weeks in the dark. This suggests that the fluorescence may have reverted in the dark.

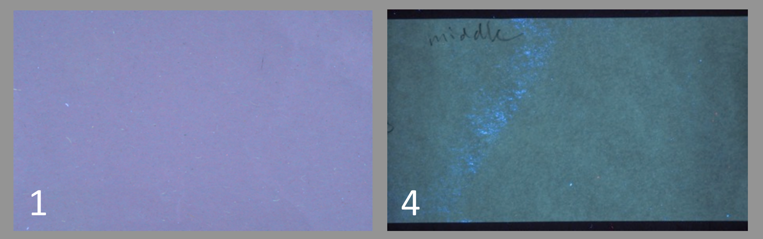


Figure 4: UV/vis fluorescence photographs of Sample 1 and 4, with a field of view of 5.4 x 8.1 cm. The exposed area should appear as a darkened square within the sample. It is not observed on these 2 samples.

Sample 6 still retains a very slight difference in the fluorescence between the exposed and the non-exposed areas. The exposed areas areas are highlighted with a square in Figure 5.

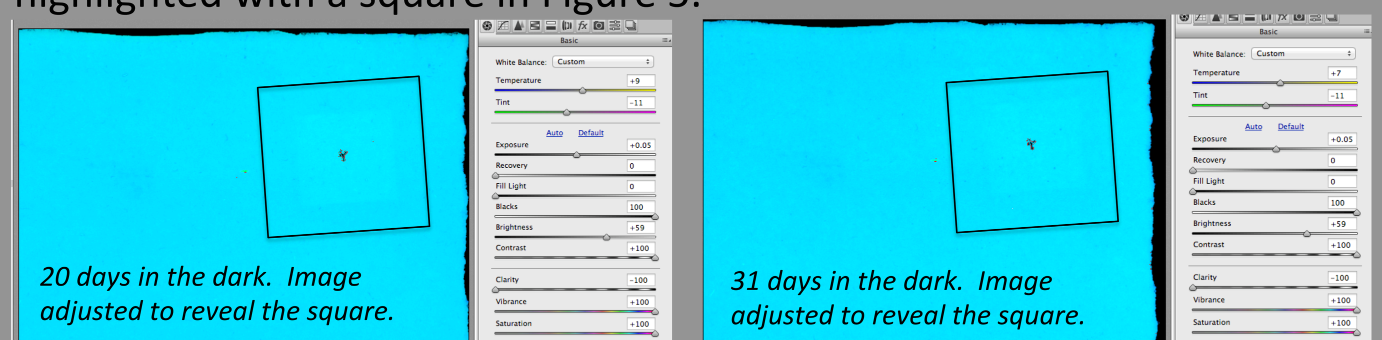


Figure 5: Extreme adjustment in Adobe Camera Raw of the UV/vis fluorescence photographs of Sample 6 to bring out the difference between the exposed and the non-exposed areas. The difference appears to lessen over time by comparing the 20 day and 31 days dark storage.

Test 2: Monitoring Reversion

Exposure and Capture Setup:

1. Each sample was held flat in a magnetic folder, with eight 1 ¼ x 1 ¼ inches square openings (see Figure 4 below).
2. Every square on the sample was uncovered one after another with a one minute interval.
3. The sample was exposed to about 260 µW/cm² UVA radiation produced by 2 Wildfire Long-Throw UVA lamps.
4. The total exposure for each square is indicated in the following table.

2080 µW/cm²-minutes (8 min exposure)	1560 µW/cm²-minutes (6 min exposure)	1040 µW/cm²-minutes (4 min exposure)	520 µW/cm²-minutes (2 min exposure)
2340 µW/cm²-minutes (9 min exposure)	1820 µW/cm²-minutes (7 min exposure)	1300 µW/cm²-minutes (5 min exposure)	780 µW/cm²-minutes (3 min exposure)

