# LAMINATION METHODS - PAPER MATERIALS

*P.Renganathan &R.Piramuthu Raja Ashok*

**ABSTRACT:**

The concept and use of conservation, is an age old tradition. The sole idea behind conservation is to ensure stabilization and protection of records against dangers and also correction of damaged wealth. The priority of placing materials in conservation is based on their rate of deterioration. The more rapidly decaying materials are given first importance than others. One such material is archival paper, as far as conservation of paper objects are concerned, the lamination process is the most widely used method.

This paper focuses mainly on the different materials and methods used for the lamination of archival paper, their characteristics and their compatibility for archival paper conservation. Since there is no standard available in Bureau of Indian Standard (BIS) for the materials used in document conservation. Archival holders, not knowing material's properties, chemistry, & disadvantages, simply adapt any one available method in vicinity with an intention to safe guard their archival holdings. But they are not achieving their goal. This paper will guide& help them to choose the correct material.

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## Introduction:

The concept and use of conservation, is an age old tradition. The sole idea behind conservation is to ensure stabilization and protection of records against dangers and also correction of damaged wealth. The priority of placing materials in conservation is based on their rate of deterioration. The more rapidly decaying materials are given first importance than others. One such material is archival paper, as far as conservation of paper objects are concerned, the lamination process is the most widely used method. This paper focuses mainly on the different materials and methods used for the lamination of paper, their characteristics and their compatibility for paper conservation.

## Paper:

Paper is undoubtedly the most common base material for documents in archives and libraries. It is a thin material used for writing upon, printing upon or packaging. It is produced by the amalgamation of fibers, typically vegetable fibers composed of cellulose, which are subsequently held together by hydrogen bonding. While the fibers are usually natural in origin, a wide variety of synthetic fibers, such as polypropylene and polyethylene, may be incorporated into paper as a way of imparting desirable physical properties. The most common source of these kinds of fibers is wood pulp from pulpwood trees. Vegetable fiber materials such as cotton, hemp, linen, and rice are also used.

Paper can be classified into types based on the type of manufacturing:

a. Hand-made paper
b. Machine-made paper

Hand-made paper is considered to be better than the latter because the machine-made paper is made out of wood pulp. Wood based papers have low permanence and service life due to the presence of lignin which causes degradation by forming acidic substances.

To give paper strength and to enable it to receive writing ink without feathering, the cellulose is treated with sizes and fillers. In early period, gelatin was used as size material. But in modern papers, the sizing agent is alum rosin, which is acidic and will contribute to the deterioration of paper. The fillers normally added are china clay, chalk and certain alkaline material.

A **document** is a bounded physical representation of body of information designed with intent to communicate. The documents are created with the aid of paper, media/ink and the sizing layer on the paper. The chief constituent of paper is cellulose.

**Factors of deterioration of Paper:**
The paper can be damaged or deteriorated with the following factors:

- Environmental factors: like light, temperature, humidity, dust, dirt, pollution, water, fire, etc.
- Biological factors: microorganisms like fungi, bacterial insects, silver fish, cockroaches, bookworms, book lice, termites, rodents, etc.
- Chemical factors: formation of acids in paper. The sizing material alum rosin in majority of paper causes acidity and makes it acidic paper.
- Human factors: like handling and improper stacking, theft, etc.
- Natural Disasters: like floods, earthquakes, etc.,

These factors attack the celluloid structure of paper and cause the degree of polymerization of the chain to decrease resulting in chain scission. These small chains have reactive end groups which on exposure to air or any factor mentioned above becomes acidic accelerating the scission reaction further. This phenomenon makes everyone to find a protection of the polymer chain from external factors.

**Conservation:**
**"Conservation is defined as the process of dynamic management of change in order to reduce the rate of decay, and to prolong the life cycle of the concerned objects. The cultural, scientific and natural heritage must be conserved as authentic documents. Intervention should be limited to actions strictly necessary to insure the techniques and materials used should not impede future treatment or examinations."**
Source: Sir Bernard Feilden, Rome, 1986.

The act of increasing the life expectancy of damaged or undamaged elements of cultural property (paper) is termed as conservation.

In general paper conservation can be measured in three ways.
1. Duplicate conservation
2. Preventive conservation.(passive way)
3. Curative conservation.(active way)

**Duplicate Conservation**:
This duplicate conservation means making copies of the particular document in another format and keeping it for future reference. It includes the following.
1. Microfilming
2. Computer scanning –digital preservation.
3. Photocopying
4. Photographs.

