Modern Food Packaging Technologies: Regulatory Aspects and Global Trends
Prof Prem Prakash Srivastav
Department of Agricultural and Food Engineering
Indian Institute of Technology Kharagpur
Week – 05
Lecture – 21

Welcome to the NPTEL online certification course on modern food packaging technologies regulatory aspects and global trends. In the last lecture we have seen different types of plastics used in the food packaging materials and now in the present lecture we will be discussing the following topics and we will be seeing the different properties of the plastic materials. The first of this is optical properties, tensile properties, bursting strength, impact resistance, impact strength, tear strength, stiffness, flex resistance, blocking, barrier properties. The first the optical properties, the optical properties are related to both the degree of crystallinity and actual polymer structure. There are number of optical properties of importance with thermoplastic polymers including clarity, haze, color, transmittance, reflectance, gloss and refractive index. The clarity of a film indicates the degree of distortion of an object when viewed through the film with see through clarity referring to the ability of the film to resolve fine details of fairly distant images viewed through the film.

Many of the optical properties of a polymer are related to the refractive index which is represented by N which is a measure of the ability of the polymer to refract or bend light as it passes through the polymer. Since refractive index is dependent on density it follows that where the crystalline and amorphous densities of polymer differ. There will be a difference in refractive index. Thus thick polyethylene objects will be opaque since they cannot be quenched rapidly and the spherulities formed have a significantly higher density about 1010 kg per meter cube than the amorphous region that is 840 to 850 kg per meter cube.

In the case of PP the difference is less marked crystal density is about 940 kg per meter cube whereas, for the amorphous density is 850 kg per meter cube and the moldings are more translucent. Generally the refractive index for many plastics is around 1.5. Amorphous polymers free from fillers or other impurities are transparent unless chemical groups which absorb visible lights radiation are present. Generally crystalline polymers are translucent, but they will be transparent when the crystal structures such as spherulities are smaller than the wavelength of light.

However, if the structures are greater in diameter than the wavelength of light the light waves will be scattered if the crystal structures have a different refractive index to that of the amorphous regions. The clarity of crystalline plastics can be improved by quenching or by random copolymerization. Light is scattered on passing through a film or sheet of a material can produce a hazy or smoky field when objects are viewed through the material. Haze can be taken as a measure of the milkiness or cloudiness of an otherwise transparent polymer and is often the result of surface imperfections particularly in the case of thin films. The appearance of haze with consequent loss of contrast is caused by light being scattered by the surface imperfections or by inhomogeneities in the film due to voids, large crystallites, incompletely dissolved additives or cross linked material.

Internal haze does not arise with amorphous polymers with crystalline polymers it increases with the degree of crystallinity and size of spherulites or other forms of crystal aggregates as well as with the ratio of density between the crystalline phase and the amorphous phase. The gloss is strictly speaking is specular gloss of a film has been defined as the degree of which a surface simulates a perfect mirror in its capacity to reflect incident light. Thus it is a function of the reflectance and the surface finish of a material where transmittance and reflectance do not add up to unity then some of the light waves are absorbed. If this absorption does not occur uniformly over the visible spectrum the material appears colored. Measurement of the gloss of plastic films and solid plastics both opaque and transparent is determined by standard test methods of ASTM D 523 and D 2457 using a device known as gloss meter which measures the percentage of light incident at an angle 20 degree, 45 degree which is most common or 60 degree to the surface of the film that is reflected at the same angle.

The fraction of the original light that is reflected is the gloss of the sample. If the specular reflectance is near 0 the surface is said to be matte. Gloss is a complex attribute of a surface which cannot be completely measured by any single number. The four properties tensile and yield strength elongation and Young's modulus are considered under a single heading because the same equipment is used to measure each of them. The stress sigma is defined as the force per unit cross sectional area of a material.

Thus, If the force is F Newton's and the cross sectional area is a square meters then the stress is given by sigma is equal to F by a Newton per meter square. The strain epsilon is defined as the fractional change in length of a material that is delta L by L 0 where L 0 is the initial length and delta L is change in length it is expressed as a dimensionless ratio. The picture shows the instrument which measures simultaneously the tensile and yield strength elongation and Young's modulus. What is happening in this instrument the segment of test a specimen is attached and then both the ends are stretched in opposite direction and then the force per unit area is measured. The tensile strength are more accurately ultimate tensile strength is the maximum tensile strength which a material can sustain and is taken to be the maximum load exerted on the test specimen during the test divided by the original cross section of the specimen.

Yield strength is the tensile stress at which the first sign of non elastic deformation occurs and is the load at this point that is known as yield point divided by the original cross section of the specimen. The elongation is usually measured at the point where the film breaks and is expressed as the percentage of change of the original length of the material between the grips of the testing machine. Its importance is a measure of the films ability to stretch a large value for elongation indicating that the material will absorb a large amount of energy before breaking. This figure the stress versus strain graph depicts the different values of the like a percent elongation, yield strength, ultimate strength and the fracture point. Both yield point and elongation are important properties during the unwinding of plastic films.

Too low an elongation should also be avoided as any sudden unbalance in the unwind operation could lead to breaking of the film because a certain amount of tension is necessary during unwind. The possibility exists that films with low yield strength could be stressed beyond their yield point. Methods for testing tensile properties of thermoplastic films are described in the methods ASTM D 882 and ISO 527 which are the three parts. In general the shape of such a curve will be of the form shown in the figure although variations occur from plastic to plastic. This stress strain graph that shows again the same that yield point, strain shafting point, strain hardening point and the rupture point.

