# The conservation of a vinyl-upholstered chair: PVC degradation and conservation

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**Abstract**

This paper is based on a case study of an Artek chair dating from the 1950s and it deals with the composition and conservation of the original vinyl-coated upholstery fabric. Vinyl – short for polyvinyl chloride or PVC – fabrics came onto the market in the 1950s as an imitation material of leather that would eventually replace the cellulose nitrate-based Pegamoid. Vinyl had properties exceeding those of genuine leather, which made it an ideal material for the upholstery of furniture especially situated in public spaces. The composition and the production of vinyl-coated fabrics are discussed in this paper, as well as the degradation and conservation of PVC. The degradation of PVC on the Artek chair upholstery was to an extent visible to the naked eye – tears and the surfacing of the phthalate plasticizer that had changed the appearance of the plastic. The treatment of the vinyl included surface cleaning and removal of the oily plasticizer from the surface, lining tears and filling holes of the vinyl with a fill made from the mixture of synthetic resin, glass microballoons and pigments. The optimal storage conditions of the Artek chair were determined, since preventive conservation is a more efficient way to conserve plastic than any active conservation. In this case study the contradicting storage recommendations of the two synthetic materials of the chair – the vinyl upholstery and a cellulose nitrate varnish – led to a compromise of storage conditions.

## PVC

PVC is a thermoplastic that is polymerized from the vinyl chloride monomer.[1] The polymerization of PVC was done for the first time in 1872, but the wide possibilities of the usage of PVC were only discovered in the early twentieth century by the addition of a plasticizer. PVC on its own is a very rigid and unstable material that is difficult to handle and, therefore, a plasticizer is often present. The plasticizer increases the flexibility of PVC by separating the polymer chains from each other and forms the PVC into a plastic with versatile properties. From the 1950s onwards, the most commonly used PVC plasticizer was di(2-ethylhexyl) phthalate, DEHP, which later proved to be harmful and was replaced by other varieties. The properties of PVC are further shaped with other additives, such as UV stabilizers, fills and pigments.[2]

PVC has been listed as one of the most unstable materials in museum collections along with cellulose nitrate, cellulose acetate and polyurethane because of its rapid degradation.[3] PVC is very sensitive to the yellowing effect of UV radiation which makes PVC degrade rapidly when exposed to light and heat.[4]

Already at its production begins the autocatalytic degradation process of PVC. Free radicals are formed in PVC in the presence of heat, impurities and UV radiation, leading to the polymer to oxidize. The oxidization instead creates further free radicals. This cycle continues until practically the entire polymer has degraded. Simultaneously, the polymer chains of PVC break caused by the oxidization of PVC, which leads to the decreasing of the molecular weight of the PVC polymer. A decreased molecular weight increases the softness of the plastic and decreases its tensile strength.[5]

As the PVC polymer degrades the plastics additives also degrade. The DEHP that had been used as a plasticizer in PVC during the first decades of PVC production started to emigrate to the surface of the plastic forming an oily, sticky surface. The oily surface allows dust and impurities from the air to attach onto the plastic surface which further accelerates the degradation of PVC. The phthalate plasticizer on the plastic surface may hydrolyze under extreme conditions creating a white bloom.[6] As the plasticizer evaporates the amount of plasticizer stabilizing the PVC decreases and makes the PVC more exposed to crazing and cracking.[7]

## Vinyl fabric – composition and fabrication in the 1950s

Initially an invention for the army during the Second World War, PVC-coated fabrics became accessible for consumers in the 1950s and they started to replace the earlier versions of imitation leather, such as the cellulose nitrate coated Pegamoid fabric.[8] Vinyl-coated fabrics were first produced as solid vinyl – non-expanded coatings on

