# Synthesis and Processing Analysis of Polymers for Biomedical Applications

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**Abstract**— There have been tremendous advancements in the synthesis and processing of polymers for a variety of applications in the recent times. These applications include bio medicals specifically replacing the joints, limbs and other bone related surgeries and also the implanting and other treatment of body parts. This paper discusses about the synthesis and processing of certain polymers which find their applications in a massive way in the field of bio medicals. The properties exhibited by the polymers that are synthesized and processed are found to be superior to those materials which are conventionally being used in biomedical applications.

**Index Terms**— Polymers, Biomedical applications, synthesis of polymers.

## 1 Introduction

The field of material science is playing a major is all technological innovations irrespective of their domains. The polymers are one of the most versatile inventions under the umbrellas of material science and chemical science. The polymers offer themselves as one of the key components in in the fields like automobile, electronics, biomedical and instrumentation etc.[1,2].The table 1 shows the number of medical devices used per year across the globe which speaks about the quantum of developments that are taking place in this field.

TABLE 1

: Medical devices used per year across the globe

| Appliance | Number |
|---|---|
| Intraocular lens | 7000000 |
| Contact lens | 75000000 |
| Vascular graft | 400000 |
| Hip and knee prostheses | 1000000 |
| Catheter | 300000000 |
| Heart valves | 200000 |
| Stunts | 2000000 |
| Brest implant | 300000 |
| Dental implant | 500000 |
| Pacemaker | 200000 |
| Renal dialyzer | 25000000 |
| Left ventricular assist devices | 100000 |

Considering specifically the field of bio medicals, the polymers have already stated replacing the conventionally used materials in the applications like prostheses, dental materials, fixation of bones, ligament augmentations plates and pins[3,4]. Biodegradability is one of the key features of the recently invented polymers which have made the process of healing the wounds after the operation relatively very simple. Current research on all new and improved biodegradable polymers which mainly focuses on the issues of addressing the problems of patients with minimum pain and with better efficacy. One such example is the tissue engineering to provide the effective substitute using polymers for the damaged human tissues [5].

Gene therapy is also found to be another noteworthy application of polymers to replace the use of viruses as vectors[6,7].The recent research on polymers has revealed that the stainless steel implant during the surgery which was creating heeling and pain problems are being replaced by the polymers with their unique biodegradable property. These polymers have also come with load handling capacity at par with that of stainless steel [8].

The problems of osteomyelitis following the surgery is reduced by using polymers that speeds up the process of healing[9,10]. Polymers are also used as prodrug which is harmless molecule releasing the active drug inside the body especial in the tumors [1,11,12].Certain polymers are also used as biomaterials having very good biocompatibility[13].These polymers are processed from natural sources by fermentation processes. These are also non-toxic.

By considering the versatility of biodegradable and non-toxic polymers especially in the field of biomedical an attempt has been made in this paper to discuss discus different processes and techniques of polymerization and analysis their properties.

## 2 POLYMERS: PROPERTIES SYNTHESIS AND THEIR BIOMEDICAL APPLICATIONS

The general properties, different synthetic methods and biomedical applications of some of the most commonly used polymers are discussed in this section.

### 2.1 Polycaprolactone (PCL)

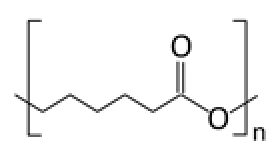

Fig 1: Structure of PCL

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**IUPAC Name**: Poly(Hexano-6-lactone)

**Chemical formula:(**C6H10O2)n

It is biodegradable polyester with a low melting point of 600c and having a glass transition temperature of about -600c. The Fig 2 shows the synthesis of PCL.

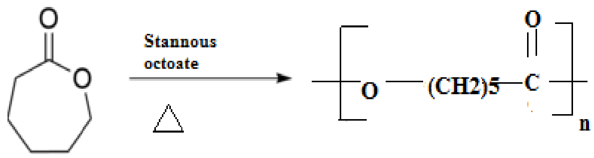


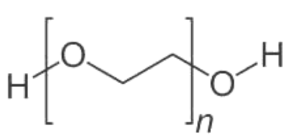

Fig 2: Synthesis of PCL

The PCL is prepared by ring opening polymerization **ϵ-caprolacton** using a catalyst such as stannous octoate.

In dentistry it is used as dental splints and also in root canal fillings. It also behaves like gutta percha, has the same handling properties and also for the retreatment purposes. The PCL being biodegradable against gutta perch its role in root canal treatment if more appreciated.

The role of PCL as an implantable biomaterial has received a great deal of attention as it is degraded by hydrolysis of its ester linkage in physiological conditions. The biodegradability of PCL is increased by mixing it with starch so that its cost can be lowered and compatibility with other of materials can be increased. Its role as a drug delivery device and surgical suture is approved by Food and Drug administration (FDA).

