Light-induced deterioration of *urushi*, *maki-e* and *nashiji* decoration

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Introduction

Urushi is widely used as a decorative surface in East Asia because of the beautiful sheen it produces on hardening. In addition, the surface of freshly cured *urushi* is resistant to moisture, heat, acids, alkalis and organic solvents. It has good insulating and antibacterial properties, and is an effective adhesive and consolidant. It is used in lacquer-making for the production of substrates, for building up foundation layers and in the application of different types of surface decoration.

Urushi is, however, vulnerable to damage by both visible light and ultraviolet (UV) radiation resulting in the loss of many of the lacquer's distinctive properties. *Urushi* objects exposed to UV radiation in outdoor environments deteriorate within a year (Ogawa *et al.* 1993). Even objects exposed to visible light indoors deteriorate but at a much slower rate. Light-induced deterioration of *urushi* results in damage to, and loss of, the decoration applied to the lacquer surface and, eventually, in lifting of the *urushi* foundation layers.

This paper begins by outlining the basic techniques of lacquering and *maki-e* decoration to clarify the layer structures present in freshly made *urushi*, *maki-e* and *nashiji* surfaces. It then uses this information, in combination with examples from the Mazarin Chest and a *nashiji suzuribako*, to illustrate the processes of photodeterioration of *urushi* and the progressive loss of *maki-e* and *nashiji* decoration that results.

Manufacturing materials and techniques

Urushi *surfaces*

The most common way of producing an *urushi* surface is by covering a substrate with hemp cloth (*nunokise*) and then applying foundation layers (*shitaji*). An initial coarse *shitaji* layer is followed by several layers of increasing fineness. Whetstones are then used to polish the surface as flat as possible followed by the application of two to three layers of *urushi* to create the middle coating (*nakanuri*). This can be left as it is, in which case it is described as a *nuritate* finish, or it can be polished to produce a glossy finish in a process called *roiro-shiage* or *roiro-age*. The latter involves the impregnation of the surface with several applications of *urushi* thinned with a solvent, followed by polishing with very fine abrasives such as powdered deer horn.

Raw *urushi* (*ki-urushi*) is used when covering the substrate with hemp cloth and for making the foundation layers, while processed *urushi* is used for the middle and upper coatings. When used with hemp cloth, raw lacquer is mixed with a paste made from rice (*nori*) or wheat (*mugi*) flour. For making the foundation layers, raw lacquer is mixed with fixed ground clay (*jinoko*) or ground whetstone (*tonoko*). There are two kinds of processed *urushi*: one is mixed with a drying oil (*shuai urushi*); the other is not. The former is normally used for *nuritate*-type coatings, the latter for *roiro-age*-type coatings. *Shuai urushi* produces a natural sheen but takes a long time to harden. Processed *urushi* that is not mixed with oil can be categorized into several different kinds, namely black *roiro urushi*, clear *suki urushi* (also known as *kijiro urushi*), and yellowish *nashiji urushi*. *Roiro urushi* is made by adding iron filings or iron hydroxide to *suki urushi*. This processing technique results in a chemical reaction that turns the *urushi* black. The other, more traditional, way of making black *urushi* is to mix soot black from oil or pine with *suki urushi*. This kind of black *urushi* is more opaque than *roiro urushi*, which is relatively translucent. The black colour of historical *urushi* objects was produced by the application of *urushi* pigmented with soot black followed by a coating of clear *suki urushi* (Okada 1995). *Nashiji urushi* is made by mixing *suki urushi* with gamboge or gardenia yellow (Sawaguchi 1966).

Maki-e *decoration*

There are three main types of *maki-e* decoration: *togidashi-maki-e* (polished sprinkled picture decoration), *hiramaki-e*

(flat sprinkled picture decoration) and *takamaki-e* (raised sprinkled picture decoration). The metal powders used in *maki-e* decoration are classified by particle shape into *marufun* (round), *hanmarufun* (semi-round), *hiramefun* (flat), *nashijifun* (irregular) and *keshifun* (super fine). Each particle shape is available in a range of up to 15 sizes. This provides the artist with considerable scope to juxtapose techniques and intermix powders to create subtle and complex designs.

In the case of *togidashimaki-e*, the middle (*nakanuri*) coating is polished smooth with *suruga* charcoal (made from the *aburagiri* or Japanese tung oil tree *Vernicia cordata* Airy Shaw). The design is drawn in *urushi* (*shitazuke*) applied by brush (a *maki-e fude* or a *damibake*). Gold and silver powders are then sprinkled on (*funmaki*) using a *funzutsu*, a sprinkling tube covered at one end with a fine mesh, while the *urushi* is still wet. The piece is then placed in a chamber (*furo*) in which relative humidity (RH) is elevated so as to cure the *urushi*. The metal powders are then consolidated with *urushi* (*urushi-gatame*), which penetrates between the *maki-e* powders and strengthens the adhesive bond between them and the underlying *urushi* surface. The *urushi-gatame* is in turn cured in the *furo*. The whole object, both the decorated and undecorated areas, is then covered in an upper (*uwanuri*) coating of *urushi*. Once this has cured, Suruga charcoal and *roiro* charcoal are used to gently abrade the surface so that the temporarily hidden design emerges from below the *uwanuri* coating. The final result is a piece in which the *maki-e* decoration and the black background are smooth and on the same level, with the metal powders effectively embedded within the surrounding layer of *urushi*.

