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GUIDE TO THE IDENTIFICATION OF COMMON CLEAR PLASTIC FILMS

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Clear plastic films often are used in collections to protect museum items from agents of deterioration such as particulates, pests, water, improper handling, and inappropriate relative humidity (Bensusan, 1966; Rose and de Torres, 1992; Ogden, 1994). These films may be used as protective coverings (Guynes, 1992) or as the construction materials for enclosures (Hawks and Williams, 1986). In most instances, users of these films select materials that are inert, stable, and sufficiently transparent that the contents can be seen (Taylor, 1988). This is particularly true when films are in close proximity to collection objects or records.

There are potential problems associated with the use of clear plastic films in collections. Most of the damaging effects of the selected plastic films result from additives that are mixed in during fabrication. These additives can improve the ease of production or allow manipulation of the plastic to acquire specific characteristics for the final product. Common groups of chemical additives include plasticizers, fillers, lubricants, antistatic agents, ultraviolet stabilizers, antioxidants, biocides, and flame retardants. Many additives in plastic films can migrate into materials near or in contact with the plastic (Baker, 1995). Another problem is that some plastic films may form harmful by-products under certain environmental conditions, such as ultraviolet radiation, heat, or solvents. In turn, these by-products can affect the chemical stability and integrity of museum objects by causing contamination and loss of organic information within the object (Horie, 1987). Other films may exhibit clinging properties as a result of static electricity. Static charges may attract abrasive or hygroscopic particles, such as dust. They also may attract minute object parts, such as flakes, hair, and fibers. No single plastic film will serve the needs of every collection application (Baker, 1995). Because of the risks associated with certain plastic films, responsible users will take precautions to select preferred products.

Taylor (1988) was one of the first authors to address the needs of the museum community by describing methods for differentiating clear plastic films. Since Taylor's (1988) work, new information on plastic films has become available (Brandrup and Immergut, 1989; Morgan, 1991; Baker, 1995; Woebcken, 1995; Braun, 1996). Although much of this information is useful, the amount of detail exceeds the needs of the collection worker.

This leaflet assimilates useful information from the literature and develops practical techniques and strategies to help in the systematic identification of common clear plastic films that may be found or used in museum collections. Although infrared spectroscopy of the plastic film can provide far more definitive answers, the necessary equipment is unavailable to many collection workers. To assist with the tentative identification of clear plastic films, simple analytical techniques are described and a dichotomous key is provided. A table summarizes descriptive information about each plastic and may be used to help verify the identification of the plastic in question. Because factors such as additives, combination polymers, and degradation products can give results that go beyond the limits of the described techniques, all results should be considered as only tentative identifications.

The plastic films incorporated in this project include polyethylene (PE), polypropylene (PP), polystyrene (PS), poly(ethylene terephthalate) (PET), poly(vinyl acetate) (PVAc), cellulose triacetate (CTA), polycarbonate (PC), poly(vinyl chloride) (PVC), poly(vinylidene chloride) (PVDC), poly(vinyli-dene fluoride) (PVDF), polyamide (PAM), and cellulose nitrate (CN).

TESTING METHODS

Seven tests were identified as simple in application, yet useful in the systematic identification of common, clear, plastic films. To conduct these tests, it is important to practice laboratory safety and to have basic supplies and equipment. For example, the Beilstein and pyrolysis tests require a Bunsen burner or a propane torch. The former also requires a clean copper wire. The diphenylamine test requires diphenylamine and 90% sulfuric acid. A 1-L beaker (for mixing solutions) and a set of pipettes with pipette bulbs are useful in handling testing fluids. A standard hole punch is useful for cutting similarly sized test samples. Flint-glass vials with polyethylene caps were used for the solvent tests; if other caps are used, they should have polyethylene liners. Finally, safety goggles, metal forceps, plastic gloves, test tubes, a test tube holder, a laboratory apron, and fume hood are recommended for safety purposes.

Awareness and concern for health and safety issues involving testing methods must be taken seriously. Because high concentrations of sulfuric acid can cause third degree burns, all precautions must be taken to avoid contact with skin, eyes, and clothing. If exposure does occur, remove contaminated clothing, flush the exposed body parts with cold water for at least 15 min, and then seek medical attention. Also, because trichloroethane and other chlorinated hydrocarbons and aromatic compounds pose serious risks to personal health and environmental quality, they must be handled and disposed of properly and according to government regulations. For all chemicals, the respective Material Safety Data Sheets should be consulted prior to use.