In these methods we have to search some other method that preserves these copies.

**Preventive Measure:**
Preventive measure is to take all the steps required to preserve the document by external ways. The preventive measure can be generalized under three headings:

1) Storage
2) Good Housekeeping
3) Pest control.

Some of the examples for preventive measures are as follow:

- To protect from light, heat, fire, etc. the library building architecture should be drawn and built accordingly.
- The control of dust, air, dirt and moisture inside the library room should be properly maintained and periodical housekeeping and cleaning is necessary
- To maintain relative humidity and temperature, air conditioning should be used.

These preventive actions will help to extend the life period of paper to some extent only. And due to improper care and natural properties of paper it automatically degrades and becomes a '**brittle paper**'.

**Curative Measure:**
Curative measure consists of all forms of direct action aimed at the life expediency of damaged or undamaged elements of cultural property (paper document). It includes the following.

a) Washing and Cleaning
b) Deacidification
c) Fumigation
d) Encapsulation
e) Lamination
f) Binding & Filing

**Washing and Cleaning:**
Due to dust and dirt, the documents become brittle which are to be cleaned first. The washing can be done by the following methods.

1. For manuscripts, which are written by water-soluble inks, we can use rectified spirit (alcohol) for cleaning and washing.
2. The insoluble ink materials can be washed and cleaned with distilled water and steam water bath.

**Deacidification:**
Due to acid formation and acid content, paper documents get decayed. To test the probable life period of paper, deacidification is necessary. It can be explained by three methods as follows:

a.) **Aqueous deacidification** in which affected paper is immersed in or brushed with an alkaline solution or suspension until the acidity neutralizes. In general, magnesium bicarbonate solution is recommended as most effective.

b.) **Vapour phase deacidification:** This employs chemicals (generally liquid ammonia) in gaseous forms to neutralize the acid. This method is an easier to use and offers greater productivity either of the immersion process.
c.) **Mass deacidification:** methods are being developed in number of countries, but are still in the developmental stage-all require expensive plan**,** mostly these are likely cost effective only where a high volume of work can be foreseen

**Fumigation:**
Due to biological factors, the paper documents are deteriorated. To eliminate 100% the above said microorganisms, insect, etc., a fumigation treatment is necessary by appropriate chemicals.
Thymol & Para dichlorobenzene is longer preferred chemical for fumigation. For this, we need a chamber. Nitrous oxide gas can also be used.

**Encapsulation:**
This is the method adopted and approved by International Organization for conservation of paper documents. In this system, only polyester film is approved. The system can be done by placing the document in between two bigger size polyester films, and their four sides are to be sealed either by double sided tape or by machinery methods. Encapsulation is not advised to be used for very fragile documents. The air in between the document and the polyester film will react with paper (hydrolysis/oxidation) and may degrade the paper still further.

**Lamination:**
Lamination is a general term for fusing together thin layers of different materials. In archival contexts, lamination refers specifically to the process of layering a sheet of archival paper with stronger materials, in order to strengthen the object. The standard method, developed by William Barrow, used heat and pressure to fuse paper between two thin sheets of a plastic (usually cellulose acetate).This refers to the cellulose acetate lamination invented during 1930s. From this method, many attempts were made to develop new techniques countering the disadvantages posed. The new methods evolved simply by replacing the materials and employing a different procedure for conservation of paper objects.

**Binding or Filing:**
Rebinding or Binding the de-acidified, laminated or encapsulated documents is also extent the life period of the documents that to be done with quality materials like acid free board, gum , cloth leather etc.

**Present Scenario in paper conservation:**
Libraries have long been aware of the magnitude of the problem of acidic paper; sometimes referred as "**brittle paper"** and the effect this has no access to collections. Literally speaking, millions of books and documents are disintegrating on library shelves. **The paper is so fragile that the items can no longer be issued for consultation**. It is clear that if these threats remain unchecked, it has the potential to lead a massive loss not

only on information but also on heritage material. It is essential to tackle the problem. In order to prevent this deterioration International Standard Organization (ISO) during 1994 arrived standard to use **"permanent paper"** for publishing **(ISO 9706).** This will help to increase the life period of paper, published after incorporating these standards only.