In the case of *hiramaki-e*, the design is applied over the upper (*uwanuri*) coating, which may be of either the *nuritate* or *roiro-age* kind. The design is drawn on in *urushi* and then covered in sprinkled gold and silver powders. This is followed by curing, *urushi-gatame* consolidation, and further curing. A fine abrasive such as pulverized natural whetstone is then used to polish the surface of the areas of gold and silver decoration. The metal powders used in *hiramaki-e* are usually finer than those used in *togidashimaki-e*.

In the case of Kōdaiji *maki-e*, a type of lacquerware popular during the period (1580–1620), the final stages of *urushi-gatame* consolidation and polishing were omitted in a simplified process known as *makipanashi* (literally 'sprinkled and left as it is'). The use of *makipanashi* is also found on export lacquerware of this period.

Takamaki-e describes *maki-e* applied over low relief designs raised with *urushi* or *shitaji*. The *maki-e* decoration may be sprinkled on and consolidated in the same way as in *hiramaki-e*, or it may be sprinkled on, covered in *urushi* and then lightly polished out in a process called *uwatogidashi*. *Uwatogidashi* sometimes involves the application of *nashiji* flakes, in which case the *maki-e* designs are covered with a thicker *nashiji urushi* coating.

Shishiai togidashimaki-e refers to the combined use of *takamaki-e* and *togidashimaki-e* techniques. Low relief designs are raised on the middle (*nakanuri*) surface and metal powders are sprinkled on. The whole surface is then covered in an upper (*uwanuri*) coating of *urushi* and charcoal is used to polish out the metal powders, which, as in the case of *togidashi-e* designs, are firmly embedded in the surrounding layer of *urushi* (Komatsu and Katō 1997).

The *urushi* used for the initial drawing on of the design (*shitazuke*) can be clear *suki urushi* or red *e-urushi*, which is *suki urushi* mixed with *shu* (mercuric sulfide/vermilion) or *bengara* (red iron oxide). The *urushi* is pigmented red to make it easier to see the designs as they are painted on and also to enhance the colour of the gold powders that are sprinkled on top. *Bengara* has the added advantages of improving the adhesion between the *urushi* and the metal powders and also of increasing the rate of hardening of the *urushi*.

The Mazarin Chest was decorated with *hiramaki-e*, *takamaki-e*, *togidashimaki-e* and *shishiai togidashimaki- e* (Figure 1). *Togidashimaki-e* was used to represent areas of water on the exterior of the lid and on the mouldings around the top and bottom of the chest. In each case gold and silver powders were sprinkled on to create a graduated effect (*bokashi*). *Shishiai togidashimaki-e*, in which gradated gold and silver powders are sprinkled over large *hiramefun* (flat flakes), was used to represent the mountains that feature in the background of the scenes on the interior and exterior of the lid and on the banks in the scenes on the sides of the chest (Figure 5a). In the case of the *hiramaki-e* decoration, there are numerous areas where needles or sharp pieces of bamboo were used to scratch away (*hikkaki*) parts of the design after sprinkling on the metal powders. Other parts of the design, such as rocks and window frames, were created through the use of a masking-out technique (*kakiwari*). There is also widespread use of *maki-e* lines (*tsukegaki*) applied over mother-of-pearl (*raden*), metal foil *(hyōmon* and *kanagai*) and areas of *hiramaki-e* decoration. The raised areas of *takamaki-e* decoration utilized both *urushi* and *shitaji* foundation mix. In some places metal powders were applied twice in order to achieve greater decorative effect.

The decorative scheme on the chest was enhanced with extensive use of metal. Small pieces of metal foil cut into squares or diamond shapes (*kirikane*) were used on many parts of the chest, while on the trunks of the pine trees, for example, small chunks of metal were embedded (*kimetsuke, kimekomi*) into the design to give a greater sense of the roughness of the bark. Pieces of metal, some of them with engraved (*chōkin*) detail, were used to represent roof tiles, as well as many of the birds and animals that feature on the chest. Lengths of round (*marusen*) or twisted (*yorisen*) gold and silver wire were used in the representation of pine needles and parts of buildings.

The facial expressions of the figures that appear on the chest were applied in a variety of ways, such as the use of black and vermilion-pigmented *urushi* and the application of *suki urushi* over *maki-e*.

Deterioration

The deterioration of *urushi* surfaces is the combined result of exposure to visible and UV light, as well as natural ageing, which causes changes to both the structure of the underlying foundation layers and the surface. The preparation of the

Figure 1 Detail of lid exterior of the Mazarin Chest (412-1882) showing types of *maki-e* decoration: *togidashimaki-e* was used for parts of the water decoration for example at top left above the bridge; *hiramaki-e* was used for the waves and *takamaki-e* was used for the tree and rocks – two methods of raising were used. The leaves on the tree were raised with *urushi*, while the tree trunk was raised with *shitaji*. Other techniques that can be seen here include applied metal decoration, the ducks with engraved *chōkin* detail; silver embedded (*kimetsuke* and *kimekomi*) in the tree trunk to represent a recess and knurl in the tree trunk; *ginbyō*, where small silver pins were used to represent water droplets on the branches and rocks; and silver and gold *kirikane* (cut foil) on the rocks and tree trunk. In the top right corner is a black area on the vertical rockface that would originally have been bright silver, representing breaking waves and foam. Photograph courtesy of V&A Images.