Diphenylamine spot test.—This test detects the presence of cellulose nitrate and is described by Williams (1994). The reagent is a solution consisting of diphenylamine (5 g), concentrated sulfuric acid (90 ml), and distilled water (10 ml). Slowly add the sulfuric acid to the distilled water, stirring continuously to help dissipate the resulting heat. Continue stirring as the diphenylamine is added to the solution. Add the diphenylamine in small portions of 0.5 g. This reagent is relatively stable but potentially corrosive. However, it can be stored in a glass bottle and used over several years. To use the reagent, simply place a drop on the plastic sample. If the sample contains cellulose nitrate, the solution will turn dark blue. If a positive response is obtained, layers of the sample should be retested under magnification to determine if only part of the film is cellulose nitrate. Simulations of a positive response can be achieved by using the reagent on Duco Cement™ (Williams, 1994). Results are recorded as (1) turns dark blue or (2) does not turn dark blue. If cellulose nitrate is potentially present, it is essential that it be identified before attempting any burn test; if it is known to be absent, it might be desirable to skip the diphenylamine spot test because of safety risks of handling sulfuric acid.

Beilstein test.—The Beilstein test indicates the presence of chlorine and is described in the literature (Anonymous, 1993; Braun, 1996). First, place a clean copper wire over a Bunsen burner or torch to burn off residual impurities. Continue to heat the wire until the flame is colorless (except for the blue color of the original flame). As the wire cools, melt part of the sample onto the wire and place both at the edge of the flame. Note any color changes in the flame. Results are recorded as (1) green or blue-green indicating the presence of chlorine, or (2) yellow, orange, or no change indicating the absence of chlorine.

Density test.—The density test qualitatively determines whether the specific gravity (sp gr) of the sample is greater than, close to, or less than, the specific gravity of a testing fluid. Fluids used include distilled water (sp gr, 1.00), saturated sodium chloride (sp gr, 1.20), saturated magnesium chloride (sp gr, 1.34), and saturated calcium chloride (sp gr, 1.45). A standard hole punch is useful for cutting out test samples. Drop the sample into the testing fluid and observe whether the (1) sample floats, indicating that the specific gravity is less than that of the testing fluid, (2) sample sinks, indicating that the specific gravity is greater than that of the testing fluid, or (3) sample remains suspended, indicating that the specific gravity is close to that of the testing fluid. If the surface tension of the water causes concern about reliable responses, this may be resolved by dipping the tip of a straight pin into liquid soap and then agitating the pin (with the adhering soap) in the water sample. Because it is possible for very small air bubbles to cause misinterpreted responses, be sure that the surface of the sample is free of bubbles.

Solubility test.—Because solvents may affect different plastic films in various ways, an understanding of sample and solvent interactions can be useful for identifying plastics. The solvents tested include acetone, toluene, trichloroethane, turpentine, and hydrochloric acid. Flint-glass vials, sealed with polyethylene caps, are used for combining and observing a hole-punched sample in the solvent. Drop the sample into the solvent, secure the cap, and gently shake the contents. Responses, such as changes in color, shape, or texture, should be checked after 10 min, 1 h, and 24 h. In some cases, it can be useful to mark the edge of the sample with a permanent marker so that it can be located easily in the solvent; however, some solvents may affect the marker as well. Recorded responses are (1) dissolved the sample or (2) did not dissolve the sample.

Burn test.—The flammability and residue of ignited plastic film can be useful in identifying some plastics. However, added manufacturing ingredients can reduce the reliability of the results. The size of the sample should be about 2 x 4 cm. Braun (1996) also describes this test as a "flame test."

Step 1.—Reduce the flame on the Bunsen burner or torch to a minimum. With the forceps, hold the sample over the flame. The sample will demonstrate a specific behavior as it melts or burns. The color of the flame may be (1) yellow, (2) orange, (3) orange and yellow, or (4) orange and blue. The consistency of any melted drops also can help identify the type of plastic. Recorded responses are (1) melts, (2) drips, and/or (3) shrinks.

Step 2.—Remove the sample from the flame before it is consumed, noting the flammability of the plastic. Recorded responses are (1) continues to burn or (2) self-extinguishing.

Step 3.—The residues left after the sample is burned are (1) charred or (2) clear.