It is to be noticed that this will not help to the issues already discussed above as '**brittle paper'** and those books and documents which are lying in the library shelves and are not issued for any consultation. In this context, we must think of conservation treatment to those documents, books and brittle paper. The conservation treatment should protect the '**brittle paper'** from further decaying and extent the life period. The material used should ensure it by its physical and chemical properties and way of its application procedure.

**Materials Used for conservation of Paper:**

The different lamination methods employ different kinds of material depending on the requirement. These methods can be compared to the processing of a composite material.

**Composites** are engineered materials made from two or more constituent materials with significantly different properties and which remain separate and distinct within the finished structure.

Generally a composite material consists of two main components viz. a **reinforcement layer and a matrix.** This is in coherence with the **lamination process**, where the plastic film is the reinforcement and the adhesive/glue is the matrix component. The only difference is that in a composite material the reinforcement is impregnated with the matrix whereas in the conservation process, both the components are distinct and a coating of matrix is applied over the reinforcement layer.

Now let us discuss the functions of each of the component pertaining to the conservation of paper object.

**Reinforcement Material:**
The reinforcement is a member or a material which gives additional strength or support for an object.
In this paper, the following materials are taken for discussion:

a) Chiffon-cloth (chiffon-silk, chiffon-synthetic fibers)
b) Tissue paper.
c) Synthetic Polymers.
    i. Polyethylene.
    ii. Polypropylene.
    iii. Polyvinylchloride.
    iv. Cellulose acetate foil
    v. Polyesters

**In context of paper conservation, the reinforcement material must satisfy the following characteristics**:

1) Must provide mechanical strength to paper objects.
2) Must protect the paper objects from environmental factors such as light, temperature, humidity, dust, dirt, pollution, water, fire, etc.
3) Must be resistant to chemicals, acids and other solvents.
4) Must be able to resist the attack of biological microorganisms such as fungi, bacterial insects, silver fish, cockroaches, bookworms, book lice, termites, rodents, etc.
5) Should not produce any acidic, toxic products during service life.
6) Should provide an aesthetic look and high optical resolution while reformatting through digitalizing, microfilming and photocopying.
7) Should not crumble after lamination.
8) Should not produce any change in color during service life.
9) Should have long term mechanical properties and must be durable for a very long period.

**Matrix Material:**

The matrix material is generally the adhesive/glue applied on surface of the reinforcement or in some case the paper object. Utmost care has to be taken in selecting the matrix material because it is this material which is in direct contact with the paper object.

In this paper, the following matrix materials were taken for discussion:

a) Starch based adhesive.
b) Methylcellulose derivatives.
c) Cellulose acetate foil and acetone system.
d) Hot melt plastics.
e) Acrylic copolymers.

**In context with paper conservation, the factors considered for the selection of the matrix (adhesive/glue) are as follows:**

1. An adhesive should never develop wrinkles or shrink after setting.
3. It should not be hydrophilic and reactive to the environment gases.
4. It should be characterized by forming stable and flexible film.
5. Stability, durability and reversibility are the desired characteristics of a quality adhesive.
6. It should be colorless and not change its color after setting.
7. It should be free from acidity.
8. It must provide an aesthetic look.

Thus the materials for conservation of paper must be selected on the basis of these factors. Adhesives prepared from wheat flour (Maida), rice (starch) and Methyl cellulose is normally preferred in Indian subcontinent for restoration and binding of Archivo-Library Wealth. In modern days, there has been a good response for the use of synthetic adhesives. Now let us discuss the materials that are in usage in different conservation methods.

**Chiffon based materials:**

Chiffon, from the French word for cloth, is a lightweight, balanced plain-woven sheer fabric woven of alternate S- and Z-twist crepe (high-twist) yarns. The twist in the crepe yarns puckers the fabric slightly in both directions after weaving, giving it some stretch and a slightly rough feel. Chiffon can be made from cotton, silk or synthetic fibers, but is usually associated with silk or nylon.

This is a reinforcement material used in the chiffon lamination process. This process was extensively used between about 1920 and 1960. In this process, aqueous adhesives (e.g. Wheat, rice starch paste) were used.

During 1930s, there was practice of using transparent silk on both sides of a paper. But later in the 1950s the silking became obsolete because the silk became chemically unstable over time. Also reversibility was a problem when silk was used. Later chiffon based on synthetic fibers was used along with aqueous adhesives.
Chiffon based reinforcements were popular in the early period of conservation. In this modern era, the chiffon based materials became obsolete due to the advent of new materials.

