

Polymers and plastics in biomedical applications



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Introduction

Polymers are increasingly being used to fabricate biomedical materials for tissue engineering and wound treatment applications, as well as for drug delivery. For tissue engineering and wound treatment applications, the mechanical properties of the polymeric material have to be matched to the specific application. An example of tissue engineering is the use of bioresorbable polymeric orthopedic materials for bone regeneration applications. The degradable material supports the growth and adhesion of new bone cells (chondrocytes) and is porous so as to provide a large, continuous surface for cell proliferation throughout the matrix. The degradable material serves to maintain mechanical integrity while the bone heals itself. The materials are designed to degrade in a time suitable for the particular application, but may be on the order of six months to twenty-four months.

An example of an external wound treatment application is artificial skin, where the polymeric material provides protection as new growth develops. Other materials are used internally to separate organs after surgical procedures. In tissue engineering and wound treatment applications the mechanical properties of the materials have to meet requirements specific to the application. In this experiment you will determine how the tensile properties of films of plasticized biopolymers depend on the chemical formulation of the material. Such applications are based on the polymer materials being degradable as well as biocompatible. Other applications might require materials that are biocompatible and nondegradable, such as long-term polyethylene implants.

Polymers

Polymers can be synthetic or biological. Synthetic polymers are almost always made from nonrenewable fossil feedstocks, mainly petroleum. Examples are polyethylene, polystyrene, poly(vinyl chloride), and polypropylene, all of which are polyolefins. Poly(ethylene terephthalate) [PET] is a synthetic polyester. None of the above-named polymers are degradable, the main reason being that the polymer backbones contain only carbon-carbon single bonds. Examples of biodegradable polymers derived from petroleum are poly(vinyl alcohol) [a polyalcohol], poly(ethylene glycol) [a polyether], and the polyesters polycaprolactone and poly(glycolic acid). Polymers with heteroatoms in their backbones are generally biodegradable, although there are exceptions.

Biological polymers (biopolymers) are found in nature; they are intrinsically biodegradable. Abundant biopolymers include plant polysaccharides such as starch (composed of amylose and amylopectin), cellulose, agarose, and carrageenan, and animal polysaccharides such as chitin and the glycosaminoglycans. Abundant proteins include gelatin(denatured/hydrolyzed collagen), casein, keratin, and fibroin.

Poly(lactic acid) (PLA) is an example of a synthetic commercial polymer in which the monomer, lactic acid, is produced in large amounts through fermentation; the polymer is then synthesized by conventional methods. PLA is biodegradable.

Mechanical Properties

In implant and wound healing applications, the mechanical properties of the materials are of critical importance. In this experiment you will carry out <https://assignbuster.com/polymers-and-plastics-in-biomedical-applications/>

tensile tests—tests in which specimens are placed between two clamps (grips) and drawn. The instrument measures and displays the force being applied (the load) and the resulting increase in the length of the sample (elongation, also called extension).

From the dimensions of the film specimen (width and thickness), the instrument software calculates and displays the tensile stress (σ), equal to the load (F) per unit area of cross section ($A = \text{width} \times \text{thickness}$).

It also calculates the (tensile) strain (ϵ), equal to the elongation (extension) divided by the original length of that portion of the specimen being measured (called the gage length). [In our experiment, the gage length is simply the separation of the grips securing the specimen.] The instrument will display percent elongation, which is the strain multiplied by 100.

As the tensile test proceeds, the instrument generates and displays a tensile stress-strain curve, which is a diagram that displays values of tensile stress (in MPa) plotted against tensile strain (%). The test continues until the specimen breaks. From the stress-strain curve, the software determines, and reports the following results in table form:

- (1) Tensile strength at break (or ultimate strength), which is the tensile stress at break.
- (2) Elongation at break, as a percentage.
- (3) Young's modulus (also known as elastic modulus or modulus of elasticity or sometimes simply as modulus).

It is calculated as the initial slope of the stress-strain curve, which is usually observed to be linear with plastic films. This initial region reflects the elastic deformation of the specimen, in which the stress varies linearly with strain, analogous to Hooke's law for the expansion of a spring. Beyond the linear region, the behavior is termed viscous; polymers and plastics are said to be viscoelastic materials. Modulus is a measure of the "stiffness" of the polymer or plastic.