Pyrolysis test.—This test (Braun, 1996) allows the characteristics of a heated film to be examined without direct exposure to a flame. Test samples can be obtained with a hole punch.

Step 1.—Place the sample in a glass test tube, gripping the tube at the upper end with a pair of tongs.

Step 2.—Reduce the flame of the Bunsen burner or torch to a minimum and slowly heat the test tube. Note changes in the sample. Recorded initial responses are (1) melts or (2) softens. The responses after moderate heating are (1) decomposes or (2) vaporizes. The final appearance of the residues are (1) charred, (2) resinous, or (3) no residue.

Step 3.—Test the acidity of the pyrolysis fumes by inserting a piece of universal pH paper, slightly moistened with water, into the mouth of the test tube so that it is contacted by the vapors. Recorded responses of vapors are (1) acidic, (2) neutral, or (3) alkaline.

Stretch-tear test.—Examining a film's response to stress by stretching and tearing can be useful for identifying clear plastic films.

Step 1.—Attempt to stretch an unnotched sample lengthwise and widthwise. Recorded responses are (1) stretches, (2) difficult to stretch, or (3) will not stretch.

Step 2.—Tear a notched sample, noting the condition of the edges along the tear. Recorded responses are (1) smooth edges, (2) stretched edges, or (3) rough unstretched edges.

Key for the Identification of Clear Plastic Films

The following textual flow chart is in the form of a dichotomous key for systematically identifying clear plastic films.

1. Diphenylamine test produces dark blue liquid................ **CN**
1'. Diphenylamine test does produce dark blue liquid **2**
2. Beilstein test produces greenish flame................................ **3**
2'. Beilstein test does not produce greenish flame.................. **4**
3. Floats (or is suspended) in saturated calcium chloride solution .... **PVC**
3'. Sinks in saturated calcium chloride solution............. **PVDC**
4. Floats in distilled water **5**
4'. Sinks (or is suspended) in distilled water............................ **6**
5. Notched sample tears with a stretched, irregular edge .... **PE, unoriented PP**
5'. Notched, clear sample tears with a smooth edge .... **.. oriented PP**
6. Sinks in saturated magnesium chloride solution **7**
6'. Floats in saturated magnesium chloride solution **8**
7. Floats (or is suspended) in saturated calcium chloride solution .... **PET**
7'. Sinks in saturated calcium chloride solution.............. **PVDF**
8. Floats in saturated sodium chloride solution....................... **9**

8'. Sinks in saturated sodium chloride solution...................... **10**
9. Pyrolysis results in vaporization and production of neutral vapors .... **PS**
9'. Pyrolysis produces residue and nonneutral vapors............ **11**
10. Ignited sample self-extinguishes; pyrolysis produces neutral vapors .... **PC**
10'. Ignited sample continues to burn; pyrolysis produces acidic vapors .... **CTA**
11. Does not dissolve in acetone; pyrolysis produces alkaline vapors .... **PAM**
11'. Dissolves in acetone; pyrolysis produces acidic vapors....... **PVAc**

Discussion

The identification of plastics is complex, and the literature is extensive. The described tests only serve as an introduction. The first limitation of this leaflet is the selection of included materials. Because of the diversity of plastics and their applications, samples selected included those that may be used in collections (particularly those that might be in close proximity to collection objects or archival materials). Clear plastic films represent a group of materials that typically are used in collections because of their transparency and protective qualities. Although this leaflet incorporates 12 types of plastic film, other types of film are currently in use, and new films will be created as fabrication technology develops new formulations and applications of plastics. Individuals must be aware that they could potentially be testing a plastic film not included in this contribution, a laminated combination of plastic films, or a coated plastic film.

Sample reliability is another factor that might influence the success of replicating the results. There are a variety of ways that a sample might be contaminated such that testing procedures could lead to questionable results. The most difficult types of contaminants to detect are those introduced by the manufacturer as part of the fabrication process. This is the primary reason that this study is restricted to clear plastic films. Samples also may become contaminated through degradation processes or by absorbing contaminates from external sources. If aged samples exhibit discoloration, tackiness, brittleness, shrinkage, or unusual odors, the results should be carefully scrutinized before making final decisions. In these cases, plastics exhibiting such qualities should be removed and avoided for collection-related uses. New and unused samples will provide the most reliable results using the described identification methods. Furthermore, it can be useful to obtain known samples of films to fully appreciate the descriptions of the responses for each testing method. Because of the variables involving material quality and user interpretation, each film sample should be tested at least three times.