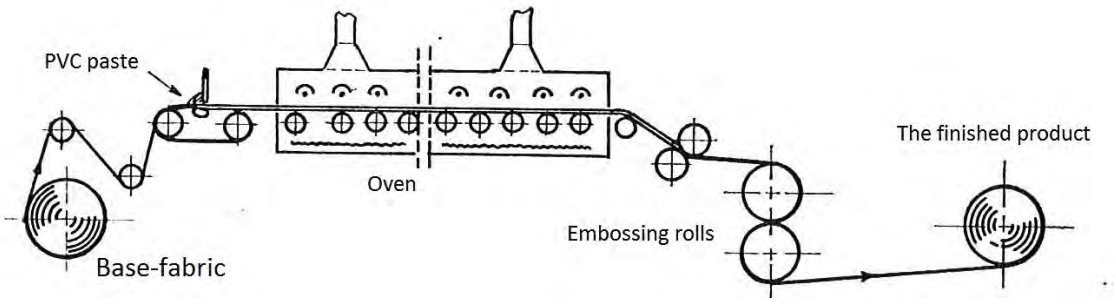


**Figure 1** A coating machine (A. Kulju, *Muovien teknologia*, Porvoo 1965, p. 283).

closely woven fabrics – and later the expanded vinyl coating was developed.[9] Cotton was used as a base-fabric in the early decades of vinyl fabric production and was later replaced by synthetic fabrics.[10]
The solid vinyl coating is achieved by spreading a mixture of PVC, liquid plastisol and other chemicals on a textile fabric that then passes through an oven (figure 1). The texture on the surface of the vinyl fabric is then created with embossed rolls.[11]

As a composite material a PVC-coated fabric is very resistant to wear and tear. The base-fabric maintains the form of the coated fabric and prevents warping. The PVC coating instead determines the chemical properties of the fabric by, for example, making the fabric impermeable to dust particles, liquids and gasses. The PVC coating also improves resistance to abrasion.[12] Due to these properties vinyl fabrics gained popularity from the mid-twentieth century, especially in the upholstery of furniture in public spaces and car seats – they could easily be cleaned and were resistant to abrasion. Initially, what was a cheaper substitute of leather eventually became a valued material of its own. This has led to vinyl-coated fabrics being fabricated in all colours and textures, which intention is no longer to imitate the genuine leather.

## Design and provenance of the Artek chair

The vinyl upholstery that was examined and conserved in this case study is from a Finnish design chair, an Artek chair no. 62 (figures 2a, b, c). According to the drawings of the chair model no. 62 from 1938 the design was made by Aino Aalto, but often the furniture design was a collaboration between Aino and her husband Alvar Aalto. When designing upholstered furniture the designer Maija Heikinheimo was often involved as well.[13] The design of the model no. 62 chair follows the style of Alvar Aalto – the birch legs are bent to a curved shape using thin lamellas. This method of bending wood was Alvar Aalto's trademark and led to the establishing of Artek in 1935.
The chair no. 62 that is the object of this case study belongs to the collection of the Alvar Aalto Museum in Jyväskylä, Finland. Even if it only dates from the previous century its provenance is not well known. It was donated to the Alvar Aalto museum in 2014 by the furniture factory Huonekalutehdas Korhonen Oy, which had began a collaboration with Alvar Aalto before the establishing of Artek. This factory was manufacturing Artek furniture until 2014 when the factory was sold. The selling of the factory led to some pieces of furniture being donated to the Alvar Aalto Museum. When the chair was donated to the museum all information of its previous use and the time of its manufacturing had been forgotten. Although, it can be assumed that the chair had been manufactured at the same furniture factory that donated it and perhaps originally the chair had been included in its public space interiors.[14]
The manufacturing of the chair no. 62 started after

**Figures 2a, b, c** Examples of the chair no. 62 with varying upholstery fabrics and coatings of wood. Alvar Aalto Museum.