foundation layers involves the use of both water and raw lacquer, which contains 25–30% water (Miyakoshi 2007), and even after hardening a small amount of this moisture remains. As the lacquer dries out over time, shrinkage and then cracking of the foundation layers occurs. Processed *urushi* that is not mixed with a drying oil (e.g. tung oil) is the most robust in terms of being able to resist the effects of light damage and natural ageing. *Urushi* that is mixed with oil or contains other impurities, in contrast, is prone to developing a fine surface craquelure caused by the polymerization and associated shrinkage of the drying oil component in the film. *Urushi* objects whose upper coatings (*uwanuri*) contain a large proportion of pigment are especially liable to light-induced deterioration. Black lacquer prepared with iron filings or other chemicals tends to change colour, fading to a light brown or greyish green through exposure to moisture and heat. *Suki urushi* also changes colour, even to the extent of turning a mottled brown on verso surfaces exposed to reflected light.

Photodeterioration of *urushi* results in a gradual loss of gloss. Inspection of damaged *urushi* surfaces with a low magnification lens reveals a fine network of micro-cracks. Micro-cracking can be observed in more detail using scanning electron microscopy (SEM). Figure 2 shows the surface of a sixteenth-century example of Ryūkyū lacquerware. Once completely smooth, it is now characterized by a dense network of microscopic rifts and valleys. There is an associated loss of lacquer along the edge of the cracks – these are not simple vertical splits, but V-shaped valleys between four-, five- or six-sided islands of original surface, in a characteristic mud-flat pattern. The cracks vary in width from 0.1 to 6.0 μm, the majority being in the 0.4–0.9 μm range. The widest

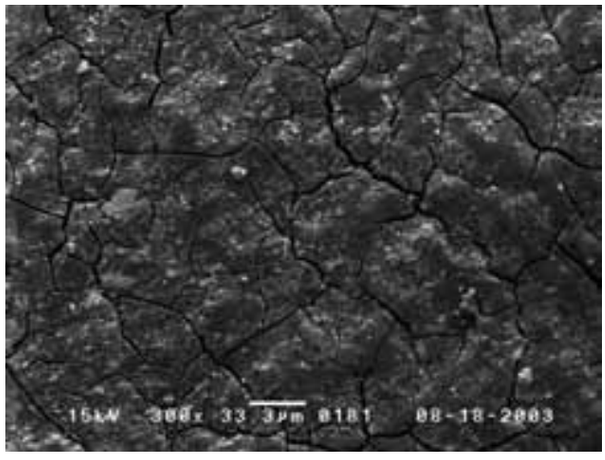


Figure 2 SEM image at ×300 magnification of the light-damaged *urushi* surface of a piece of sixteenth-century Ryūkyū lacquerware. Photograph courtesy of Y. Yamashita.

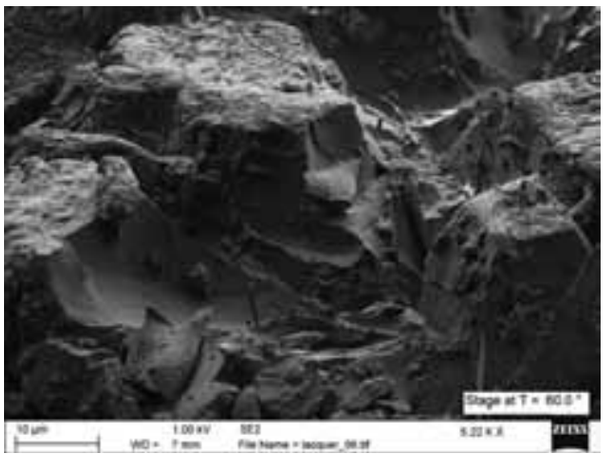


Figure 3 SEM image of the light-damaged surface of the lacquer frame of a nineteenth-century Japanese screen. The image is 70 µm wide and was taken on a variable pressure SEM at 1.0kV. Image courtesy of Nigel Meeks and Caroline Cartwright of the British Museum.

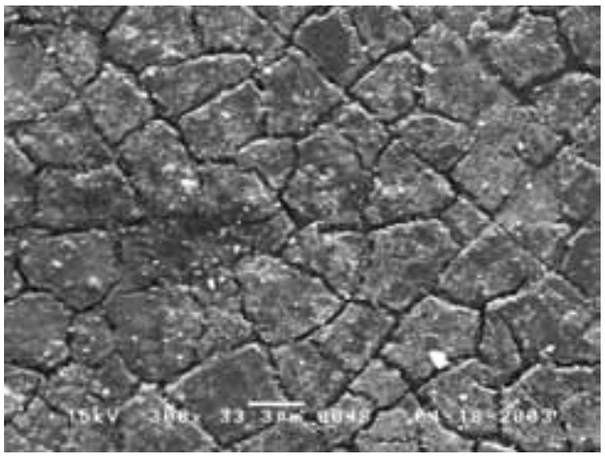


Figure 4 SEM image at ×300 magnification of the photodegraded *urushi* surface from the exterior of the Mazarin Chest. Image courtesy of the V&A and N. Hayakawa of the National Research Institute of Cultural Properties, Tokyo.

cracks are those that formed in the first stages of light-induced degradation. These are followed by the appearance of growing numbers of finer cracks. Dirt and dust that accrue on the *urushi* surface contribute to the loss of gloss. Observation of the deepest cracks revealed that the micro-cracking had penetrated right through to the foundation layers.

