CELLOPHANE IN COLLECTIONS

Anne Léculier

Cellophane Objects from Vietnam

In 2003 the American Museum of Natural History presented *Vietnam, Journeys of Body, Mind and Spirit*, an exhibition illustrating Vietnamese culture in the early 21st century. Lanterns from this exhibition, made with cellophane stretched over a bamboo structure, showed unusual conservation problems. The cellophane on these objects split soon after arrival from Vietnam. Uncoated cellophane is a very hygroscopic material and these objects, with the movement of the cellophane constrained by the structure of the lantern, exhibited extreme sensitivity to low RH levels.

The objects were manufactured in Vietnam, where the average humidity is 80-90% and rarely drops below 70%. At the time of construction, when stretched over the bamboo framework, the cellophane had a high moisture content. Climate controlled areas at the museum are at 70°F and 50% RH. Even in this environment the objects were under considerable strain as their moisture content lowered, and the cellophane appeared tight and puckered. As winter approached, the RH in non-climate controlled work spaces dropped dramatically, with data loggers frequently recording levels of 15-25% RH. When moving the lanterns through these spaces it would take less then 5 minutes before crackling sounds were heard, a sign that the cellophane was contracting further and/or the adhesive failing. On one occasion several panels of a cellophane lantern exploded, with multiple fractures, when it was moved from a climate controlled area to an uncontrolled area for photography.

The challenge presented by these objects was to keep them stable by providing an environment at the highest RH possible, and to devise a treatment to repair and stabilize those that had split.

Figure 1. Child with rabbit lantern at the Mid-Autumn Festival. This festival was once a prelude to the harvest and a petition for abundance, but has now become a celebration of children. Gleeful children parade around their neighborhoods wearing colorful masks and carrying bobbing lanterns.

Figure 2. Market scene. The lanterns are mostly constructed with single sheets of uncoated cellophane, paper and foil stretched over open bamboo structures. In some cases the lanterns are constructed flat but are designed to be pried open with bamboo spacers during festival time, further straining the cellophane.

The Manufacture of Cellophane

Cellophane is a solid cellulose film product, developed by Swiss chemist Jacques Brandenberger in 1908 following the discovery of the viscose process by English chemist Charles Cross and Ernest Bevan in 1891. It is a transparent, strong, flexible sheet, and is produced to many different specifications. (Plastic Distributor and Fabricator Magazine, www.mfa.org).

Cellophane is made using the viscose process with some minor adjustments at the end of the procedure. Cellulose is first extracted from raw products: wood pulp or cotton. Raw wood pulp with a cellulose content of 50% is treated with acid and steam followed by basic sodium sulfide, yielding a 92-98% cellulose product. Raw cotton has a cellulose content of 95%, and when treated with 2-5% aqueous sodium hydroxide (which removes impurities) produces 99% cellulose. The alpha-cellulose produced has a degree of polymerization (DP) ranging from 1400-800. Natural cellulose (untreated) can have a DP of up to 10000 (Odian 1981, Heuser 1947, Hutchins1984, Hyden 1929).

The cellulose, produced as sheets, is soaked in 18-20% aqueous sodium hydroxide at room temperature for 20-60 minutes. The sodium hydroxide is physically absorbed, swelling the cellulose polymer, forming an unstable alkali-cellulose compound and dissolving the hemicelluloses in the caustic solution. The excess alkali is pressed out of the cellulose pulp. The pulp is then shredded and left to age over a 2-3 day period under controlled temperature and humidity. During this period, through oxidative degradation, the cellulose reaches a degree of polymerization of 480-470. The aged alkali-cellulose is converted into an ester, sodium cellulose xanthate, by treatment with liquid carbon disulfide at 25-30°C. This produces a viscous, light amber substance called viscose (Heuser 1947, Hyden 1929, Mayhew 2000).

This viscous solution of alkali cellulose xanthate is ripened at a constant temperature, and then extruded as a film into a bath containing 10-15% sulfuric acid at 35-40°C. The acid hydrolyzes the xanthate to the unstable xanthic acid, which decomposes without isolation. Thus the cellulose precipitates out forming sheets of 100% cellulose that have a degree of polymerization of 360-350, nearly one quarter that of the original cellulose pulp (Heuser, 1947). The process is illustrated in Figure 3.