**Disadvantages of Chiffon based material:**

1. The objects treated with this material may be detected by pieces of thread sticking out of the edges.
2. Since the material is of natural source, there are many possibilities for biodegradation to take place.
3. Since the surface is rough, it facilitates dust accumulation resulting in the absorption of moisture attracting mold growth.
4. The size of the laminate becomes very large and the legibility is poor.
5. The removal of chiffon-silk while reversing is a difficult task while water soluble ink is used.
6. The aesthetic look is not guaranteed and problems arise while duplicating by photocopying, microfilming, etc.
7. The cost is also very high.

**Starch based adhesive:**

Starch-based adhesives are made from natural polymers derived from roots, tubers and seeds of higher plants such as maize, potatoes, wheat, rice and tapioca.

A starch-based adhesive is either cold or warm water-soluble depending on the application specifications. Starch granules are slurred in water. The mixture is heated

until the granules burst. The granules absorb water and swell increasing in viscosity forming the paste or adhesive. The starch source depends on performance, machining and economics. Dextrin is a type of dry roasted starch. A wide range of gums and pastes can be developed by controlling acidity, moisture content, and roasting temperature, varying levels of solubility and viscosity can be produced.

**Disadvantages:**

1. As starch is a biological substance, they are easily susceptible to attack by biological factors and lead to biodegradation.
2. The starch based adhesives are water soluble and the reversibility is justified.
3. When very brittle paper is reversed with water, the information gets lost and bleeding of ink is seen.
4. Starch based adhesives have poor moisture resistance and enhances mold growth, fungal attack, etc.

**Tissue paper:**

**Japanese tissue** is a thin, strong paper made from vegetable fibers. Japanese tissue may be made from one of three plants, the kozo plant, the mitsumata shrub and the gampi tree. The long, strong fibers of the kozo plant produce very strong, dimensionally stable papers, and are the most commonly used fibers in the making of Japanese paper (washi).

Tissue made from kozo, or **kozogami**, comes in varying thicknesses and colors, and is an ideal paper to use in the mending of books. The majority of mending tissues are made from kozo fibers, though mitsumata and gampi papers also are used.

**How is it used?**

Japanese tissue is used in the conservation of books and manuscripts. The tissue comes in varying thicknesses and colors, and is used for a variety of mending tasks, including repairing tears, mending book hinges, and reinforcing the folds of signatures (the groups of pages gathered and folded together at the spine) or for reinforcement of an entire sheet through backing. The mender will select a piece of Japanese tissue that closely matches the color of the paper being mended, and chooses a thickness (weight) suitable to the job at hand. The Japanese tissue is used as a reinforcement material in many lamination processes. The extremely thin Japanese tissue papers are sometimes produced in grammages as small as 6 to 8g.

**Disadvantages:**

1. Tissue paper is also a kind of paper which has similar degradation properties of an ordinary paper.
2. This type of paper generally fails when inappropriate adhesive is used
3. The tissue paper reduces the shine, clarity of the original documents, altering their colors and appearance.
4. A hazy look is seen on the final laminate making the reader difficult to see.

**Methyl cellulose adhesive:**

The methyl cellulose compounds can be subdivided into two polymer categories pertaining to the paper conservation application.

1. Methylcellulose
2. Sodium carboxymethylcellulose.

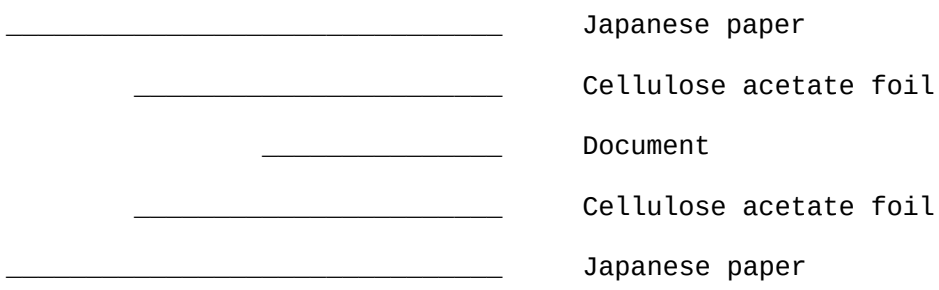
Most conservators regard the MCs and sod. CMCs primarily as adhesives. These cellulose polymers can be purchased in grades ranging from coarse to fine particles and in varying viscosities.