Figure 3 shows an oblique SEM view of a nineteenth-century Japanese lacquer surface that has suffered significant exposure to light. Vertical brittle fractures can be seen, as well as lateral cracks, which may occur along any stress-relieving layers within the lacquer surface or foundation as deterioration progresses.

The smooth *urushi* surface of the Mazarin Chest indicates that it was polished using the *roiro-age* technique. While the overall pattern of the micro-cracking on the Mazarin Chest (Figure 4) is similar to that of the Ryūkyū lacquer in Figure 1, the cracks on the chest range in width from 0.3 to 7.2 µm, with an average of 3.4 µm. These are much wider than on the Ryūkyū piece. Another difference is the way in which the edges of the cracks appear to be crumbling. These differences suggest that the surface of the Mazarin Chest has deteriorated considerably more than that of the Ryūkyū piece. The most likely reason for this is that it has suffered from greater exposure to light and has also been kept in much drier conditions. The presence of natural resin varnish and other western restoration materials on various parts of the chest indicate that it has been restored several times in the past. The only documented treatment was carried out in 1986, when the chest was 'cleaned' with a mixture of almond oil and gas black pigment prior to the application of carnauba, paraffin and beeswax mixed with white spirit. Though this was acceptable practice at the time, it would not be considered appropriate now.

Photodegradation of *maki-e* and *urushi* surfaces: examples from the Mazarin Chest

The deterioration of *urushi* has consequences both for *urushi* surfaces and the *maki-e* decoration applied onto them. In the case of *togidashimaki-e*, the decoration is suspended between the middle (*nakanuri*) and upper (*uwanuri*) *urushi* layers. The particle sizes of the metal powders used are relatively large. Because the proportion of each particle of metal protruding above the *urushi* surface is in the order of 40–50%, it has hitherto been thought that deterioration of the *urushi* surface has relatively little impact on the stability of the decoration. However, as the *urushi* surrounding the metal particles disintegrates, more and more of the metal is exposed so that adhesion of the larger particles to the underlying surface is so weakened that they can be rubbed off and lost comparatively easily, particularly during cleaning. Furthermore, lifting of the middle (*nakanuri*) and lower (*shitanuri*) *urushi* layers induced by ageing can result in their loss, the microscopic flakes taking parts of the *togidashimaki-e* decoration with them.

In the case of *hiramaki-e*, the *urushi* used to consolidate the designs deteriorates in the same way as the *urushi* of the undecorated background areas. As the *urushi* holding the *maki-e* decoration in place deteriorates and is reduced to powder, the metal particles loosen and are in turn lost. Because the metal powders used for *hiramaki-e* are finer than those used for *togidashimaki-e*, it can be difficult to see that deterioration and associated loss is taking place. *Makipanashi*-type *hiramaki-e* decoration, which does not have a consolidating layer of *urushi* applied over it, is especially vulnerable to degradation and loss.

With *takamaki-e*, where *urushi* may have been used to consolidate either just the areas decorated with *maki-e* or the whole surface, deterioration takes place in the same way as with *hiramaki-e*. Also, because *takamaki-e* is liable to damage from surface abrasion, it is not uncommon to find partial loss of the *maki-e* powders accompanied by exposure of the underlying *urushi* or *shitaji* foundation mix used to create the raised designs (see for example, Figure 11a).

The Mazarin Chest is particularly useful for illustrating the effects of photodegradation on *maki-e* because the inside and outside of the lid have many decorative techniques in common. The interior has been protected from light damage and looks much as it would have at the time of its manufac-

ture, while the exterior has suffered significant and prolonged exposure to light. Comparison of the interior and exterior where they are decorated with the same *maki-e* techniques provides stark evidence of the effects of photodegradation and contrasts with changes that can be attributed solely to the passage of time.

The area of *shishiai togidashimaki-e* on the lid interior shown in Figure 5b shows that the surfaces of both the *urushi* and the metal powders were originally smooth and flat. On the comparable area on the lid exterior shown in Figure 5c, the *urushi* surface has a network of fine micro-cracks, the *maki-e* powders are no longer embedded in the surrounding *urushi* but are exposed on the surface, and in some cases have been lost, exposing the middle (*nakanuri*) *urushi* coating below.

On areas on the lid interior where parts of the *hiramaki-e* design have been scratched away (*harigaki*), the *suki urushi* that was subsequently applied to add tonal variation is still in place (Figure 6a). On comparable areas of the exterior, this *suki urushi* has been lost, with the result that the *maki-e* powders of the *hiramaki-e* decoration below are now exposed (Figure 6b). This loss of subtle parts of the design has also occurred with the *takamaki-e* rocks.

