

Science Education Collection

Overview of Biomaterials

URL: <https://www.jove.com/science-education/5797>

Abstract

Biomaterials are materials engineered to interact favorably with biological organisms or molecules. These materials can be derived from or produced by an organism, or can even be a synthesized polymer. Engineers use these novel materials in a wide range of applications, such as tissue engineering, biosensing and drug delivery.

This video introduces common biologically derived materials, and provides examples of common techniques used to process them. Key challenges in the field are discussed, along with several applications of these methods.

Transcript

Biology is now being used to meet engineering challenges as biologically derived materials offer key properties that manmade materials cannot. Bio-derived materials, sometimes called biomaterials, are created from living or once living organisms. These materials have gained popularity recently as they are biocompatible and can act as matrices that can house biomolecules and cells. This video will introduce several bio-derived materials and introduce common techniques and challenges in the field.

There are many biologically derived polymers, or biopolymers, used in bioengineering research. First, collagen is a widely used protein polymer typically derived from bovine skin, tendon and bone and even rat tails. Collagen fibers possess a triple helix structure which gives the material strength and rigidity. Because of this property, collagen is often used as a structural component of engineered tissue constructs especially in bone and skin like artificial tissue. Another common protein polymer is silk which is derived from the cocoon of silk moth larvae. This protein's secondary structure has vast crystalline regions of beta sheets enabling high strength and flexibility. As with collagen, silk is often used as the structural component of artificial tissue, typically in flexible tissue like skin and muscle. However, silk is also cast as a thin film for optical devices as well as electrical device substrates. Chitosan, another biopolymer, is the polysaccharide derived from crustacean shells like crabs or lobsters. The polymer's solubility is pH based. This enables the simple control of fabrication processes by increasing the pH to solidify the material. Chitosan is often used in wound healing by creating a film that is biocompatible with regenerating tissue.

Now let's take a look at some prominent methods used to manipulate these biomaterials. First, biomaterials are often cast as a hydrogel to create a highly hydrophilic structure with increased biocompatibility. A hydrogel is a solid-like polymer network with high water content and is often used as a tissue construct in artificial tissue. To make a hydrogel with collagen, first heat the polymer in an aqueous solution, like growth media, and then cast the solution in a mold. The solution is then cooled until solid. UV crosslinking can also be used to improve stability of the gel by covalently linking residues on the polymer chains. Alternatively, hydrogel beads can be formed by adding the polymer solution dropwise to a crosslinking solution. The beads are then used to stabilize cells in proteins. Biomaterials can also be used to form fibrous mats via electrospinning. This technique is performed by applying an electric field between a collector surface and the tip of a syringe containing biopolymer solution. This induces the formation of microscale fibers which then create structures that mimic the extracellular matrix in tissue. Alternatively, biomaterial thin films can be prepared via electrodeposition. For this, a potential is applied to a two electrode cell containing the biomaterial solution. The biomaterial migrates to one of the electrodes forming a thin film on the surface. These thin films can be used to make a surface biocompatible, for example, to stabilize surface assembled enzymes in cells. In this case, a chitosan thin film stabilizes the enzyme glucose oxidase. In addition, biomaterials are often solution cast on a surface to form a thin film. The solution is first dropped onto a substrate then dried to remove all solvent. The film thickness is controlled using the volume and concentration of solution.

Although biomaterials are widely used in bioengineering, there are inherent challenges associated with their use. First, biomaterials possess natural properties that are governed by their source and molecular structure. While these materials can be harnessed for a wide range of applications, modifying their inherent properties can be difficult. In addition, processing of the material alters their properties, sometimes in an adverse way. Biomaterials are derived from natural sources which can vary based on the organism species and environmental factors like season. This can result in batch-to-batch variability that causes small differences in the final application. Finally, most biomaterials are water soluble thereby limiting their stability. Since some applications require the material to be permanent, crosslinking or stabilizing techniques may be required to extend their lifetime. However, this can result in undesirable changes to the mechanical properties.

Biologically derived materials are used in a wide range of applications in bioengineering research. First, biomaterials are frequently used in drug delivery applications since they are typically biodegradable and biocompatible. For example, hydrogels offer a biocompatible matrix able to hold sensitive drug molecules. They degrade at a predictable rate depending on the properties of the material thus enabling the controlled release of a drug. Biomaterials have been used extensively in medicine, specifically with silk sutures and with chitosan-based bandages and adhesives for wound healing. In this example, chitosan surgical adhesive films were prepared with a medical diagnostic dye. They were later fused across cut tissue to close the wound as an alternative to sutures. An evolving area of the biomaterials field treats proteins and other biomolecules, such as DNA in this case, as polymer materials. For this, DNA strands are designed with a specific sequence which induces the precise folding of the DNA strand into complex structures and patterns called DNA origami. These structures can then be used to create functional assemblies able to sense biological cues, change shape, or release embedded biomolecules.

You've just watched JoVE's overview of biologically derived materials. You should now understand the origins and properties of several common biomaterials, some techniques used in the lab to process them, and some challenges associated with their use. Thanks for watching.