Finally, differences in interpretation among observers could potentially lead to different results. For this reason, attempts were made to standardize and simplify the options that might be influenced by individual interpretation. This effort is reflected in the descriptions of testing procedures, option selections in the dichotomous key, and the tabulated summary for the plastics reviewed (Table 1).

The selection of a plastic film will depend on its intended use and proximity to materials that need to be protected (Baker, 1995). Permeability, flexibility, ease of handling, and resistance to heat, abrasion, and light, are important factors that will lead to a preference for a specific product. Any clear plastic film that is to be used in contact with valued materials should be carefully selected and not contribute to problems such as abrasion, static, condensation, or release of harmful chemical compounds. There may be less risk from these problems, if the plastic film is not in contact with the material to be protected. The risk of chemical interactions might be reduced if the plastic film does not touch or encapsulate materials to be protected. However, because the future use of an existing plastic film in the collection may change, it would be best to start with an acceptable product. For plastic films, a clear, stable, untinted, and nonreactive product would be preferred.

With regard to chemical preference, plastic films composed of only carbon, oxygen, and hydrogen (i.e., polyethylene, polypropylene, and polyester) tend to be more stable and less reactive. In contrast, products that include elements, such as chlorine, fluorine, and sulfur (i.e., poly[vinyl chloride], poly[vinylidene chloride], poly[vinylidene fluoride]), should be avoided because of the risk of harmful by-products. Similarly, any plastic that has an odor should be avoided because of the risk of plasticizers or degradation by-products.

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Table 1.—Characteristic properties of plastics. Supplementary information, including product densities, was taken from Young (1989), Krause et al. (1983), Windholz et al. (1983), Horie (1987), Lipe (1996), and Saechtling (1996). DPA = diphenylamine spot test.

Plastic	DPA	Beilstein test flame color	Specific gravity	Solvents dissolving sample	Burn test	Pyrolysis test	Stretch-tear test Stretch (no notch)	Tear (notched)
PE	no	yellow	0.85–0.98		yellow flame drips continues to burn clear residue	melts vaporizes no residue neutral vapor	stretches	stretched edge
PP	no	yellow	0.85–0.92		yellow flame melts continues to burn clear residue	melts decomposes resinous residue neutral vapor	does not stretch (oriented) stretches (unoriented)	smooth edge (oriented) stretched edge (unoriented)
PS	no	yellow	1.04–1.08	toluene trichloroethane turpentine	orange/yellow flame not applicable self-extinguishes charred residue	melts vaporizes no residue neutral vapor	does not stretch	smooth edge
PET	no	no change	1.38–1.41		orange flame melts & drips continues to burn charred residue	melts decomposes charred residue acidic vapor	does not stretch	rough edge
PVAc	no	yellow	1.17–1.20	acetone hydrochloric acid	yellow flame melts, drips, & shrinks continues to burn charred residue	melts decomposes resinous residue acidic vapor	difficult to stretch	smooth edge
CTA	no	orange	1.28–1.31	acetone	orange flame melts & drips continues to burn charred residue	melts decomposes charred residue acidic vapor	does not stretch	smooth edge
PC	no	yellow	1.20–1.22	toluene	orange/yellow flame not applicable self-extinguishes charred residue	melts decomposes resinous residue neutral vapor	does not stretch	smooth edge
PVC	no	green	1.15–1.45		yellow flame melts & shrinks self-extinguishes charred residue	softens decomposes charred residue acidic vapor	stretches	rough edge
PVDC	no	blue/green	1.65–1.88		orange flame melts & shrinks self-extinguishes charred residue	softens decomposes charred residue acidic vapor	stretches	smooth edge
PVDF	no	orange	1.76–1.80		yellow flame not applicable self-extinguishes charred residue	melts decomposes charred residue acidic vapor	stretches	smooth edge
PAM	no	orange	1.10–1.16	hydrochloric acid	orange/blue flame melts & drips continues to burn charred residue	melts decomposes charred residue alkaline vapor	stretches	stretched edge
CN	blue	white **explosive**	1.35–1.40	acetone	**AVOID TESTING** **violent white flame** harmful vapor	**AVOID TESTING** **explosive** does not melt	difficult to stretch	smooth edge

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