While the areas of the chest decorated in *hiramaki-e* have deteriorated to a lesser extent than those decorated in *togidashimaki-e*, close inspection shows that some of the smaller metal particles in the *hiramaki-e* have been lost. Figure 7a is an SEM of *hiramaki-e* scroll decoration on the borders of the Mazarin Chest, made by pinching up and sprinkling on (*tsumemaki*) metal powders of mixed particles size. Originally, the particles near the surface were only partially attached to the *shitazuke urushi* underdrawing and were mainly held in place by the *urushi-gatame* consolidant coating. As the *urushi-gatame* coating deteriorates, the metal particles near the surface become vulnerable to loss, leaving small holes in the decoration (Figure 7b).

Because *urushi* adheres relatively weakly to mother-of-pearl and metal foil, *tsukegaki*-type *maki-e* lines applied over these materials are prone to loss. In the case of the Mazarin Chest, many of these lines have disappeared, leaving the shell and metal surfaces devoid of their original decoration (Figure 8).

The propensity of silver powder to tarnish can be seen all over the chest. This tarnishing is often accompanied by silver sulfide creep onto adjacent *urushi* and *maki-e* decoration, which can be difficult to remove if the *maki-e* below is photodegraded and poorly adhered. In some cases, however, the corrosion products protect the surface below from photodegradation, and original colour is revealed when the corrosion products are removed (Figure 9).

The deterioration of the *urushi* on areas of the design executed in *togidashimaki-e* is especially damaging to the *hirame-fun* (flat flakes) mixed in with the round *marufun*. The loss of the *urushi* top coat leaves them very vulnerable to loss, particularly during cleaning (Figure 10). In this case, losses on the lower moulding had been filled during a previous, possibly nineteenth-century restoration treatment. It appeared that the *togidashimaki-e* had suffered considerable abrasion and loss during this treatment, which had culminated in the application of a natural resin varnish. The *togidashimaki-e* was particularly vulnerable to further loss during removal of this varnish in 2007.

Inspection of the *maki-e* on the Mazarin Chest showed that *togidashimaki-e* and *shishiai togidashimaki-e* were more vulnerable to the effects of photodegradation than *hiramaki- e* and *takamaki-e*. Even so, significant parts of all types of *maki-e* decoration had been lost due to the progressive effects of light damage.

Photodegradation of *nashiji* decoration

In connection with research on the deterioration of the *urushi* surface and *maki-e* decoration of the Mazarin Chest, careful inspection was made of a late seventeenth-century *suzuribako* decorated with a deer among autumn plants (Figure 11a). Scratch marks on the surface of the writing box were evidence of past use. It was in generally good condition and there was little evidence of damage to its wooden substrate. Visual inspection of the *nashiji* ground and *takamaki- e* decoration revealed a very high quality finish. The *nashiji* ground was made by sprinkling on *nashiji* flakes and the subsequent application of multiple layers of *nashiji urushi*. The *takamaki-e* decoration was raised using black *urushi*. *Maki-e* powders were sprinkled on designs drawn out in *bengara urushi* and then polished.

The lid protected the interior from light damage. Observation with a handheld lens showed that the interior was also scratched from use, but was otherwise relatively stable. There was a small degree of micro-cracking resulting from natural ageing, which had desaturated the colour slightly. Figure 11b shows two different degrees of light damage on the side of the *suzuribako*. The upper part, mostly protected by the overhanging lid, had suffered less light damage than the lower part, where light damage to the surface was somewhat more advanced. The exterior of the lid had suffered the most from light damage.

Figure 11c is a macrophotograph of the interior of the *suzuribako*, which shows that the majority of the *nashiji* flakes were fully covered by *urushi*, with only a few protruding through to the surface. There was also a slight clouding and discoloration of the *nashiji urushi*. Figure 11d, the upper part of the side of the *suzuribako*, shows the early stages of light-induced deterioration. It had suffered a degree of mechanical damage during use and there were many scratch marks. *Urushi* adheres weakly to metal and in some cases the *nashiji urushi* had been lost from the surface of the *nashiji* flakes. However the colour of the *nashiji urushi* was much the same as it would have been when the writing box was first made.

Figure 11e, the lower part of the side of the *suzuribako*, had suffered much more from photodegradation. It had lost its lustre and was covered in fine micro-cracks. In this case, 50% or more of *nashiji urushi* had been lost from the *nashiji* flakes. Since *nashiji* flakes are extremely thin and easily damaged, in many places the exposed and protruding edges had been lost, so that the flakes were now smaller than they were originally.

Of all its surfaces, the lid of the *suzuribako* had received the greatest exposure to light and was considerably more damaged than the interior or the sides of the base (Figure 11f). Most of the upper (*uwanuri*) coating that originally covered the *nashiji* flakes had disintegrated, leaving the upper