**Disadvantages:**

1. The cellulose backbone adheres well with the paper object at the same time is subjected to the same kind of degradation mechanism as that of paper.
2. As the reversing medium is water, the information present in the paper objects will get lost if the ink is not a permanent one.
3. Poor resistance to moisture will lead to peeling off the layers.

**Cellulose acetate and Acetone system:**

Cellulose acetate foils along with acetone have been used as adhesive for lamination between 1950 and 1960. In later stage for this kind of lamination technique, the Japanese Tissue paper is used as reinforcement. This kind of lamination technique was developed by William Barrow and certain modifications were done with advancements in technology. **The sandwich layers can be illustrated as follows:**




Cellulose acetate foil is placed over the paper object along with the Japanese tissue for strengthening purpose. Then acetone is added in order to dissolve the cellulose acetate foil and make it an adhesive. Certain plasticizers are added in order to enhance flexibility to the laminate. In another method the sandwich structure is heat melted under certain temperature and pressure.

**Disadvantages:**

1. The formation of acetic acid due to the reaction of cellulose acetate and acetone causes further degradation of paper. This phenomenon is generally referred as vinegar syndrome.
2. The objects treated with this become strongly yellowed and damaged by acetic acid or hydrochloric acid emitted by the film material or migration of its external plasticizers.
3. The application of heat and pressure during lamination was sometimes poorly controlled, resulting burnt papers.
4. The cellulose acetate laminate greatly alters the appearance and texture of documents, giving the paper a shiny surface with an uncharacterized hard, plastic feel.
5. Cellulose acetate is considered to be inherently unstable and prone to degradation easily which results in warpage, stretching, peeling off and creating greater stress on the paper object.
6. The plasticizers added to increase the flexibility, exuded as a liquid may collect on the surface of the laminate, giving it an oily appearance and often leaving the surface quite sticky.
7. The unstable laminate and plasticizers do not affect single document rather it starts the degradation of the paper objects at its vicinity and neighborhood.

**Synthetic Polymers:**

The synthetic polymers used for paper conservation purposes include both the reinforcement and the matrix (adhesive/glue). They can be listed as follows:

1. Polyethylene.
2. Polypropylene.
3. Polyvinylchloride
4. Polyester.
5. Acrylic copolymers.

**Polyethylene:**

Polyethylene is a polymer consisting of long chains of the monomer ethylene It is created through polymerization of ethane.

Polyethylene is classified into several different categories based mostly on its density and branching. The mechanical properties of PE depend significantly on variables such as the extent and type of branching, the crystal structure, and the molecular weight.

- Ultra high molecular weight polyethylene (UHMWPE)
- Ultra low molecular weight polyethylene (ULMWPE - PE-WAX)
- High molecular weight polyethylene (HMWPE)
- High density polyethylene (HDPE)
- High density cross-linked polyethylene (HDXLPE)
- Cross-linked polyethylene (XLPE)

- Medium density polyethylene (MDPE)
- Low density polyethylene (LDPE)
- Linear low density polyethylene (LLDPE)
- Very low density polyethylene (VLDPE)

The glass transition temperature is defined as the temperature, below which the polymer is hard and brittle and above which the polymer is soft and flexible. In other words, below Tg the material is glassy amorphous and above Tg the material is crystalline. It is this Tg which determines the service temperature range for a polymer.
Among the types mentioned above, only HDPE, LDPE and LLDPE are used in manufacturing of films. These films are generally used in packaging applications.

- **High density polyethylene (HDPE)** is a rigid translucent solid which softens on heating above **100º C**, and can be fashioned into various forms including films. It is not as easily stretched and deformed as is LDPE. HDPE is insoluble in water and most organic solvents, although some swelling may occur on immersion in the latter.
    a. Density = 0.96 g/cm$^3$
    b. Melting temperature = 125°C-130°C
    c. Glass Transition Temperature = -20°C
    d. Continuous operating temperature = 110°C
    e. Short term temperature = 120°C

- **Low density polyethylene (LDPE)** is a soft translucent solid which deforms badly above **75º C.** Films made from LDPE stretch easily and are commonly used for wrapping. LDPE is insoluble in water, but softens and swells on exposure to hydrocarbon solvents.
    a. Density = 0.92 g/cm$^3$
    b. Melting temperature = 120°C
    c. Glass Transition Temperature = -20°C
    d. Maximum temperature =80°C
    e. Minimum temperature =50°C