## B. Polyethylene glycol (PEG)




The Fig. 3 shows the structure of PEG.

**IUPAC Name:** Poly (Oxyethylene)

**Chemical formula:** (C2nH4n+2On+1)

**Flash point:** 182-2870c

Fig 4 shows the synthesis of PEG

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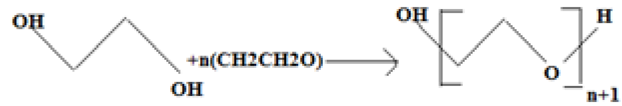


Fig. 4 Synthesis of PEG

PEG is produced by the interaction of ethylene oxide with water and ethylene glycol. The reaction is catalyzed by acidic or basic catalyst. PEG is basis of a number of laxatives. Whole bowel irrigations with PEG and added electrolytes are used for bowel preparation before surgery and colonoscopy .the patients suffering from constipation had a better response to the medicines with PEG. These medications soften the fecal mass by osmotically drawing water into the gastrointestinal tracks.

PEG is used as an excipient in many pharmaceutical products. Low molecular weight variants are used as solvents in oral liquids and soft capsules where as solid variants are used as ointment bases, tablet binders, film coatings and lubricants.

## C. Polydioxanone or poly-p-dioxanone (PDO/PDS)

The Fig 5 shows the structure of Polydioxanone.

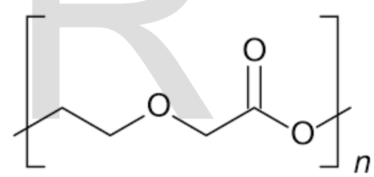


Fig. 5: Structure of Polydioxanone

It is a colorless crystalline biodegradable synthetic polymer. Its glass transition temperature is in the range of -10 to 00c and has a crystalinity of about 55% and a melting point of 107.80c.

The Fig 6 shows the synthesis of PDO/PDS.

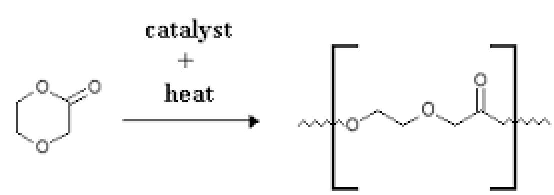


Fig. 6 Synthesis of PDO/PDS

The PDO/PDS is obtained by ROP (Ring Opening Procedure) of the monomer, p-dioxanone. The process requires heat and an organometallic catalyst like zirconium acetylacetonate.

The PDO/PDS is used in surgical sutures, other biomedical applications include orthopedic ,plastic surgery, drug delivery, cardio vascular devices and tissue engineering[14,15].It is degraded by hydrolysis and the end products are mainly excreted in urine, the reminder being eliminated by digestive or exhaled as CO2.

## D. POLYGLYCOLIC ACID / POLYGLYCOLIDE (PGA)

The Fig. 7 shows the structure of PGA

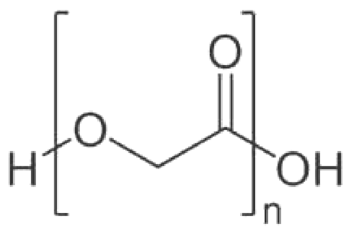

Fig.7 Structure of PGA

**IUPAC Name**: Poly [Oxy(1-oxo-1,2-ethanediyl)]
**Chemical formula**: (C2H2O2)n
Melting point: 225-2300c
It is linear aliphatic polyester and undergoes biodegradability. PGA has a glass transition temperature in the range of 35-400c and exhibits crystalinity of about 45-55%.
The Fig. 8 shows the synthesis of PGA.

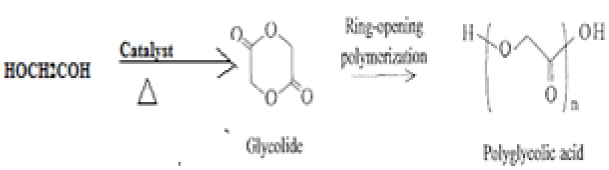


Fig 8. Synthesis of PGA

The monomer glycolide can be prepared by heating glycolic acid further ROP of glycolide can be catalyzed by Antimony Trioxide or Stannous Octoate. Fibers of PGA exhibit high strength and modulus hence they are particularly stiff. PGA suture is absorbable. PGA is naturally degraded in the body within 60 to 90 days by hydrolysis. This will help the elderly or malnourished patients to absorb the suture more quickly. Its uses are also explored in the tissue engineering and controlled drug delivery.