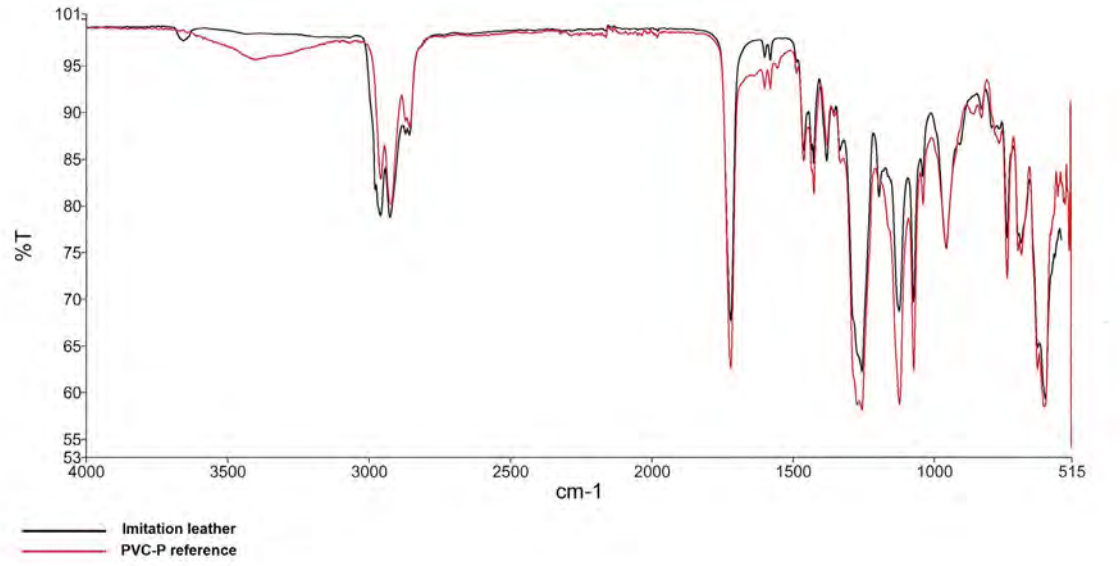


**Figure 3** The FTIR spectra of the imitation leather of the Artek chair and the PVC-P reference clearly indicated that the imitation leather had a PVC coating.

1938 and continued for several decades. The Artek chair to be conserved was dated to the 1950s due to the materials and the structure of the chair. The number of lamellas that the bent birch legs were constructed of indicated that the chair had been manufactured in the 1950s at the latest. The vinyl upholstery was an original one and could not date to decades prior to the 1950s since vinyl-coated fabrics only became accessible for consumers in the early 1950s. This information indicated that both the chair and its upholstery dated from the 1950s.

## Examination

The identification of the plastic is the key to all plastic conservation because the chemical properties of the plastic material are complex and so might be their compatibility with conservation materials. The coating of the imitation leather was first examined externally, and by comparing it with archival data of Finnish vinyl products, which indicated that the coating was most likely PVC. The FTIR spectra of a sample taken from the imitation leather was then compared with a reference sample of plasticized PVC to ensure that the coating was PVC (figure 3). The base-fabric was identified under microscopy as cotton (figure 4), which was the typical base-fabric of vinyl coated fabrics in the 1950s. The close-up of the vinyl surface (figure 5) shows the grain of the vinyl on the Artek chair. The texture is not intended to imitate genuine leather but instead the thin vertical and horizontal lines give a softer look to the otherwise flat and shiny surface of vinyl.

The structure of the upholstery of the Artek chair was studied and documented (figure 6) and no synthetic material had been used for the underlying