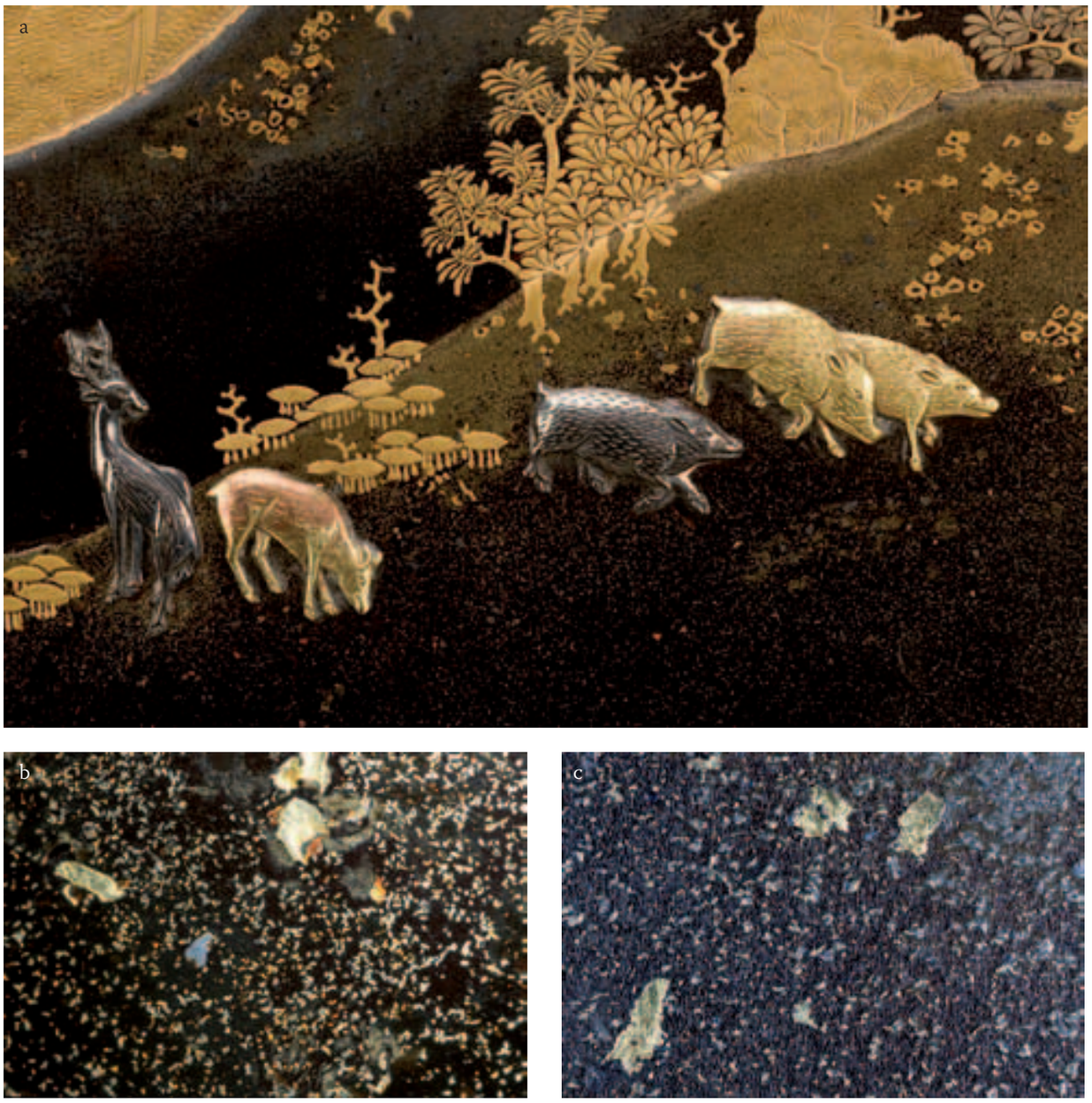


Figure 5 (a) Detail of mountain on lid interior decorated with *shishiai togidashimaki-e* and *hiramaki-e*. Courtesy of V&A Images. Macrophotographs of *shishiai togidashimaki-e* from (b) the interior and (c) the exterior of the Mazarin Chest. Macrophotographs: Y. Yamashita, courtesy of the V&A.

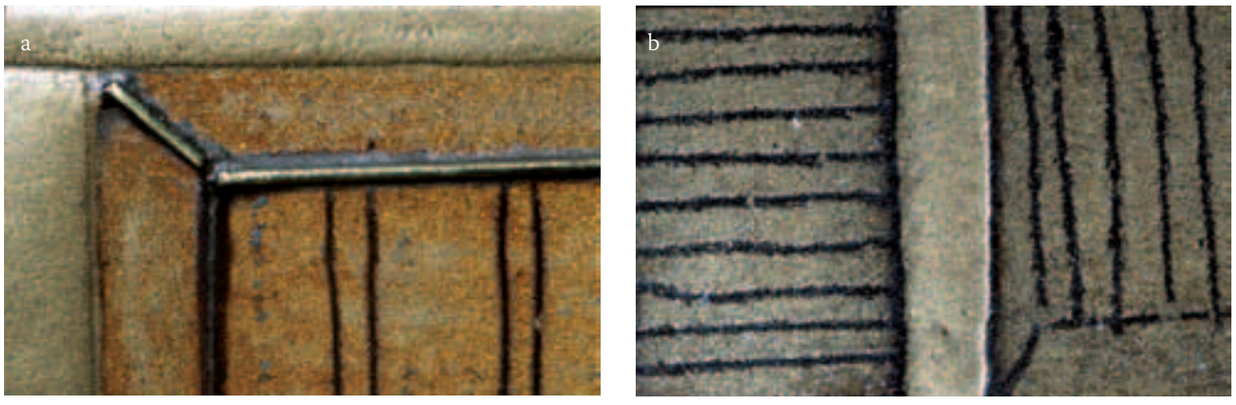


Figure 6 Macrophotographs of *suki urushi* on *hiramaki-e* decoration (a) from the interior and (b) from the exterior of the Mazarin Chest. Macrophotographs: Y. Yamashita, courtesy of the V&A.