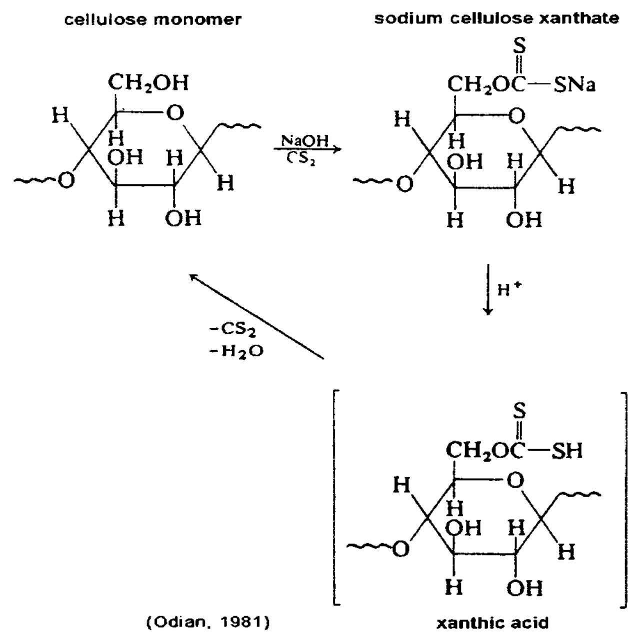

Figure 3. Chemical process from natural cellulose to regenerated cellulose.

After the casting of the regenerated cellulose sheet, it is transferred through successive tanks for finishing treatments. Immersion in tanks with fresh water removes residual acid that has carried over from the casting tank. It is rinsed in a solution (commonly sodium hydroxide, sodium sulfide or sodium sulfite) to remove free sulphur. The sheets are washed again, then bleached (using sodium hypochlorite) and washed again to neutralize the bleach bath. Cellophane produced in this way is brittle, and therefore is usually plasticized with glycerol, glucose or polyhydroxy alcohols. The sheets may also be passed through dye baths, achieving a wide range of colors (Hyden 1929, Stecher 1960, Baldwin 1999, www.goodfellow.com).

Cellophane can be left uncoated, however, it is often coated to improve the water vapor barrier and to make it heat-sealable. The coating may be a cellulose nitrate lacquer, such as pyroxylin, or more recently polyvinylidene chloride (the same material as Saran Wrap) is the common waterproof coating (Seymour and Mark 1990, Plastics Distributor and Fabricator Magazine 1998). The newest type of water-resistant coating, polyurethane/ poly(methylacrylate) interpenetrating polymer networks (IPN), will increase the biodegradability of cellophane film (Yu et al. 1999).

Properties of Cellophane

Cellophane differs from natural cellulose in two ways. First, the average degree of polymerization is one quarter its original length. Second, it is less crystalline in molecular structure, and the amorphous regions of cellophane compared to those of natural cellulose contain more irregularities in the form of chain ends, tangled chains and folded chains. When the amorphous regions absorb water molecules, the inter-molecular hydrogen bonds are broken, the distance between chains is increased, and surrounding crystalline areas become more amorphous (Hatakeyama 1989, Cardamone et al. 1992, Heuser 1947), see Figure 4.

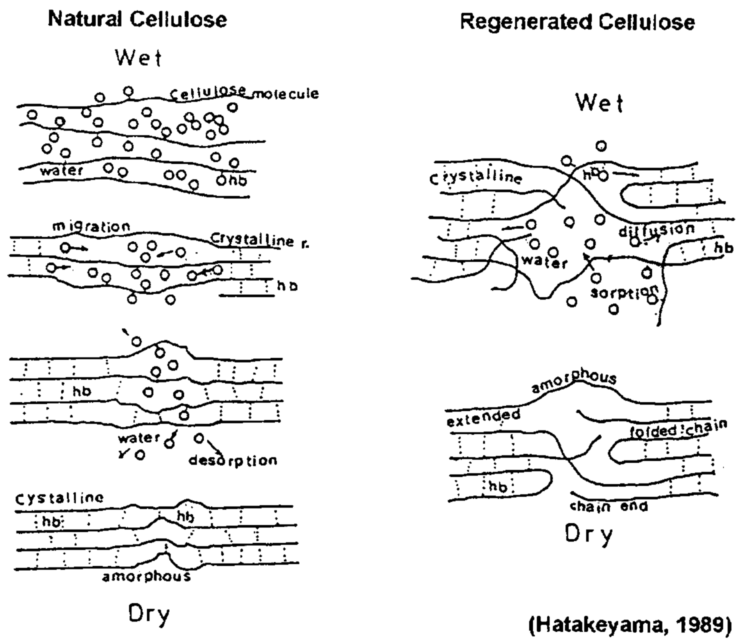

Fig. 4. Molecular models of the amorphous regions of natural cellulose and regenerated cellulose in states of humidification to desiccation.

