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Preliminary Investigations into Thermochromatic Changes in Asian Lacquer

Overview

There are numerous ways for lacquer to discolour. Conservators are most familiar with the fading of lacquer due to light. The lighter colour of faded lacquer on the surface of boxes for instance can easily be compared with the original surface where the lid has protected part of the lower box.

Most conservators, however, are not quite as familiar with the discolouration of lacquer by exposure to the combination of heat and moisture. The most prevalent example of this type of discolouration is seen on the interior of lacquer soup bowls. The original dark lustrous black of the lacquer has turned to a light brown on the interior.

This discoloured lacquer has been observed by many conservators but not examined in detail or even published. There are only two known references to the phenomenon. In 1995 Shôsai Kitamura gave a lecture at the Tokyo National Research Institute of Cultural Properties in which he mentioned three types of discolouration of lacquerware. The first was discolouration by light; the second he described as fading by heat, moisture and salt; and the third was discolouration by unknown causes – most likely exposure to other substances. The second type he described as typically found on the interior of soup bowls.

Another conservator, Vladimir Simonov, also wrote briefly about the thermochromatic change in his paper on the conservation of a Vietnamese lacquer sculpture in the ICOM-Committee for Conservation 1990 Preprints. He stated in this case that care had to be taken when using a hot wax resin mixture because the lacquer could change colour around 100 degrees Celsius.

Further examples of this phenomenon exist. On the Japanese sake pot (fig. 1) the exterior of the lid remains a dark lustrous brown but the interior of the lid has changed to a light beige colour due to the combination of heat and moisture.

The Japanese tea tray (fig. 2) is another example. It can be clearly seen how the hot tea cups have caused a dramatic change in the colour of the lacquer.

This type of colour change is not gradual such as happens with exposure to light. It happens rapidly once the right conditions are reached. This sudden and dramatic change of colour was observed at the Royal Ontario Museum (ROM) on at least one particular (and dramatic) experiment. In this instance the painting conservator was trying to 'help' the decorative arts conservator flatten some curled lacquer. The experiment involved using BEVA 371 in mineral spirits to flatten the curled lacquer on a vacuum hot table as if it were a painting. However, the adhesive which had been applied from the back did not penetrate the ground. The attempt to force BEVA 371 through the ground layer by softening the adhesive with a hot air gun resulted in an instantaneous change in the lacquer from black to brown. On the left (fig. 3), the original black colour can be seen and on the right is the lighter colour that resulted from the excess heat. Fortunately, the piece was not an artifact but a sample for experiments. These illustrations clearly show that the flattening experiments were not very successful either.

Although, for many years, there has been some curiosity about this phenomenon, it did not seem necessary to explore it further. It was a simple matter to avoid situations where lacquer was exposed to excess heat. Only after several inquiries about the use of heat for pest eradication it was realized, that the exact temperature of this thermochromatic change had not been clearly established. At that time, a series of experiments was undertaken, mainly to answer a recurring question: 'Can heat be used to eradicate insects in lacquer objects?'

Initial experiment

In the initial experiment a number of small chips of lacquer from sample boards or unaccessioned low quality artifacts were exposed to rising temperatures and observed under the microscope. A thermal heating sheet controlled by a rheostat provided heat.

Since previous literature mentioned a change around 100 degrees Celsius, these samples were exposed to temperatures ranging from 90 to 105 degrees Celsius. They shrunk, they turned darker, but they did not exhibit the expected colour change. It was apparent that as they were exposed to the heat, they dried out. Evidently, the moisture must be kept in contact with the lacquer for the thermochromatic change to occur. This makes the phenomena less likely to happen naturally, since both conditions must be present for the colour change. However, these two conditions may still possibly occur during the proposed pest eradication. Objects bagged in polyethylene, a common procedure for pest control, might trap moisture. These conditions could also occur during treatment using heat and adhesives.

In the first attempt each sample was sealed in a mylar envelope to maintain the humidity. Unfortunately, as the samples were heated, the increased air pressure caused the sealed mylar envelope to leak in every instance. Many of the samples dried out before reaching the critical temperature for visible colour transformation. Although some of them changed colour between 90 and 100 degrees Celsius, the results were not consistent. At this juncture it was determined that in order to confirm or deny the hypothesis two things were needed: better equipment to determine the exact temperature and a more efficient method of maintaining the moisture.