- **Linear low density polyethylene** (**LLDPE**) is a substantially linear polymer (polyethylene), with significant numbers of short branches, commonly made by copolymerization of ethylene with longer-chain olefins such as butene, hexene or octene.
    a. Density = 0.92 g/cm$^3$
    b. Melting temperature = 120°C to 160°C
    c. Glass Transition Temperature = -20°C
    d. Maximum operating temperature =50°C

**Bi-axially Oriented Polypropylene (BOPP):**

Polypropylene is manufactured by the polymerization of propylene. It has similar properties like polyethylene only difference being the extra methyl substituent group which alters the characteristics of the polymer.The general properties of polypropylene are given as follows:

a. Density = 0.85-0.95 g/cm$^3$
b. Melting Point = 165°C
c. Glass Transition Temperature = -10°C
d. improved stiffness, high tensile strength, excellent optics and good water barrier properties

Bi-axially oriented polypropylene film is designed for flexible packaging and label applications. OPP, oriented polypropylene, is a flexible material derived from melting and orienting a polymer called polypropylene. This raw material, an oil by-product, is inert and unaffected by most chemical agents occurring in daily life. Bi-axially oriented means that the polypropylene film is stretched in both the machine direction and across machine direction.

**Polyvinylchloride (PVC):**
Polyvinylchloride is a thermoplastic manufactured from the monomer vinyl chloride. This is the most widely used thermoplastic in many fields of applications. In terms of revenue generated, it is one of the most valuable products of the chemical industry. It can be made softer and more flexible by the addition of plasticizers, the most widely used being phthalates. **The structure is a homologue of polypropylene with chloride instead of methyl subsistent.**

Some of the important characteristics of this polymer are:

a. Melting Point: 212°C
b. Glass Transition Temperature = 60°C
c. Available in both rigid and flexible form
d. Thermally sensitive material that it gradually degrades before reaching the melting point. So heat stabilizers are added.
e. Undergoes thermal degradation liberating hydrochloric acid HCl vapors.

The three categories of polyethylene, polypropylene and polyvinyl chloride play a major role in thermal lamination and cold lamination processes. These polymers are generally categorized under **Commodity plastics or Low temperature thermoplastics.**

**In thermal lamination**, these materials can be used as both reinforcement (film) and matrix (hot melt gum). The outer layer of the film has a heat activated resin coating - hence the term Thermal Lamination. The film is coated with the polyethylene coating which on a certain temperature melts and fuses the document together. These films are also known as Heat set laminating films.

**The cold laminating film** sometimes called tape laminating uses pressure sensitive adhesives to bind the film to the material being laminated. This film is most important for the documents that are heat sensitive. The surface of the document is flooded with a water-soluble adhesive. It is then sent through a set of rollers with the laminating film rolled onto the top of the adhesive and the document. Pressure is applied to bond the film to the document. The application of acetone on cellulose acetate foil and tissue paper sandwich also comes under cold lamination technique.

**Disadvantages of Commodity plastics:**

1. The materials once sealed cannot be removed i.e., they are irreversible.
2. High temperature conditions damages the paper object and the plastic material used.
3. The hot melt gum, generally polyethylene based glue turns yellow within a short span.
4. The operating temperature and the pressure conditions are to be maintained accurately or it results in degradation of paper.
5. Paper objects which are very fragile and brittle cannot be treated as they get broken because of high temperature profile and while passing through the rollers.
6. While using Polyvinylchloride based films, one must be very careful in temperature settings as it is a thermally sensitive material.
7. PVC films generate toxic products such as vinyl chloride monomer, dioxins, etc.
8. PVC films are very vulnerable as it liberates hydrochloric acid vapors which are totally unacceptable for paper conservation.
9. These commodity plastic films generally turn yellow and the pages stick to each other on long run.

**Polyester:**

Polyesters are **engineering thermoplastics** made from the condensation polymerization of diacid and a diol. It is one of the most environmentally safe polymer products made today.

This material is available in two forms:

a. Polyethyleneterephathalate (PET)
b. Polybutyleneterephthalate (PBT)

Among these two, PET has excellent properties when compared with the latter. Also the films used for conservation purposes are based on PET because of its superior properties.

Poly(ethylene terephthalate) is manufactured by the condensation polymerization of ethylene glycol and dimethyl terephthalate (DMT).

