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Striking the right balance between bioabsorbable polymer strength and degradation rate

Whether you're manufacturing 3D printers or just bought a shiny new 3D printer to work with, even the best one can be rather useless without the right ink.

What's the right ink? Only you know that. You know the material properties you'd like to have and what the printed part should be able to do, and not do, but finding a polymer that meets those requirements is easier said than done.

Some of the key bioink material requirements are:

- Good 3D printability
- Biocompatibility
- Water solubility
- Good strength
- Photocurable
- Supporting cell viability before, during, and after bioprinting

In this article, we're going to focus on absorbable synthetic polymers for 3D bioprinting (or additive manufacturing) applications and highlight the breadth of options available by Bezwada Biomedical. We'll start with the classics, cover the next tier, and then close with the superstars, the bioabsorbables you've probably never heard about.

The Classics: PLGA and PEG for 3D Printing

Poly(lactic-co-glycolic acid), or PLGA, copolymer based inks are widely used in 3D printing. They are often chosen due to their tunable degradation rate and mechanical properties that can be dialed in by altering the lactide to glycolide ratio (Table 1). Poly(glycolic acid), PGA, degrades faster and has higher modulus than poly(lactic acid), PLA. PLA has higher strength and is more hydrophobic than PGA.

Table 1. Physical properties of synthetic absorbable PLA/PGA homopolymers and PLGA copolymers

Polymer	Melting Point (°C)	Glass Transition Temp (°C)	Modulus (GPa)	Degradation Time (months)
PGA	225 to 230	35 to 40	7.0	3 to 4
L-PLA	173 to 178	60 to 65	2.7	> 24
DL-PLA	Amorphous	55 to 60	1.9	12 to 16
85/15 DL-PLA/PGA	Amorphous	50 to 55	2.0	5 to 6
75/25 DL-PLA/PGA	Amorphous	50 to 55	2.0	4 to 5
65/35 DL-PLA/PGA	Amorphous	45 to 50	2.0	3 to 4
50/50 DL-PLA/PGA	Amorphous	45 to 50	2.0	1 to 2

Poly(ethylene glycol), or PEG, is another popular ink. PEG hydrogels are often photocrosslinked, are highly hydrophilic, and fairly good mechanical stability can be achieved by modulating the molecular weight of the starting polymer and the concentration of the crosslinker. PEG derivatives of acrylates and methacrylate functionalized PEGs, di- or tri-block copolymers of PEG or Pluronics with PLGA or PLA are designed to further tune the hydrolytic degradation profiles, enable crosslinking, and modulate mechanical properties.

Check out our [PLGA](#) and [PEG Derivatives](#) portfolio for a complete list of all the options available and their properties.

The Next Tier: PCL and PDS for 3D Printing

Poly(ϵ -caprolactone), or PCL, is a semicrystalline polymer with a 60-64°C melting point and -60°C glass transition temperature. PCL is quite hydrophobic and is therefore often used as a copolymer, instead of as PCL alone, such as PCL/PLA, PDLA/PCL, or PCL/PGA to enhance cell attachment

and growth, optimize tensile properties and tailor degradation rate. PCL's degradation time frame is over 24 months; therefore, blends are often used to accelerate its degradation rate.

Poly(p-dioxanone), or PDS, has approximately 55% crystallinity, 110-115°C melting temperature, -10°C glass transition temperature, and a medium absorption rate of 9-12 months. Bezwada Biomedical has developed PDS Rapid™ that provides faster absorption within 3 months without negatively impacting the polymer's physio-mechanical properties.

The Superstars: Bioabsorbable Polyurethanes and Polyoxaesters for 3D Printing

Polyurethanes, PUs, have gained popularity in biomedical applications due to their excellent blood compatibility, outstanding hydrolytic stability, superior abrasion resistance, & excellent mechanical strength.

Bezwada Biomedical has developed [absorbable polyurethanes](#) with distinct and unique advantages over existing biostable polyurethane formulations used in commercial biomedical applications: our isocyanates include a degradable linkage bridging the aromatic rings instead of the non-degradable methylene group in other formulations. Furthermore, the degradable linkage in our isocyanates is derived from safe and biocompatible glycolic acid, lactic acid, caprolactone, p-dioxanone, and diols. The degradation rate of these isocyanates is controlled by varying the chain length of the degradable linkage and by varying the safe and biocompatible molecule within the degradable linkage. These PUs thus possess, for the first time, degradable hard segments, while maintaining the toughness and mechanical properties of commercially biostable PUs.

Polyoxaesters, POEs, formed by the reaction of oxadiacids with diols, have found use in a number of medical applications based on their design flexibility as lubricious coatings for stents, needles, meshes, and fibers, and controlled drug delivery systems.

Bezwada Biomedical has developed hydrophilic POEs of varying mechanical properties and absorption rates using functionalized oxacids and diols.

Hydrolysis rate of polyoxaesters can be tuned from slow to fast by combining POEs with lactic acid, caprolactone, p-dioxanone, and glycolic acid. Melt temperatures can also be customized by changing the monomers to go from viscous liquid to formable solid to high melting solid polymers.

Our bioabsorbable polymer design expertise allows for a wide breadth of oinks/bioinks suitable for 3D printing/bioprinting to meet even the most challenging properties requirements. [Get in touch](#) to discuss your medical application and find the right ink for your printer.



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