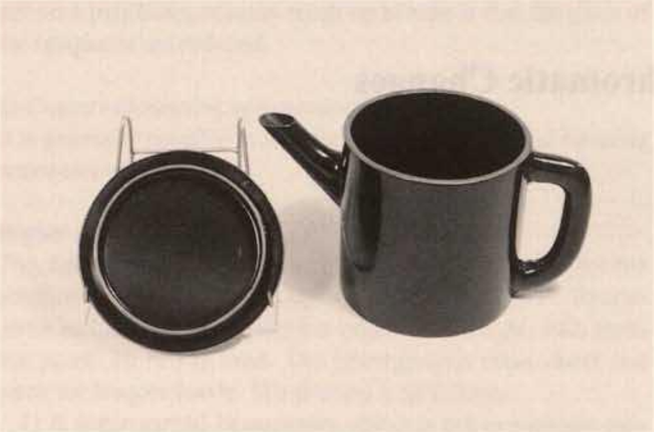


Fig. 1. The interior of the lid of this Japanese sake pot has turned from lustrous black to opaque beige in colour

Second set of experiments

The first problem regarding better equipment was solved by a trip to the Canadian Conservation Institute in Ottawa to use their Mettler hot stage. Their hot stage for the microscope not only offers one superior control over the temperature but allows one to set the rate of temperature increase. This makes it much easier to find the exact temperature that the colour change takes place. The microscope can also be hooked up to a video camera allowing the entire procedure to be filmed. It is very important to ensure that the light levels during filming are brilliant enough in order to produce a useful videotape.

The second problem of maintaining the moisture was solved by enclosing the sample in a glass ring covered with a watch glass. This enclosure was filled with wheat starch paste to supply a continuous source of moisture.

The purpose of this second set of experiments was the same as the first: to find the exact temperature at which the colour change takes place.

It was suspected that the colour change might also be related to light damage, therefore a number of samples was used from experiments on light degradation performed more than a decade ago. Each of these samples had been exposed to measured amounts of light. In addition to the controlled light samples, small samples from other lacquer artifacts were used to compare their reactions.

The samples from the original light degradation experiments included: a) black lacquer from a small plate made in the 1950s; b) red lacquer coloured with cinnabar from a nineteenth century bowl; and c) a film of Chinese raw lacquer made in 1986. All of the above were exposed to ultraviolet light in 1986. As well, the original unexposed controls were still available for comparative use. The samples had all been stored in sealed envelopes for the intervening decade. During this set of experiments the reaction of several other artifacts were being tested. All of these artifacts had been exposed to unknown amounts of light. These artifacts included an eighteenth century palanquin that had been exposed to uncontrolled light levels for many years of display. Also used were some small fragments that had lifted off a Han dynasty spear handle. Since this spear handle had never been displayed, it was unlikely to have been exposed to much light at all.

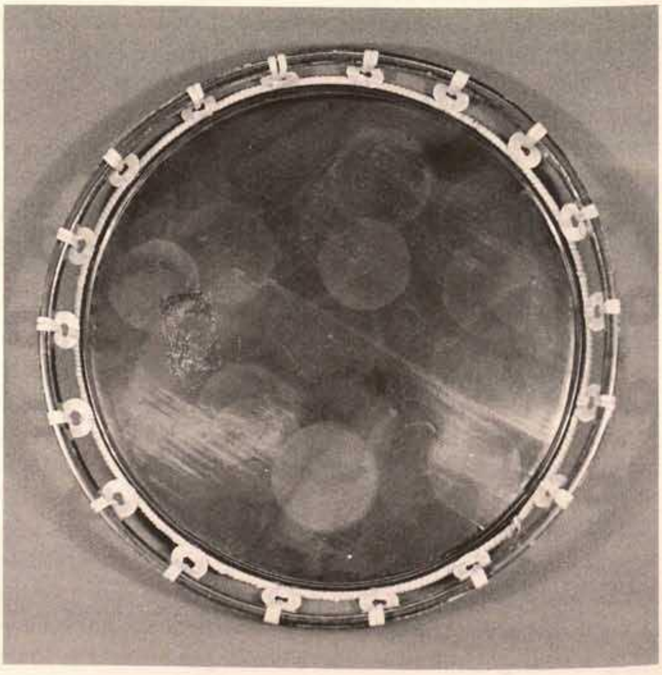
Observations

For the samples of the translucent lacquer film, the hot stage was set to run from 70 degrees to 90 degrees rising at three degrees per minute. The intention was first to do a run below the temperature at which the thermochromatic change would occur. The sample, which had been exposed to the ultraviolet light for four weeks, was enclosed in the paste capsule. For this first sample it was difficult to determine the exact temperature at which the change took place, but by 90 degrees the sample had turned to an opaque beige colour (fig. 4).