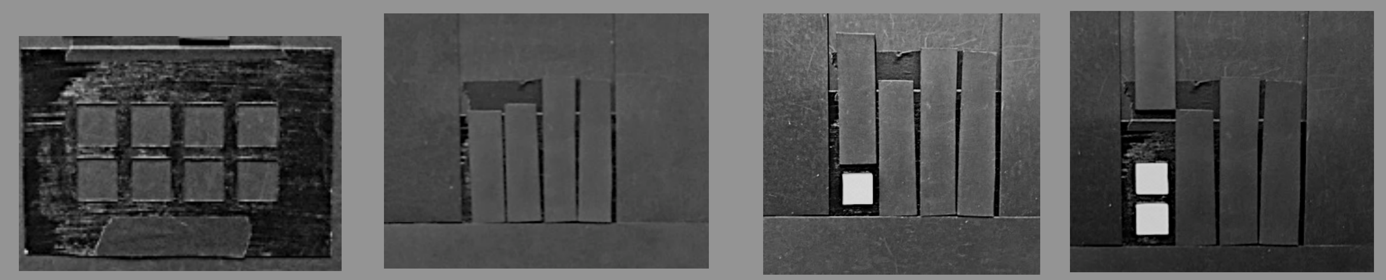


Figure 6: Left, magnetic sample holder with eight openings; 2nd from the Left, sample covered under the holder, secured by magnetic sheets on three sides, and 4 magnetic strips covered the openings; 2nd from the Right, an opening uncovered by removing the magnetic strip; Right, another opening uncovered after 1 minute.

5. 40 samples were tested. They were photographed with the following setup to ensure consistency as the samples will be photographed repeatedly over time.

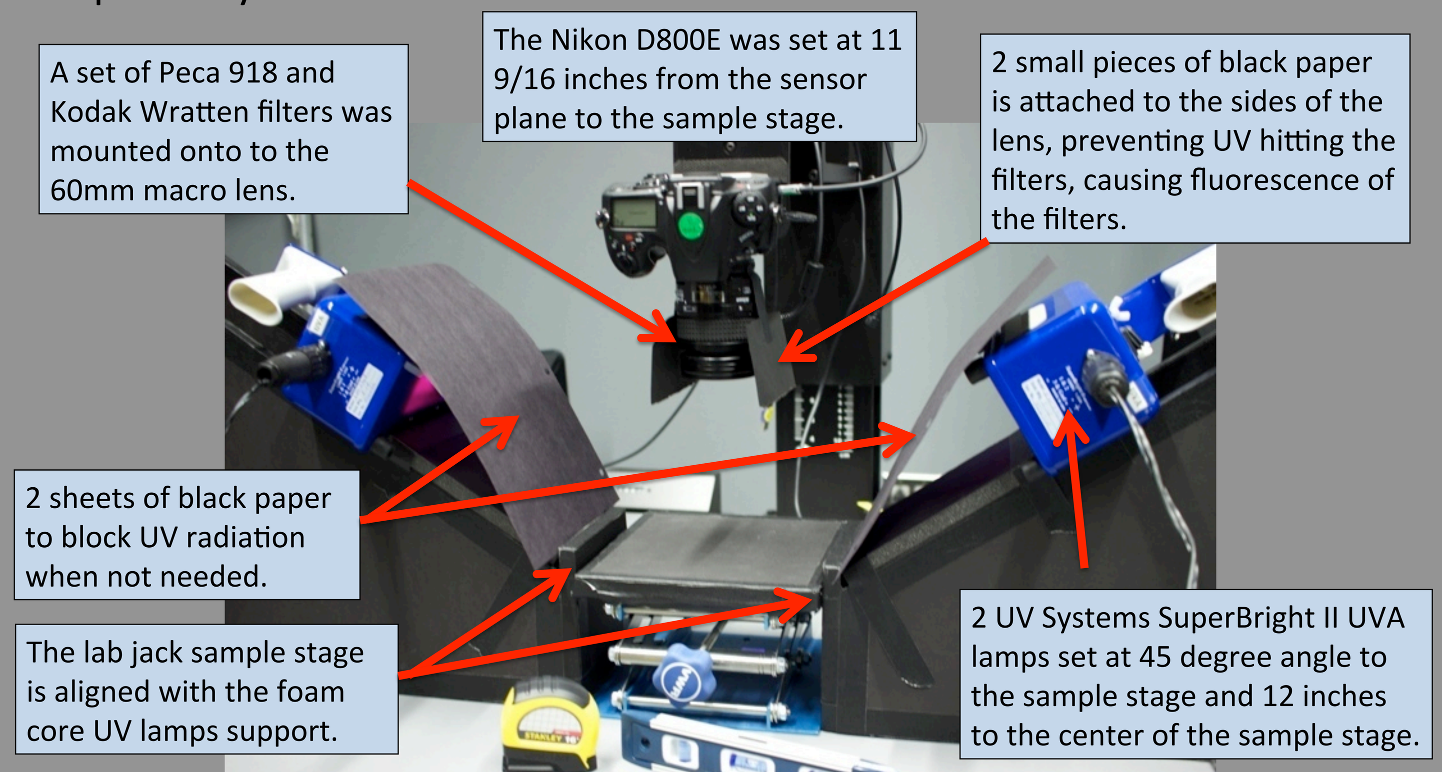


Figure 7: Consistent UV/visible fluorescence photography setup for Test 2 samples.

Result and Evaluation:

Some of the samples show obvious reduction in fluorescence intensity after exposure to UV as low as 520 µW/cm²-minute.