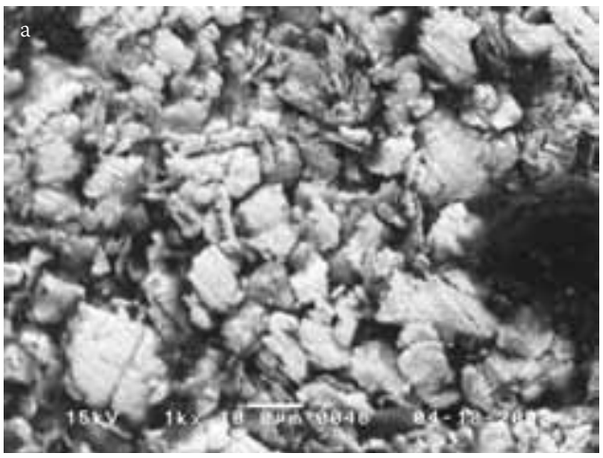


Figure 7 The Mazarin Chest: (a) SEM image at ×1000 magnification of scrolling *hiramaki-e* decoration from the border, lid exterior. Image courtesy of the V&A and N. Hayakawa of the National Research Institute of Cultural Properties, Tokyo. (b) Macrophotograph of a flake from the scrolling border of the lid exterior showing loss of small areas of *hiramaki-e* decoration. Macrophotograph: Y. Yamashita, courtesy of the V&A.

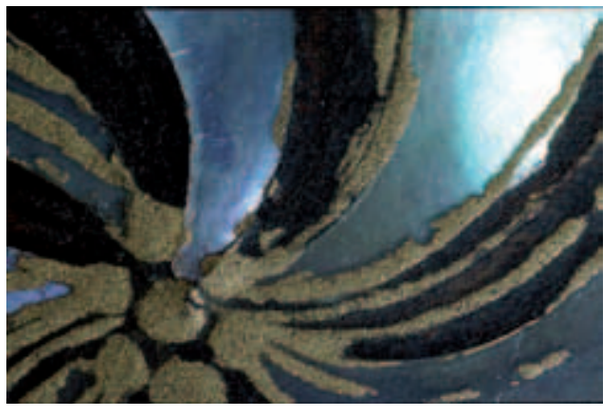
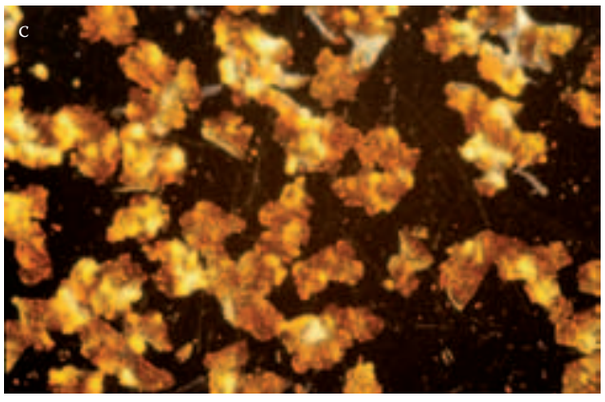


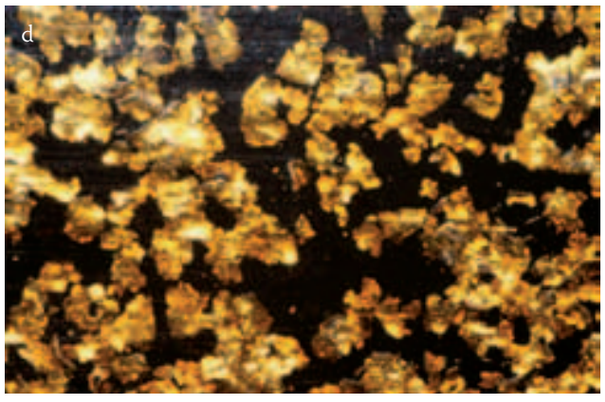
Figure 8 Losses from *tsukegaki*-type *maki-e* decoration applied on and around shell (*raden*) decoration. Photograph: Y. Yamashita, courtesy of the V&A.

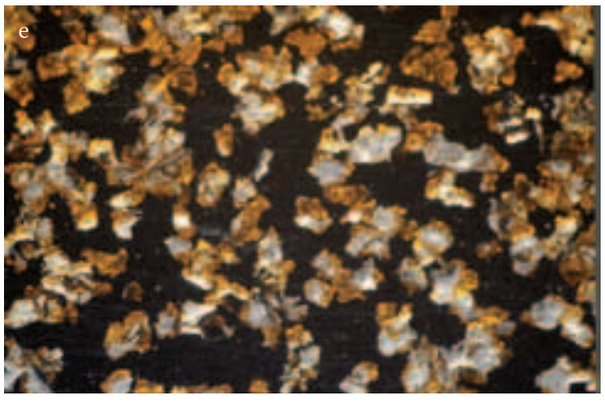
Figure 9 (a) Silver sulfide 'creep' over adjacent *maki-e* decoration; (b) careful removal of silver sulfide from *maki-e* decoration revealed a surface protected from light damage. Photographs: S. Rivers, courtesy of the V&A.