The next step was to run the control through the same process. In this instance, the lacquer turned darker but did not exhibit the same colour change. To ensure that the change was not by exposure to the moisture alone, a third sample of degraded lacquer was enclosed with wheat starch paste for two hours. In this third instance, there was no change to the appearance of the sample. From this initial samples it became clear that the colour change was also related to light degradation.

As with all good experimentation, answers to initial questions only create further questions. These are the questions which came to mind: Would the results be the same if black lacquer were used since the black pigment gives some measure of protection against light degradation? The sample from a black lacquer plate that had been exposed to ultraviolet light for four weeks was tried next. The hot stage was set to raise the temperature from 70 to 90 degrees at four degrees per minute. The results were the same. The degraded sample changed to a beige colour by the time it reached 90 degrees. The undegraded sample that had been stored in the dark remained unchanged in appearance when exposed to heat and moisture. Also the degraded sample did not change colour when exposed to the moisture alone.

Fig. 2. The discolouration caused by hot tea cups is readily apparent in the photograph of a Japanese tray



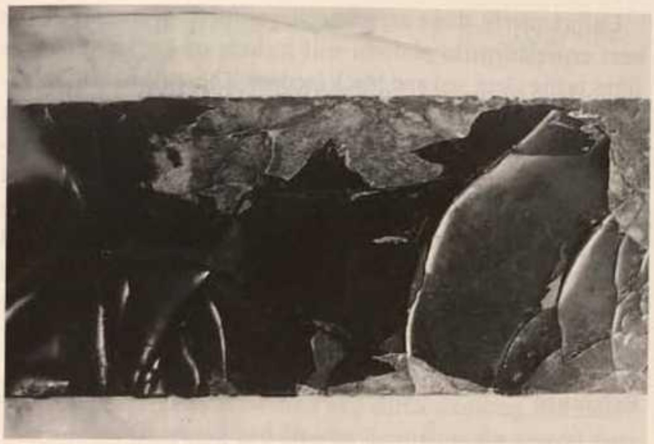


Fig. 3. An experiment in flattening lacquer on a vacuum hot table resulted in the instantaneous change in the colour from black to brown on the right hand side of this sample board. The use of a facing which held moisture against the surface played a part in the thermochromatic change

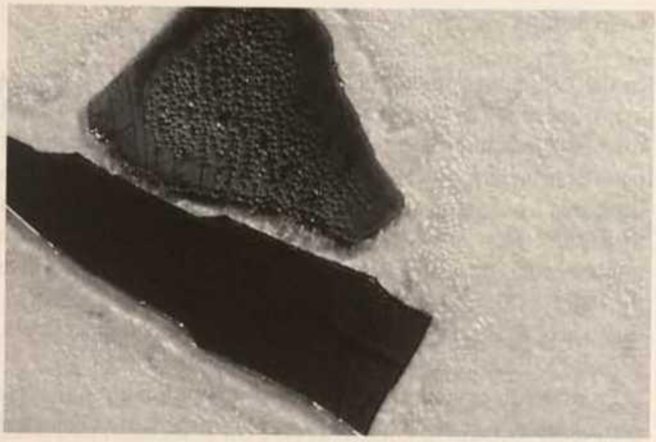


Fig. 4. The upper sample was exposed to moisture and heat of 70 degrees Celsius to effect this colour change. The change in colour can be seen when compared to the unexposed control in the lower part of the picture

The results for the 19th century red lacquer bowl were slightly different. The control, unexposed to light, remained unchanged when exposed to heat and moisture. The samples that were exposed to ultraviolet light were already dark in colour due to the effect of the light on the cinnabar pigment. The depth of the light degradation could easily be seen on the side of the sample. When this sample was exposed to the wheat starch and paste without heat there was some change in the degraded surface layers. Under the heat and moisture, again using a range of 70 to 90 degrees Celsius, rising at two degrees per minute, there was the same colour change noted as the black and clear sample. This colour change was not as dramatic as the others, however, the change was visible only on the degraded surface layer.