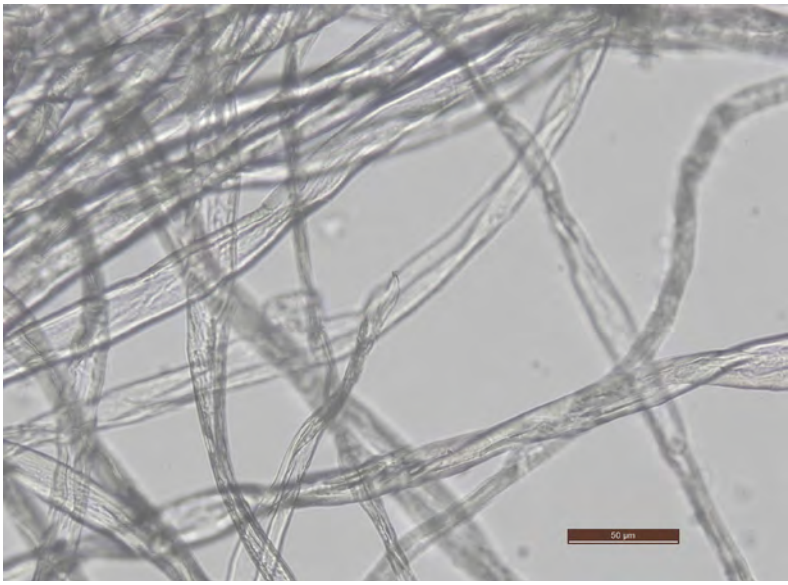


**Figure 4** The fiber of the base-fabric was identified as cotton.

**Figure 5** The grain of the vinyl on the Artek chair has thin vertical and horizontal lines, forming a square-like pattern.

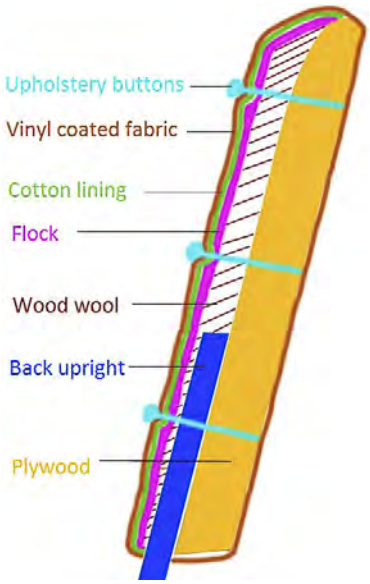


**Figure 6** The structure of the upholstered back support of the Artek chair.

**Figure 7** A thick layer of dirt had stuck onto the oily vinyl surface which was caused by the emigrating plasticizer.

layers of the upholstery of the chair. The underlying layers of the upholstery were not in need of conservation and, therefore, were left intact.

### Condition of the vinyl

There were no signs of previous restoration or reupholstering of the chair. Instead, the condition of the chair gave an insight into its neglect in the past years and decades, either being stored in poor conditions or even having been used as a 'workbench' at the furniture factory.

The vinyl upholstery showed slight signs of the deterioration of the plastic. A sticky surface had formed onto the top of the back support and a thick layer of dust had stuck to it (figure 7). The emigrating plasticizer was also visible as a white bloom on the lower parts of the back support. Also, areas where no stickiness was recorded were full of dust and stains of paint and dirt. There were numerous scratches on the vinyl, most of them matte lines on the surface of the vinyl and a few cuts penetrating through the entire vinyl coating. The matte surface scratches could be found on all sides of the vinyl upholstered seat and back support, and the deeper cuts especially in the front of the seat where most of the abrasion had occurred.

The structure of the chair was very unstable and had caused the back support to come loose from the back upright so that it was only attached to the chair by the upholstery. This had caused excessive stress on the vinyl upholstery and consequently both the vinyl coating and its base-fabric were torn 1-2 cm on both sides of the back uprights. The vinyl upholstery also had two large holes in both top corners of the back support which seemed like the chair had been dragged against the floor causing the holes and the surrounding areas of vinyl to deform and loose the shiny embossed surface. The lining fabric and the flock beneath it were visible through these two holes.

### Treatment of the vinyl upholstery

The vinyl fabric of the Artek chair was cleaned using distilled water, and ethanol was added to remove the oily surface caused by the emigrated plasticizer. The removal of the emigrated plasticizer is not always necessary since it may cause further degradation of the PVC, but on the vinyl fabric of the Artek chair the removal of dirt and grease layer was considered the best alternative for aesthetic reasons. Ethanol may cause the molecular weight of PVC to decrease and therefore its use on PVC should not be a decision taken lightly.