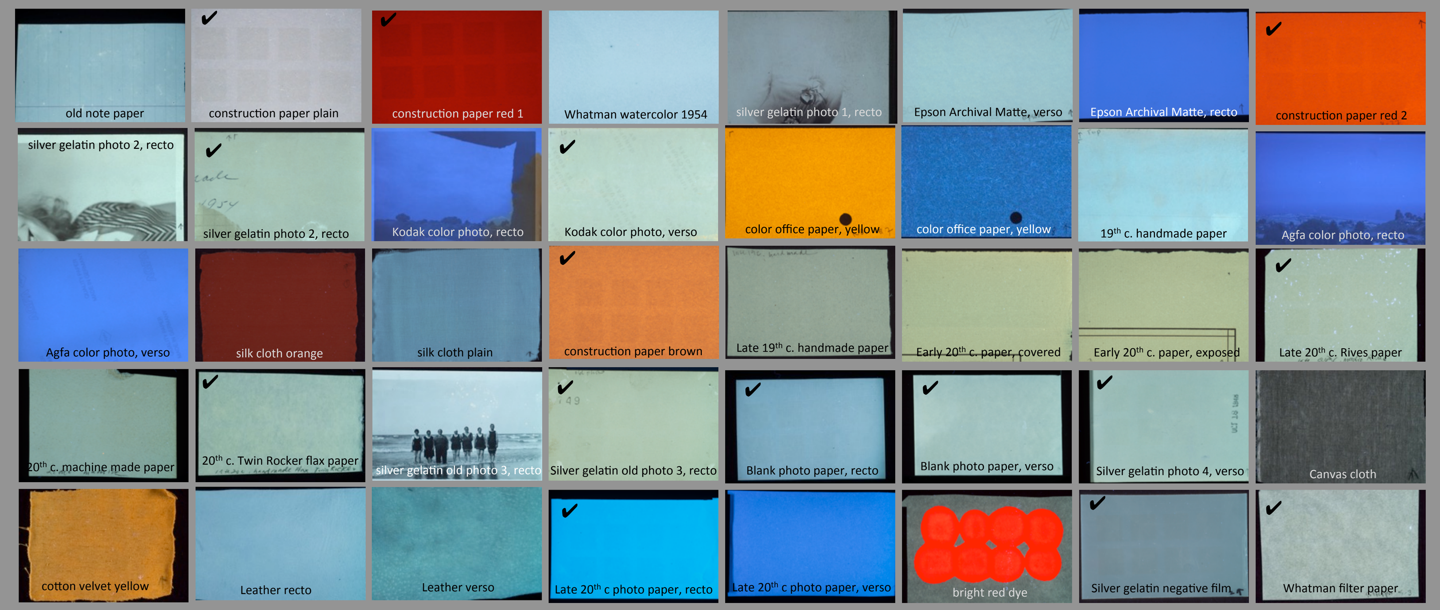


Figure 8: UV/visible fluorescence photographs of all 40 samples. Those show obvious reduction in fluorescence after UV exposure are marked with a "✔" mark.

After a few days in the dark, the reduction in fluorescent brightness appeared to revert in every sample. Some samples showed complete reversion as the exposed squares were no longer visible in the images.

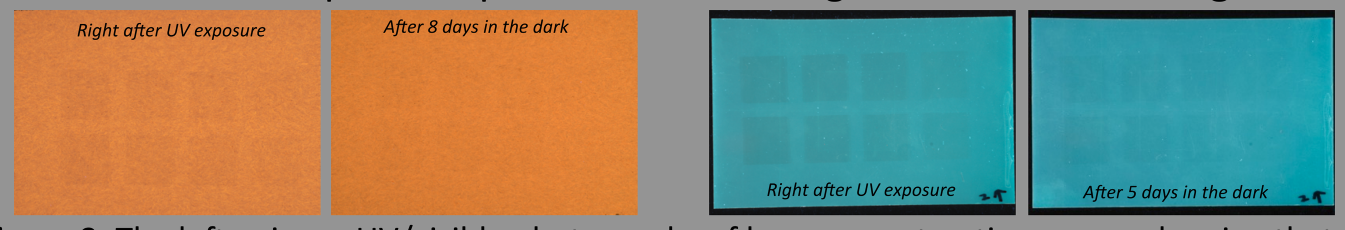


Figure 9: The left pair are UV/visible photographs of brown construction paper, showing that the exposed squares are no longer prominent. The right pair were heavily adjusted images for black and white negative film, showing the left 2 squares are no longer visible.