These two molecular features explain the increased sensitivity of cellophane (over natural cellulose) to changes in relative humidity (Hutchins 1984). A study carried out by Urquhart and Eckersall (1932) shows that regenerated cellulose absorbs and desorbs moisture at a higher rate then cotton. As was discovered with these lanterns, the rate of desorption occurred rapidly. The desiccated cellophane contracted, became glassy in appearance, and irreparable damage from splitting occurred.

Identification of cellophane

	Uncoated	Coated
Physical characteristics	• Transparent • Thin • Very flexible • Makes crackling sound when crumpled • Holds crease well • Becomes limp and cockles when wet and damp • Tears easily once the tear has begun. • Does not stretch easily and when forced will remain in a deformed shape • Glassy when desiccated	• Water resistant • Mists up when breathed on
Density	1.44 – 1.45 g cm^3 (varies depending on additives in the film) This is a reliable test as cellophane is one of the densest plastics.	
Solubility	Insoluble in most solvents including water, ethyl alcohol, ethyl acetate, diethyl ether, methylene chloride, benzene, gasoline	
Pyrolysis	• Ignites easily • Continues to burn when removed from the flame • Burns like paper; same color flame, same speed of burning and same smell • The vapors given off are neither acidic or alkaline (neutral)	
Additional identification		Nitrocellulose coatings can be identified by dissolving a few crystals of diphenylamine in 0.5ml conc. sulfuric acid, add the sample. A blue color is a positive identification.

(Braun, 1982, Coxon, 1993)

Cellophane in collections

Some of the early uses of cellophane are as a packing material for hygienic, functional and decorative reasons. The latter addition of a protective coating meant that cellophane packaging could be heat-sealed. Previous to this cellophane packets were closed with ties, adhesive or adhesive tape. The adhesive tape itself was made with a cellophane backing and some tapes continue to be made as such.

In the medical industry cellophane was used as a kidney dialysis membrane, a second-skin for burns, and was experimented with for procedures such as replacing the membrane covering the brain, for tendon transplant, connecting cut nerves, in artery surgery and plastic operations on joints (British Cellophane Limited Sales Promotion Department 1955).

Non-waterproof cellophane was used as a glass laminate for the prevention of condensation build up on instrument dials and observation windows. It was used in the plywood and plastic mold industry as a separating layer between the mold and the cast. Cellophane''s resistance to penetration by oils and grease led to its use in lining tubes conveying gasoline and oil, as well as for plugging cracks in the walls of oil wells. This film was once used as a sausage casing, for drinking straws, hat linings, braids and ribbon (British Cellophane Limited Sales Promotion Department 1955). Cellophane is widely found in the textile industry as an alternative material. Some examples of these are toe-puffs for shoes, a woven cellophane hat, decorative cellophane flowers, and a cellophane embroidered cape.

Cellophane can be found in modern textile and fashion collections, medical collections, industrial collections, modern art collections, ethnographic collections, and in archival collections. It has also been used as a packing material for specimens and artifacts themselves and in the adhesive tape that may attach the catalogue information to the artifact/specimen

Treatment carried out at the American Museum of Natural History

Damage to the cellophane lanterns was in the form of tears and punctures (Figs. 5-6). The tears were multi-forked or single forked, with the cellophane flapping loosely. Repairs were needed to prevent further splitting and to restore the objects visual integrity. The issues faced were to join the split edges and to allow the cellophane to move as it needs with future changes in relative humidity, without disrupting the colorful transparent aesthetic.