Table 1. Typical tensile properties of materials

Material t. s.(MPa) elong.(%) modulus(MPa)

polyethylene, low density 10 620 166

polycaprolactone 26 600-1000 435

polypropylene 36 - 1380

poly(lactic acid),

biaxially oriented film 110/145 160/100 3310/3860

keratin(human hair) 526 46 6700

copper, annealed 240 30 100, 000-130, 000

steel 380-700 - 200, 000-250, 000

glass 2160-4830 - 50, 000-70, 000

Encyclopedia of Chemistry, 4th ed.; Handbook of Physics, 2nd ed.

Experimental Procedure

1. Film casting

Prepare the following cast films of plasticized biopolymers.

Sample 1 Place 32 mL of 2%(v/v) aqueous glycerol solution in a 200 mL beaker. Add 88 mL water and 2. 40 g starch and 4. 8 g agar. Heat with stirring to approximately 85-95 °C or until the polymer is in solution; do not boil. Slowly pour the solution into the big petri dish on a flat level surface. Try to remove all imperfections (bubbles) from the surface.

Sample 2. Repeat using 32 mL glycerol solution, 88 mL water, and 1. 20 g starch and 3. 6 g agar.

Sample 3. Repeat using 48 mL glycerol solution, 72 mL water, and 1. 20 g starch and 3. 0 g agar.

Sample 4. Repeat using 48 mL glycerol solution, 72 mL water, and 2. 40 g starch and 3. 5 g agar.

Allow the solutions to set for approximately one hour then place the petri dish in the drying oven. Label all petri dishes.

2. Film conditioning

After the agar films have been in the drying oven for about 24 hours, remove the petri dishes from the oven and place them in the large relative-humidity conditioning box (maintained at approximately 50% relative humidity) for 24-48 hours.

3. Preparing test specimens

After conditioning, the films are ready to have test specimens prepared from them. Working with one sample at a time, remove the petri dish from the conditioning box. Slowly and carefully remove the film from the petri dish by first peeling one corner and then applying fairly equal pressure to the entire width of the film as it comes off the petri dish lengthwise.

Place the sample on a piece of cardboard. Using the 1/4" wide aluminum template as a straight edge, and the cutting knife, cut a rectangle approximately 3.5" x 3" from the center of the film, so as not to include any edges, as they are often not as uniform in thickness as the center.

Align the sample on the cardboard as follows:

Place the 1/4" wide aluminum template vertically near one of the edges. Using the cutting tool, cut on both sides of the template to produce a specimen 3.5" long and 1/4" wide. Cut as cleanly as possible so as not to notch or tear the specimen. Cut six or seven additional strips, but do not use the second cut of the previous specimen as the first edge of the next; make two new cuts to produce each specimen.

Place the cut specimens on a piece of filter paper and transfer them into the dessicator located next to the Instron instrument. Similarly prepare specimens from the other three film samples.

4. Measuring mechanical properties of test specimens

During the laboratory you will measure the mechanical properties of the four cast films. Measure at least five specimens for each of the four film

samples. As you remove each specimen from the dessicator, you will be measuring the thickness of the specimen with a digital caliper.

5. Operating the Instron Testing Instrument

Refer instrument manual.

6. Laboratory Report

1. Express the compositions of the four film samples in terms of the weight percent of each component to two significant figures (excluding water); i. e. % agar, % glycerol (the density of glycerol is 1. 26) and, if present, % starch.
2. Prepare a summary table of results showing the mean values of tensile strength (Mpa) (to 3 sig. figs.) and its standard deviation, elongation (%) (to 2 sig. figs.) and its standard deviation, and elastic modulus (MPa) (to 3 sig. figs.) and its standard deviation. [ASTM specifies these numbers of significant figures; a smaller number of significant figures would otherwise be justified given the observed standard deviations.]
3. For the three agar-glycerol films what correlation do you observe between the effect of glycerol on one property and its effect on the others? Prepare a graph for each of the properties showing variation with composition. In Excel you can show a standard error for each point separately by using a separate data series for each point. Do not show a trend line and do not attempt to connect the data points.