Test 3: Instrumental Measurement

Two sets of six samples were chosen for this test because they were clearly affected by UV exposure based on the observation in Test 2. One set was exposed to UVA for 1 hour at an average of 800 µW/cm² irradiation to induce clear change in fluorescence. The second set of the same samples was used as a control and kept in the dark.

FTIR-ATR Analysis:

The FTIR-ATR analysis on these 2 sets of samples did not reveal any difference between the exposed and the non-exposed areas. This does not exclude the possibility that a chemical change has occurred; the change may be below the detection limit of the instrument.

Visible Light Emission Measurement:

The samples' visible light fluorescence was recorded with an X-Rite i1 Spectrophotometer set at the "Emission-Light" measuring mode as the samples were irradiated with UVA in a completely darkened room.

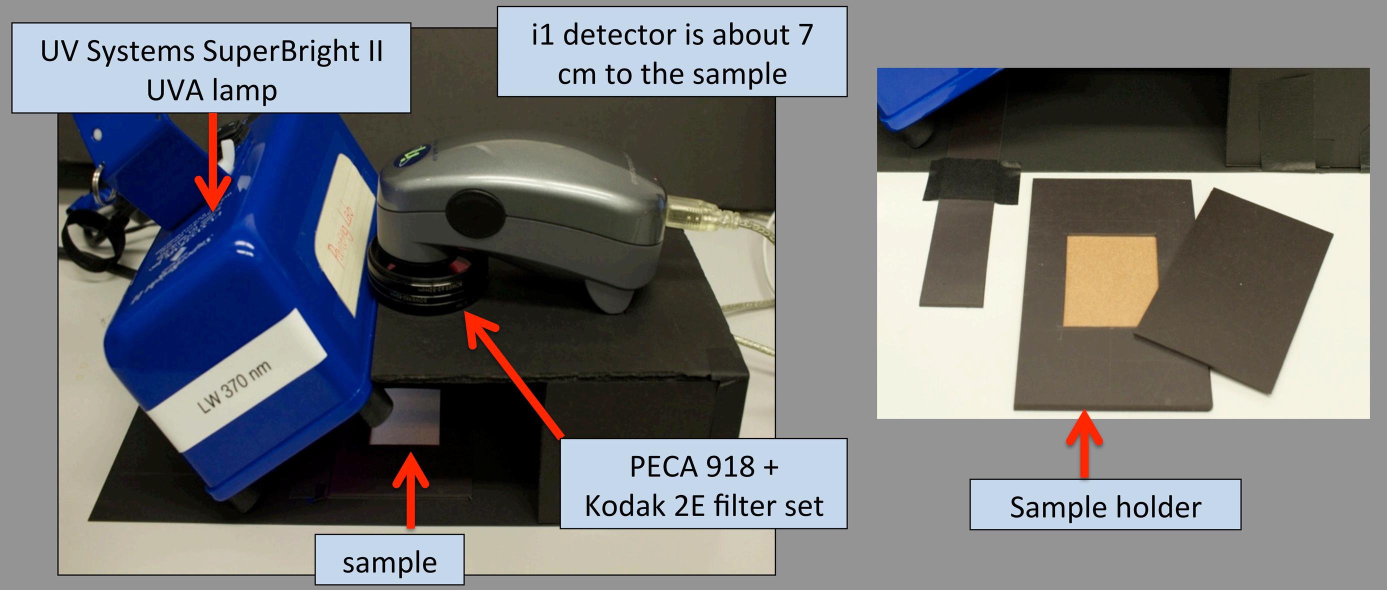


Figure 10: Left, i1 setup to measure the visible light emission from the sample in the dark; Right, sample holder with an opening of 4x5 cm; the opening is kept covered with a magnetic sheet except during measurement.

From the spectra collected, it appears that the exposed samples display reduced fluorescent intensity rather than a change in fluorescent colors.

Figure 11: The spectra for all the exposed and non-exposed samples was collected with an i1 with SpectraShop software. The solid lines represent the emission spectra of control samples while the dotted lines of the same colors are for exposed samples.

Conclusion and Recommendation:

The reduction in fluorescence is certainly materials dependent, though it is still unclear to the authors why some types of paper are more affected by UV than the others. The reversion in fluorescence intensity is observed for all samples tested to varying degrees. Complete reversion is observed on a few samples after 780 µW/cm²-min UV exposure. Thus, it is inconclusive what total UV exposure will induce irreversible change in different materials.

We are still hoping to find an underlying relationship between the fluorescence change and chemical change with different analytical methods.

Before more data is collected and more information comes to light, we strongly recommend avoiding unnecessary UV exposure to artifacts, in particular to light sensitive materials. Easy precautions can be taken, such as not aiming the UV lamps at the artifacts or covering the artifacts with available materials, such as a ¼-inch black foam core, except during the capturing process.

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