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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
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Letter Circular
LC 402

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CELLOPHANE

The widespread use of transparent cellulose in sheet form for packaging purposes has resulted in numerous inquiries regarding this material. Frequently the substance of the inwuiries has indicated that the nature of the product is not generally understood. The purpose of this letter circular is to give general information about the material and to direct the reader to sources where special or detailed information may be obtained. The literature on cellophane is not extensive, and a great deal of it is not readily available. A good description of its manufacture is contained in an article on the "Manufacture and Properties of Regenerated Cellulose Films", by W. H. Hydon, Ind. Eng. Chem., vol. 21, pp. 405-410; 1929. The process is also described in U.S. Patents 981, 368 (January 10, 1911) and 1,601,289 (September 28, 1926) issued to Edwin Brandenberger.

Manufacture

The raw material for cellophane is cellulose, the principal building material of the cell walls of plants. Its chief sources are wood and cotton. To better understand the reactions which occur during the manufacture of cellophane, cellulose, which has the empirical formula $C_6H_{10}O_5$, may be regarded as behaving in its reactions like an alcohol. Its formula will therefore be written as $C_6H_9O_4OH$ to indicate the presence of a hydroxyl (OH) group which is characteristic of an alcohol.

In the manufacture of cellophane, wood pulp or cotton linters, the short fibered cotton attached to the cotton seed, is first treated with an 18 to 20 per cent water solution of sodium hydroxide (caustic soda, lye) for a definite period of time at a definite temperature. In this treatment the cellulose fibers swell, become translucent, and acquire a silky appearance. The change taking place involves the reaction between the alkali and the hydroxyl group of the cellulose which is expressed as:

$$C_6H_9O_4OH + NaOH = C_6H_9O_4ONa + H_2O$$

The resulting product is known as sodium cellulose. The reaction is analogous to that between ethyl alcohol and sodium hydroxide resulting in the formation of sodium ethylate:

$$C_2H_5OH + NaOH = C_2H_5ONa + H_2O$$

After a period of aging the sodium cellulose is treated in air-tight drums with carbon disulphide, which results in the formation of sodium cellulosexanthate. The formation of alkali xanthate is a general one. Thus the addition of carbon disulphide to sodium ethylate, whose formation is shown above, yields sodium ethylxanthate:

$$C_2H_5ONa + CS_2 = NaSCSOC_2H_5$$

The reaction with sodium cellulose is:

$$C_6H_9O_4ONa + CS_2 = NaSCSOC_6H_9O_4$$

The sodium cellulosexanthate is mixed with a dilute solution of sodium hydroxide. The resulting solution is orange-colored and of the consistency of corn syrup. It is shown technically as viscose. It is very unstable and undergoes a series of reactions, which are not clearly understood, which involve the formation of a more complex molecule. The changes taking place affect the coagulability of the viscose. The latter property is closely followed during a period of "ripening". After sufficient "ripening" the solution is ready for regeneration. The preparation of viscose, the parent material for the viscose type of rayon, as well as cellophane, is described in "Cellulose Chemistry" by Heuser, published by the McGraw-Hill Book Company, New York City.

In the formation of the regenerated film of cellulose, the viscose solution is forced through a narrow slot and passes immediately into an acid solution which contains sulphuric acid and sodium sulphate. The regeneration takes place in two stages: first, the coagulation of the viscose by the sodium sulphate simultaneously with the neutralization of the alkali by the sulphuric acid; and second, by the decomposition of the cellulosexanthate to hydrated cellulose through the continued action of the acid. In its simplest form the reaction is expressed:

$$NaSCSOC_6H_9O_4 + H_2SO_4 = C_6H_9O_4OH + CS_2 + NaHSO_4$$

In the manufacture of cellophane in tubular form the viscose solution is extruded into the acid solution as a seamless tube supported by a mandrel.

After the precipitation of the hydrated cellulose film, it passes over rolls into water to remove acid and salts, through a solution which may contain sodium hydroxide or sodium sulphite to remove residual sulphur, and through a bleaching bath containing sodium hypochlorite, followed by further washing in water. Finally it is bathed in a solution of water and glycerol. The glycerol which remains in the dried film imparts pliability to the finished material. The process from the coagulation of the viscose to the finished film is continuous and progressive.

Chemical Properties

It is desirable to remember that fundamentally the chemical composition of cellophane is the same as that of the raw cellulose. The process of manufacture may be expressed as a cycle:

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Cellulose (wood, cotton) ——→ sodium cellulose
                                   ↓
                             sodium cellulose xanthate
                                   ↓
Cellulose (regenerated
              film)    ←———— viscose
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Cellophane has all the chemical properties of cellulose. It swells in a sodium hydroxide solution. It undergoes all the typical cellulose reactions such as formation of the nitrate, acetate, ethyl ether, and xanthate. When ignited it burns with about the same flame as newsprint. It can not be dissolved in organic solvents such as alcohol, acetone, and esters. It differs in this respect from cellulose nitrate and acetate which enter into the composition of lacquers and plastics.

Physical Properties

Cellophane is characterized by considerable tensile strength but very low resistance to tearing. The tensile strength is greatest in the direction of the movement of the film during its manufacture. The weight required to break a 1 5/8-inch strip having a thickness of about 0.001 inch is stated to be 15.7 lbs. in the longitudinal direction and 7.3 lbs. in the transverse direction.

Perhaps the most interesting of its properties is its permeability to gases, water vapor, and ultra-violet light. The material is practically impermeable to hydrogen and helium but readily allows the passage of oxygen, carbon dioxide, and water vapor. Toward water solutions it behaves as a dialyzing membrane, permitting the separation of substances of varying molecular size. It has been found particularly useful in this respect in the field of biological chemistry and the separation of substances whose acidities or alkalinities are not excessive.

The transparency of cellophane to light waves in the therapeutic region 2900 Å to 3100 Å is stated to be about 70 per cent. It has been suggested as a window material in the treatment of disease by heliotherapy since it does not lose a great deal of its transparency upon prolonged exposure to ultra-violet light.

Moisture-Proofed Cellophane.

For a great many packaging purposes it is imperative that the passage of moisture through the film be prevented. To render the film moisture-resistant it is coated with a solution containing cellulose nitrate, which may also contain gums, resins, and plasticizers, in a lacquer solvent. Upon evaporation of the solvent the material is covered with a thin film which is more impermeable to water vapor than the plain cellophane.

Adhesives

Fabrication of cellophane into articles requires the use of an adhesive. For plain cellophane, water-soluble adhesives such as mixtures of glue and glycerol are employed where a strong bond is desired. For use particularly on the moisture-proofed material a special adhesive containing cellulose nitrade is employed.

The following references furnish more detailed information regarding the properties of the material. The journal "Chemical Abstracts", published by the American Chemical Society should be consulted with regard to patents issued for improvements in manufacture, fabrication into articles, adhesives, etc. This publication should be available in most public and university libraries.

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