PET has the ability to exist in either an amorphous or a crystalline state. The degree of crystallinity can range from 0 to 60%. This feature is very important in manufacturing PET films. The films are extruded and quenched at ambient temperatures.

The important properties of PET can be listed as follows:

a. Film thickness: 18-22 micron
b. Tensile strength: 117-173 MPa (ASTM D882)
c. Percentage Elongation: 175 (ASTM D882)
d. Glass transition Temperature: 80°C
e. Melting temperature: 265-275°C

It has very low air permeability, rich in elongation, good heat barring property, water resistant, tear resistant, non absorbent to dust and non-evasive material. It has high bonding molecules and has low degradation property than paper.

These properties make PET films to be used in the conservation of paper objects and counter the disadvantages posed by other reinforcing materials. In processes like encapsulation, thermal lamination, cold lamination, Photolam laminating system, the polyester (PET) films are used as a reinforcement material. The commercially available polyester films are **Mylar®, Melinex®, Teijin®, etc.**

**Disadvantage:**

Polyesters (PET) by nature undergo hydrolysis at high pressure and temperatures in the presence of catalyst to form terephthalic acid (TPA) and ethylene glycol (EG). This hydrolysis reaction takes place at the stringent conditions which are tabulated below:

| Catalyst | Temperature | Pressure | Time | Product |
|---|---|---|---|---|
| $NaCOOCH_3$ | 220ºC | - | 4hr | TPA & EG |
| H2SO4 | 90 ºC | 1 atm. | Minutes | TPA & EG |
| NaOH 10%wt | 200 ºC | 15-20 atm. | >4hr | Solid TPA & EG |
| NaOH | 100 ºC | 1 atm. | <1hr | Solid TPA & EG |

**Source:** Page 164, Hydrolysis of PET, by John Scheirs (1998). Polymer Recycling – Science, Technology & Applications, New York: Wiley Interscience.

With reference to paper conservation, the above mentioned conditions and catalysts are never to be met in day today life unless they are performed wantedly. So polyester films are stable than other materials as discussed above.

**Acrylic Adhesives:**

The acrylic adhesives are a new group of adhesives that are being developed for various applications. It is a synthetic polymer or a copolymer of different monomers giving rise to a wide range of properties. These adhesives are considered to be superior to the other types of synthetic adhesives because of their inherent structure and varied viscosity range.

The acrylic adhesives can be of two categories:

a. Thermoplastics based
b. Thermosetting plastics based.

The thermoplastics based acrylic adhesives constitutes the acrylates and the methacrylates. E.g., Polymethylmethacrylate (PMMA), Polymethacrylate (PMA), etc. This type of adhesive is reversible and used widely for domestic and packaging applications.

The Thermosetting plastics based acrylics include the cyanoacrylates. This resin is heat cured at a temperature to form a three dimensional network structure. This type of adhesive is irreversible due to the network structure formed. Generally they are used to join metals and for high performance applications.

For an application like conservation of paper, the adhesive must be reversible and should possess certain properties. These aspects are met with an addition of another monomer and copolymerizing with the acrylic adhesive.

A **heteropolymer** or **copolymer** is a polymer derived from two (or more) monomeric species, as opposed to a homopolymer where only one monomer is used. **Copolymerization** refers to methods used to chemically synthesize a copolymer. The copolymer is generally prepared in order to enhance the properties of homopolymer as a whole giving rise to a synergistic effect.

**PHOTOLAM SYSTEM:**

Photolamsystem developed in India by P. Renganathan and ***Government of India Granted patent*** for this product and the name **Photolam** is also registered as trade mark.

Photolamsystem has developed three types of products:

- Photolam film lamination
- Photolam encapsulation
- Photolam Cloth mending:

**Photolam film lamination:**

In Photolam System film is polyester processed specifically for paper conservation purpose. Special coatings like waterproof, antiglare, anti-reflective, heat retardant, non sticky coating are done on one side of the film. Research is on the way to produce **fire retardant** coatings also. Thus when compared with the commodity plastics like Polyethylene, Polypropylene, Polyvinylchloride and other reinforcing materials like Japanese tissue, cellulose acetate foil, the Polyester (PET) film possess excellent characteristics required for paper conservation.