The two large holes in the vinyl of the back support were filled. Because the vinyl around the two holes had become deformed and matte, a new type of fill material for PVC had to be established, one that would imitate the damaged vinyl fabric. A silicone mould could not be used in imitating the texture of the vinyl surface since the size of the area to be filled was greater than any existing area with the same type of damaged vinyl texture. Instead, a patch was prepared with Reemay polyester non-woven fabric where a mixture of Laropal A81 together with dry pigments and hollow glass microspheres used as a filler were added. The fill material could be eas-

**Figures 8a, b** A hole in the vinyl fabric before and after conservation. The fill was prepared with Laropal A81, pigments and hollow glass microspheres to imitate the damaged and matte vinyl.

**Figures 9a, b** The tears of the vinyl were supported with Reemay.

ily modified to imitate the sheen of the matte vinyl surface well (figures 8a, b). The fill patch was then applied to the backside of the vinyl fabric.

The tears were lined using the Reemay fabric. The choice of adhesive was made considering that it had to be compatible with PVC, since the lining would not only be in contact with the underlying cotton fabric of the imitation leather but also with its vinyl coating. A 1:1 mixture of the acrylic adhesives Lascaux 404 HV and 398 HV was used to adhere the Reemay to the backside of the vinyl (figures 9a, b).

During the treatment the appearance of the Artek chair went through a major change. Once the tears and holes were no longer visible and the surface of the vinyl had been cleaned the chair recovered the aesthetics of a piece of design furniture (figures 10a, b).

## Preventive conservation and safe handling

Since the degradation of the plastic material can't be stopped but only slowed down by optimal storage conditions the preventive conservation measures are especially important in the conservation of plastics. The right storage conditions are a more efficient way of conserving the plastic than any active conservation treatment.[15]

PVC is best preserved in a hermetic glass container where it is protected from UV radiation. Another option is to store it inside a bag made of polyester.[16] It is likely that a new sticky surface of the migrating plasticizer will form on the surface of the vinyl in the future even if it is once removed. The sticky surface does not necessarily have to be removed if the chair is stored in such a way that dust cannot stick to the surface.[17] The vinyl should not be in direct contact with other objects because the migrating plasticizer of PVC could attach to other objects. It also should be ensured that a protective textile on top of the vinyl does not stick to the oily vinyl surface. A suitable protection that can be in contact with the vinyl is a silicone-coated polyester Melinex film, which does not stick to the vinyl. PVC should, however, not be protected with fabrics made of polyethylene since it absorbs the phthalate plasticizer from the PVC.

The wooden parts of the Artek chair are varnished with a cellulose nitrate lacquer. This has very different storage requirements compared to those of PVC. Storing the Artek in a hermetic box or bag is out of question since cellulose nitrate lacquer finished objects should be stored in a well-ventilated space due to the vapors that the degrading cellulose nitrate releases.[18]

Low temperatures protect the plastic from degradation. The optimal storage condition for both the vinyl and the cellulose nitrate lacquer of the Artek chair are at a temperature below 20 °C and stable relative humidity around 50%, protected from UV radiation. Storing the chair in complete darkness would be optimal, and the maximum exposure to light should not exceed 50-100 lux.[19]

PVC objects dating from the 1950s to 1970s must be handled with caution because of the phthalate plasticizers that have been commonly used during those decades. These plasticizers can be absorbed through skin contact and, therefore, museum professionals and conservators should wear gloves while handling these objects.[20]

## Final words

The conservation of plastics is a growing field of conservation. This paper is one take on the conservation of PVC and serves as a reference for similar conservation cases. More research and long-term monitoring is needed to establish conservation methods for degrading PVC.

This article is based on the author's bachelor's thesis in furniture conservation at the Helsinki Metropolia University of Applied Sciences in May 2016.

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## Notes

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**Figures 10a, b** The Artek chair before and after conservation.

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