Thus far all of the samples used had been exposed to four weeks of ultraviolet light. What would be the effect of an unknown sample? The next sample was taken from an 18th century Japanese palanquin. The hot stage was set to run from 70 to 80 degrees Celsius at a two degree increase per minute. After a few minutes exposure to heat the colour began to change. By 76 degrees Celsius the sample was completely opaque as seen in figure 5. Since the colour began to change very soon after the beginning of the run, a second sample was run at a lower temperature. The hot stage was set for 60 to 70 degrees Celsius rising, again, at a rate of two degrees per minute. The colour change became evident soon after the exposure to the heat. By 69 degrees Celsius colour had completely changed.

Further samples were run setting the temperature parameters ten degrees lower, beginning at 50 and going to 60 degrees Celsius. Again, the colour changed after a few minutes. The hot stage was then set for 40 to 50 degrees Celsius. At the end of this run the sample remained unchanged. Using short runs from 50 to 55 degrees Celsius, then 50 to 52, the colour change was finally established at a temperature of 51 degrees Celsius.

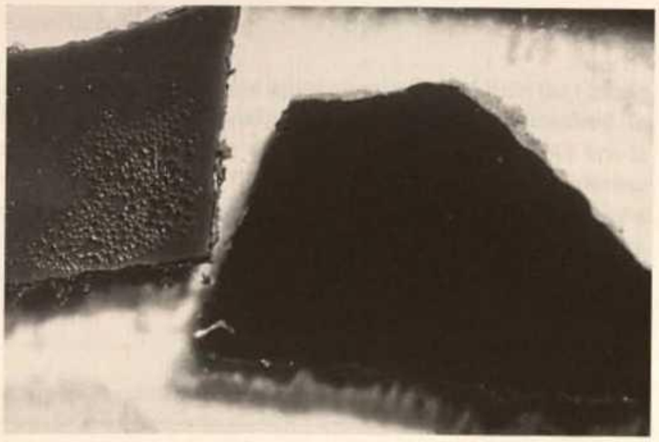


Fig. 5. The sample on the left was exposed to heat and moisture resulting in a colour change. The control is on the right

This final figure is surprisingly low. This temperature might easily be encountered during a conservation treatment. Without knowing the total light exposure to an object it is difficult to estimate whether this thermochromatic change would occur at even lower temperatures if the object was exposed to more light.

In this set of experiments, the final sample to be exposed came from the Han dynasty spear handle. The hot stage was set, as in previous experiments, to rise from 70 to 90 degrees at a rate of three degrees per minute. After the entire run there was no visible change to the lacquer. It was concluded that, since the appearance of the sample was also very good, there was insufficient light exposure to cause the colour change phenomenon.

Conclusions

In the end, it was found that this set of experiments raised as many questions as it answered. The question of heat treatment for pest eradication seems a qualified no. Heat treatment for pests is usually about 60 degrees Celsius. There is probably no danger of a colour change if there is no moisture in contact with the surface. However, there are circumstances where this contact might occur. Other objects resting against the surface or where the object is stored in polyethylene bags might result in a situation where the moisture cannot escape. The same danger exists, if facings are used to hold detached lacquer in place.

From the observations of these experiments it is clear, that the sudden colour change of lacquer when exposed to heat and moisture is also related to the amount of light degradation encountered by the object. However, what is still not clear is the exact temperature at which this change occurs. It can occur at a temperature as low as 51 degrees Celsius, however most samples changed colour at a higher temperature. What is the difference? Clearly, it must be the amount of light degradation.

Unfortunately, these experiments are far from complete. The next experiments to perform will include new created lacquer films using clear, red and black lacquer. These films will be exposed to known amounts of light; and the samples will then be run through the same heating experiments to determine more accurately, if there is a correlation between the amount of light degradation and the temperature, at which the colour change takes place. If this hypothesis proves true, this information will be valuable for the calculation of the total past light exposure of an object. This would be very useful to know in setting display restrictions for a particular object.

Reference

SIMONOV, VLADIMIR: 'The method for the Conservation Treatment of the Vietnamese Lacquer Sculpture "Donatur"', in *Preprints, ICOM-CC 9th Triennial Meeting,* V., Dresden, 1990, p. 658

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