The properties of film used in Photolam system is as below:

## Polyester film:

| | |
|---|---|
| Thickness: | 15-24 micron |
| Density: | 1.4g/cc(ASTM-D1505) |
| Tensile strength at break MD/TD: | 1800kg/sq.cm (ASTM D882) |
| Percentage elongation: | 120 (ASTM D882) |
| Haze: | 65% |
| Luminous Transmission: | 80% |
| Melting point: | 255˚C |
| Shrinkage@150˚C 30min MD: | 1.6% |
| TD: | 0.5% |
| Permeability to air : | Very Low |
| Resistance to dilute acids and alkalis: | Good |
| Resistance to i.) Conc. HCl: | Fair |
| ii.) conc. sulphuric acid: | Good |
| Resistance to grease, oils and fats: | Good |
| Resistance to solvents, alcohol and hydrocarbon: | Good |
| Resistance to Phenols and chlorinated phenols: | Poor |

The following special coating are given on one side of the film :

- Waterproof,
- Antiglare,
- Antireflective,
- Heat Retardant,
- Non-Sticky Purposes

In context to paper conservation, a specific type of copolymer was developed by **Photolam System P Ltd**, comprising monomers of **acrylic, cellulose derivative** along with traces of **vinyl acetate**. It has high viscosity and low crystallinity which justifies the nondrying capacity. Also it possesses high aging performance and good resistance to temperature and humidity cycles.

The specifications are:

1. pH - 7.80 ± 1
2. Viscosity RVT/5/20/30˚C - 40-60
3. Film clarity - Clear glossy and bit free
4. Solid at 105˚C for 3 hrs - 55±1%
5. Appearance - Milky white emulsion
6. Flammability - Nonflammable
7. Toxic - Nontoxic, non hazardous under normal condition.

**Note**: These specifications are given with the appropriate permission given by the patent holder.

This kind of adhesive is reversible with a solution named **Photolam Reversing Liquid** which consists of acetone, paraffin, hydrocarbon and ammonia in a calculated percentage. This helps in deactivating the adhesive bonding with the paper and releases the original document.

**Photolam Encapsulation:**

In this method specially processed polyester film of glossy finish is used thickness ranging from **50 to 175 micron**. All the four sides are pasted with double sided acid free quality adhesive coated hand made tissue paper. It is easy to use, while preserving fragile document it is to be strengthened by applying cellulose coatings first and then encapsulated. This is a ready to use method. Available readymade encapsulations are to suit A4, FS, & A3 size documents.

**Photolam Cloth Lamination**:

This m ***Photolam cloth lamination. (Type – I)*** **Photolam –PCL 120**

This is a traditional method called chiffon lamination. In this process we have changed the material alone. Instead of natural chiffon cloth we are using cotton blended synthetic polyester meshed cloth and instead of starch paste we are using Poly vinyl Alcohol (PVOH) & Corboxy methyl cellulose (Sodium) [CMC (Na) ] mixed adhesive this is a water soluble adhesive .

**In this method adhesive is prepared as follows:**
50 gms of PVOH in 1000 ml. of lukewarm distilled water in a jar stirred well until dissolved. Then 50 gms of CMC(Na) is to be dissolved in another 1000ml of lukewarm distilled water in separate jar stirred well and close the top of the jars. Leave these two jars for an hour to settle, and then mix the two solutions in a big single jar. Leave them for twelve hours to settle; now we got our adhesive. This adhesive should used within 48 to 72 hours.

**Lamination method:**

We should have base tale top of smooth matte surface with wooden, acrylic or glass of thickness 3 mm and size according to our document, normally 2' x 2'6". We should place one matte finished acrylic sheet with top surface cleaned on a table. Then we apply the adhesive on the top surface with a soft brush. The polyester meshed cloth is laid over it, and then the adhesive is applied on top of the cloth to remove the air in between the cloth and acrylic sheet. Now lay the document on the cloth without any shrinkage. Guard to be fixed and again apply the adhesive on the top of the document smoothly to avoid any damage to the document. Again another piece of polyester meshed cloth to be layered over the top of adhesive coated document and then adhesive is to be coated on the top of the cloth. This is kept in room temperature for eight hours for curing. Now the document get laminated both side by meshed cloth. After curing, the cloth laminated document is removed form the acrylic sheet. The edges are trimmed and binding or filing is to be done. This is a reversible process and delaminating is possible with steam, sprit, or water.

**Conclusion:**

Having dealt with the materials used for paper conservation, it is high time for the conservationist to select the right materials and to recommend appropriate materials which ensure that the life period of the paper has been prolonged and there is no further prone to attack from the deterioration factors.

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