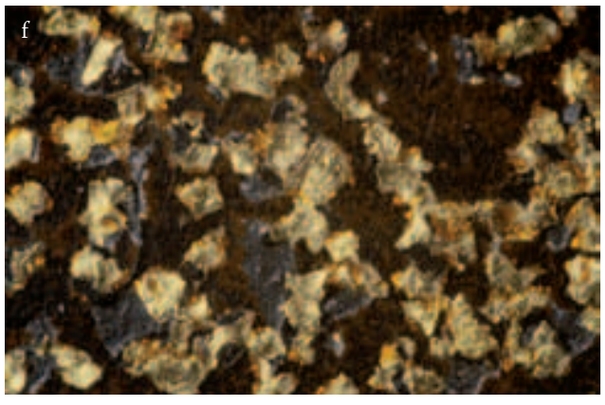
Figure 10 (a) Intact *togidashimaki-e* decoration on the upper moulding, lid exterior and (b) *togidashimaki-e* decoration on lower moulding damaged and abraded in past restoration treatment/s. Photographs courtesy of V&A Images.

Figure 11 (a) Late seventeenth-century *suzuribako* decorated with deer and autumn plants (FE.202-1974). Photograph: S. Rivers, courtesy of the V&A. (b) Side of base of *suzuribako*. Photograph: Y. Yamashita, courtesy of the V&A. Macrophotographs of *nashiji* decoration on (c) the inner tray, (d) the upper (covered) part of base side and (e) the lower (exposed) part of base side. (f) Macrophotograph of *nashiji* decoration and *urushi* surface on the lid. Macrophotographs: Y. Yamashita, courtesy of the V&A.









surface of most of the *nashiji* flakes exposed. As the micro-cracking had progressed deeper into the surface, light brown patches had started to appear where the upper (*uwanuri*) coating of *nashiji urushi* had begun to separate from the middle (*nakanuri*) coating of black *urushi*. In some areas the *nashiji* flakes had fallen away, leaving small holes through which the black colour of the middle (*nakanuri*) coating was visible.

The combination of natural ageing and light degradation results in deterioration, damage to and loss of the *urushi* surface and *nashiji* decoration in the following way:

1 The *shitaji* foundation layers shrink, causing unevenness in the *urushi* surface.
2 The first signs of deterioration of the *urushi* surface is the change in appearance to one resembling dry, leathery skin.
3 Very fine fissures appear in the *urushi* surface.
4 The fissures join up to give a finely micro-cracked surface consisting of flat islands surrounded by V-shaped valleys.
5 As the cracks become deeper, the *urushi* covering the *nashiji* flakes begins to lift.
6 This *urushi* then falls away, exposing the *nashiji* flakes.
7 The parts of the *nashiji* flakes thus exposed are rubbed away and lost.
8 The cracks that started in the upper (*uwanuri*) coating progress downwards into the middle (*nakanuri*) coating, causing the layers to separate (lateral cracking and flaking) and the *urushi* between the *nashiji* flakes to disintegrate.
9 The *nashiji* flakes fall away, exposing the middle (*nakanuri*) coating below.
10 The middle (*nakanuri*) coating is further exposed as the upper (*uwanuri*) coating of *urushi* over the plain, black areas disintegrates.
11 The cracks continue to deepen and, in a repeat of the process above, the damage progresses down into the *shitaji* foundation layers.

Conclusions

Freshly cured *urushi* is highly resistant to heat and moisture, but once it starts to deteriorate as a result of exposure to light and fluctuating RH, it loses its special qualities and weakens. The metal powders used in *maki-e* decoration are lost as the *urushi* holding it in place disintegrates.

In Japan, various steps are taken to reduce light damage, including limiting light levels when lacquer is on display, limiting the length of time objects are put on display, the provision of storage boxes and, wherever possible, controlling the temperature and RH in which *urushi* objects are kept. In addition to these preventive measures, Japanese lacquer conservators undertake remedial treatment of light-damaged surfaces, using *urushi-gatame* to consolidate the decoration and strengthen the surface. *Urushi-gatame* and other treatments can extend the life of *urushi* objects by many hundreds of years. The (Japanese) use of *urushi* to conserve *urushi* objects in preference to synthetic materials is more than just a matter of endeavouring to preserve the sheen and texture unique to lacquer surfaces – it also draws on ideas of cultural integrity in a country that has valued *urushi* so highly over the centuries.

In the West, it is well understood that light damage causes micro-cracks to form. It has not been widely understood that light damage not only causes lifting and loss of the *urushi* surface but also, most importantly, that it leads to incremental loss of the decoration, particularly *maki-e* particles and *nashiji* flakes. This decoration is where much of the value of *urushi* ware lies thus unrestrained light damage leads to irrecoverable loss of the locus of historical, technical and artistic value.

Urushi objects handed down in western collections have typically been treated with other materials such as shellac that are now known to be extremely detrimental to *urushi* surfaces and *maki-e* designs. It is hoped that, by elucidating the processes of manufacture and deterioration undergone by *urushi* objects, conservators will be better placed to make informed decisions about the treatment of light-damaged *urushi* objects.

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