The damaged panels were lined with a clear, lightweight Mylar (polyester) sheet attached with spots of adhesive applied along the internal bamboo structure. Each loose cellophane flap was similarly spot adhered to the Mylar. The adhesive chosen was polyvinyl acetate AYAH resin because of its flexibility at room temperature. In dealing with the torn pieces of cellophane, the edges did not come back together because the cellophane could no longer be placed under as much strain as it had previously been.

The treatment was successful in that the lanterns transparency was maintained, the flaps of cellophane were secured, and the Mylar lining and adhesive were not visible. The drawbacks are that the tears were still visible and the smooth cellophane surface could not be restored.

The objects were stored and handled in climate controlled spaces and when transported through the museum, they were packed in closed polyethylene bags buffered with silica gel to reduce potentially damaging fluctuations.

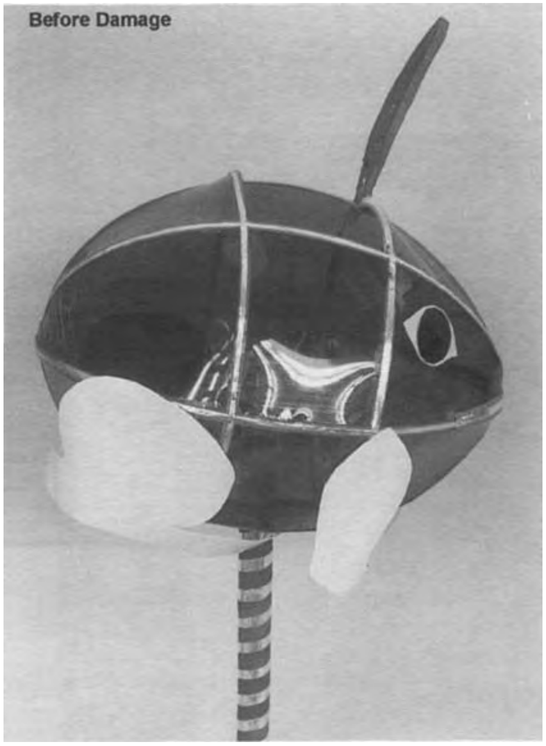

Fig. 5. The cellophane on this rabbit lantern is visibly taught over the bamboo structure.

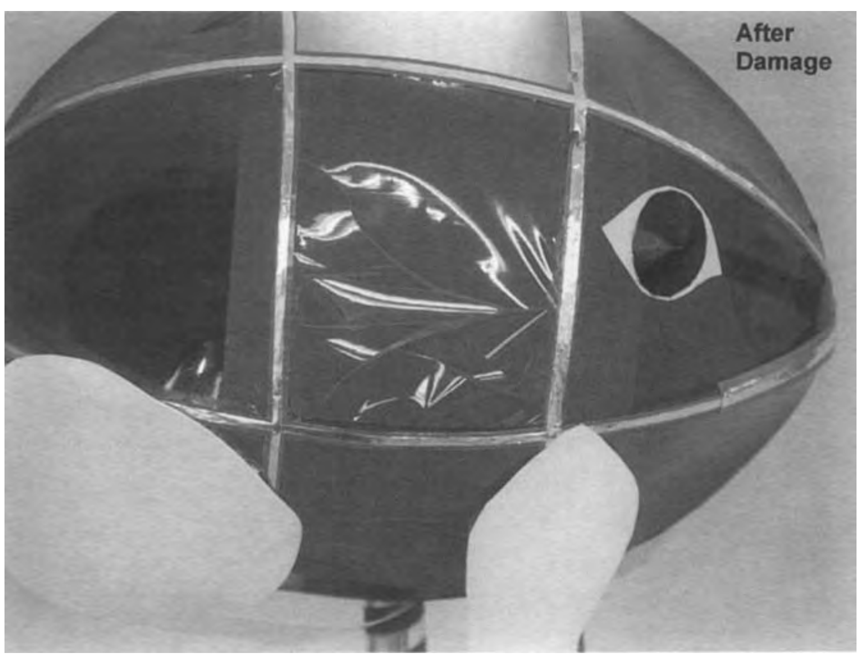

Fig. 6. Several panels on this lantern shattered within 15 minutes of transfer from a climate controlled space into a low relative humidity environment.

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Author's Address

American Museum of Natural History, Anthropology Department, Central Park West at 79th Street, New York, NY 10024, (leculier@amnh.org)