## E. POLIVINYLPYRROLIDONE (PVP)

Polivinylpyrrolidone is commonly called as polyvidone or povidone.
**IUPAC Name**: 1-Ethenylpyrrolidin-2 –one
**Melting point**:150-1800c
The Fig 9 shows the structure of PVP

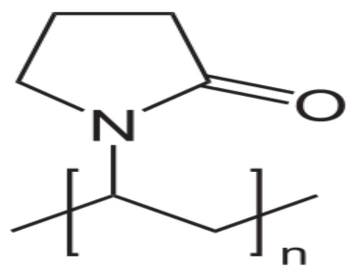

Fig.9: Structure of PVP
It is a water soluble polymer made from the monomer N-Vinyl pyrrolidone [16]. Dry PVP is a light flaky hygroscopic powder and readily absorbs up to 40% of water by its weight.
The Fig 10. Shows the synthesis of PVP.

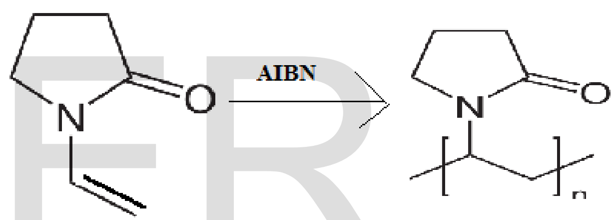


Fig 10. Synthesis of PVP

PVP can be prepared by free radical polymerization from its monomer N vinylpyrrolidone in the presence of AIBN as an initiator as shown in Fig 10 [16].The PVP is being used as blood plasma expander for trauma victims. It is also used as binder in many pharmaceutical tablets and it simply passes through the body when administered orally. A complex called Povidone –Iodine is formed when PVP is added to iodine that processes disinfectant properties.

## 3. CONCLUSION

It can be concluded that the polymers discussed in this paper play an important role in in the field of biomedical applications because of the unique properties they exhibit compared to their conventional counterparts. As the advents in the material science, polymer science in particular take place further it is expected that of such polymer are likely to find more and more applications in this field .Increased development of medical devices as a result of improved process of polymerization is expected to take place in the near future which can be a giant leap in aiming to improve the health conditions of human beings.

## References

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[1] J Jugur Grodzinski, "Biomedical application of functional polymers", React,Funct,Poylm 39(1999)99-138,

[2] J. C. Middleton et.al "Synthetic biodegradable polymers as orthopedic devices ,Biomedicals 21 (2000) 2335-2346.

[3] M E gomes et.al ," biodegradable polymers and Composites in biomedical applications: From catgut to tissue engineering, Part I Available systems and their properties, Int. Matter Rev 49(2004),261-273.

[4] L Durselen et.al ," resoursable polymer fibers for ligament augmentation ,J Biomed, Matter Res 58(2001)666-672.

[5] L S Nair et. al.," Polymers as biomaterials for tissue enginnering and controlled drug delivary. Adv, Biochem Engg Biotechnol 102(2006)47-90

[6] H.C.Kang et.al,,"Polymeric gene carriers, Crit. RevEukaryot.geneexpr,15(2005)317-342

[7] Q. Li n ,m " Naturally occurring polymer biomaterials" in S Donglu (Ed)Introductions to Biochemicals ,World Scientific Publishing Pvt. Ltd. Singapore 2006 pp 158-171

[8] M H Shridhan et. al ," Bio absorbable polymer scaffolds for tissue engineering capable of sustained growth factor delivery , J Control Release 64(2000)91-102

[9] K A Athanasiou et. al ,"Orthopedic applications for PLA,PGA Biodegradable polymers , Arthoscopy 14 (1998)726-737

[10] N A Gharibjanian et. al. ," release kinetics of polymer bound bone morpho generic protein -2 and its effects on osteogenic expression of MC3T3-E1 oestroprecursor cells , plast. Reconstr. Surgry.123(2009)1169-1177

[11] M Azori et.al, "polymeric pro drugs", Crit. Rev Ther. Drug Carrier system4(1987)39-65

[12] V.F.M.H .Degroot,"Pordrugs: Challenges and rewards,Targetting cancer small molecules,Springer,USA 2007 pp. 478

[13] J Nicolas et. al," Design Functionalization strategies and biomedical applications of targeted biodegradable, biocompatible polymer based nano carriers for drug delivery, Chem.soc Rev 42(2013)1147-1235

[14] ] E. D Boland," Electrospinning Polydyoxanone for biomedical Applications, Acta bio Matter 1 ,2005-115-123

[15] J Middleton," Synthetic biodegradable polymers as medical devices',Med Plast biomatter .Mag. March 1998

[16] F. Haaf et.al,"Polymers of N Vinyl pyrrolidone synthesis ,characterization and uses ",Polym J,1985 143-152

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