This region is the elastic region and this region is the plastic region where it does not regain its shape. Thus for instance brittle plastics will break at a much earlier stage of the curve sometimes before the yield point has been reached. The slope of the initial linear portion of a stress strain curve is called the Young's modulus or the modulus of elasticity and has units of pressure that is the mega Pascal. It is a measure of the force required to deform the film by a given amount and so is also a measure of the intrinsic stiffness of the film. This table represents the Young's modulus and percent elongation of different polymers like polyethylene that is both the polyethylene that is the SDP, LDP, propylene, PVC etc

The second important property is tensile properties. The larger the value of e the stiffer and more brittle the material. For example, e for LDP is 250 mega Pascal and for crystal grade polystyrene it is 2500 mega Pascal. In industry the secant modulus of elasticity is very common alternative test. It is defined as the slope of the line connecting the origin and a given point on the stress strain curve or the ratio of nominal stress to corresponding strain at any specified point on the stress strain curve expressed in force per unit area.

A great deal of information about the material can be obtained from the shape of its stress strain curve. In addition to the numerical values for tensile strength, Young's modulus, elongation and so on it is possible to obtain some idea of the toughness of the material by measuring the area under the curve. This area is a measure of the energy needed to break the test specimen and hence is directly related to toughness. The third important property which is measured in plastics is bursting strength. The bursting strength of a film is the resistance it offers to a steadily increasing pressure.

Applied at right angles to its surface under certain defined conditions. The bursting strength is taken to be the pressure at the moment of failure of the film and is essentially a measure of the capacity of the film to absorb energy. Methods for measuring bursting strength are usually based on those developed for paper that is ISO 2758 in which paper is submitted to increasing hydraulic pressure. It is applicable to paper having bursting strengths within the range of 70 to 1400 kilo Pascal. The bursting strength tester commonly called Mullen tester has claims for holding sample over a circular rubber diaphragm of 30.48 millimeter diameter and a pump that forces a liquid usually glycerol into a pressure chamber under the diaphragm. The measure of the total hydraulic pressure expanding the diaphragm at the time the sample ruptures is its bursting strength. Although the test is simple and rapid its exact significance as an index of performance has been questioned. The figure represents the Mullen tester where this is the diaphragm in which the test material is fitted and the from this pump the liquid glycerol is fed until the test specimen is fractured. The another important property is impact strength.

The impact properties of polymeric materials are directly related to the overall toughness of the material. Toughness being the ability of the polymer to absorb applied energy. The area under the stress strain curve described in the preceding session is directly proportional to the toughness of the material. The impact strength of a film is a measure of its ability to withstand shock loading. The standard methods for determining the Izod pendulum impact resistance of plastics which is given in the methods ASTM D 256 and ISO 180.

The pendulum impact test indicates the energy to break standard test specimens of specified size under stipulated parameters of specimen mounting, notching and pendulum velocity at impact. The results are expressed in energy lost per unit of thickness that is joule per centimeter at the notch. Alternatively the results may be reported as energy lost per unit cross sectional area at the notch that is joule per meter square. This method provides a means of determined parameters of plastic films at strain rates closer to some end use applications than provided by low speed uniaxial tensile tests. Dynamic tensile behavior of a film is important particularly when the film is used as a packaging material.

An arm held at a specific height that is at constant potential energy is released. The arm hits the sample and breaks it from the energy absorbed by samples its impact strength is determined. This test measures the difference between the potential energy of the pendulum at the maximum height of its free swing and the potential energy of the pendulum after the rupture of the sample. This difference in energy is defined as impact strength and is useful in predicting the resistance of a material to breakage from dropping or other quick blows. A test similar to scope method and significance is the dirt drop impact test which is given in the methods ASTM D 1709 and ISO 7765 known as the free falling dirt method.

The dirt consists of a hemispherical head fitted with a shaft to which removable weights can be added. These methods cover the determination of the energy that causes plastic films to fall under specified conditions of impact of a free falling dirt. This energy is expressed in terms of weight or mass of the missile falling from a specified height which would result in 50 percent failure of specimens tested. These tests given index of the films dynamic strength and approximate what will occur when a package is dropped. The impact resistance of plastic film while partly dependent on thickness has no simple correlation with sample thickness.

The puncture resistance is a measure of the energy absorbing ability of a film in resisting a protrusion is very important in end use performance of a stretch wrap film. The method ASTM D 5748 provides a means of measuring the puncture resistance performance of a stretch wrap film under essentially biaxial deformation conditions. A biaxial stress being representative of the type of a stress encountered by a stretch wrap products in many end use applications. The maximum force, force at break, penetration distance and energy to break are determined. Now the tear strength is an important property of packaging films and knowledge of resistance to both tear initiation and tear propagation is often helpful.

Samples for testing should be cut from both machine and transfer directions as the tear strength can vary widely according to the direction of tear. Due to orientation during their manufacture plastic films and sheeting frequently show marked anisotropy the property of being directionally dependent in their resistance of tearing. The one of the most common test for measuring tear strength is the Elmendorf test which like so many other films tests was originally developed for paper testing. It measures the force required to propagate a tear or pre cut slit through a specified length of plastic film with a pendulum and is described in full in ASTM D 1922 and ISO 6383 methods. Tear strength is commonly reported as tearing force in milli newtons with specimen thickness also reported.

Materials can be tested according to this method include PVC and polyolefin films, but variable elongation and oblique tearing effects on the more extensible films may cause poor reproducibility of test results. This method may not be suitable for testing more rigid materials such as nylon and polyester films and rigid PVC that is all for today. Thank you very much.