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REFERENCE

HANDBOOK OF BIODEGRADABLE POLYMERS

Edited by Catia Bastioli

3RD EDITION

Biodegradable Polymers Book

Sampa Saha, Chandrani Sarkar



Biodegradable Polymers Book:

Handbook of Biodegradable Polymers Catia Bastioli, 2020-03-09 This handbook covers characteristics processability and application areas of biodegradable polymers with key polymer family groups discussed It explores the role of biodegradable polymers in different waste management practices including anaerobic digestion and considers topics such as the different types of biorefineries for renewable monomers used in producing the building blocks for biodegradable polymers

Biodegradable Polymers David K. Platt, Rapra Technology Limited, 2006 Biodegradable polymers have experienced strong growth over the last three years and are set to make further inroads into markets traditionally dominated by conventional thermoplastics in future Four main classes of biodegradable polymers are analysed in this report polylactic acid PLA starch based polymers synthetic biodegradable polymers such as aromatic aliphatic co polyesters and polyhydroxyalkanoates PHA The report analyses their key performance properties applications development market drivers and future prospects Each product section also contains an estimate of market size by world region and end use market plus forecasts to 2010 There is also an analysis of key suppliers and their products *The Complete Book on Biodegradable Plastics and Polymers (Recent Developments, Properties, Analysis, Materials & Processes)* NIIR Board of Consultants & Engineers, 2006-10-01

Biodegradable plastics made with plant based materials have been available for many years The term biodegradable means that a substance is able to be broken down into simpler substances by the activities of living organisms and therefore is unlikely to persist in the environment There are many different standards used to measure biodegradability with each country having its own The requirements range from 90 per cent to 60 per cent decomposition of the product within 60 to 180 days of being placed in a standard composting environment They may be composed of either bio plastics which are plastics whose components are derived from renewable raw materials or petroleum based plastics which contain additives Biodegradability of plastics is dependent on the chemical structure of the material and on constitution of the final product not just on the raw materials used for its production Polyesters play a predominant role as biodegradable plastics due to their potentially hydrolysable ester bonds Bio based polymers are divided into three categories based on their origin and production polymer directly extracted from biomass polymers produced by classical chemical synthesis using renewable biomass monomer and polymers produced by microorganisms or genetically modified bacteria In response to public concern about the effects of plastics on the environment and in particular the damaging effects of sea litter on animals and birds legislation is being enacted or is pending in many countries to ban non degradable packing finishing nets etc This book basically deals with biodegradable plastics developments and environmental impacts hydro biodegradable and photo biodegradable starch synthetic aliphatic polyester blends difference between standards for biodegradation polybutylene succinate pbs and polybutylene recent developments in the biopolymer industry recent advances in synthesis of biopolymers by traditional methodologies polymers environmentally degradable synthetic biodegradable polymers as medical devices

polymers produced from classical chemical synthesis from bio based monomers potential bio based packaging materials conventional packaging materials environmental impact of bio based materials biodegradability and compostability etc Environmentally acceptable degradable polymers have been defined as polymers that degrade in the environment by several mechanisms and culminate in complete biodegradation so that no residue remains in the environment The present book gives thorough information to biodegradable plastic and polymers This is an excellent book for scientists engineers students and industrial researchers in the field of bio based materials TAGS Bioplastics and Biodegradable Plastics Biodegradable Plastics and Polymers Biodegradable Products Biodegradable Plastics from Waste How to Make Biodegradable Plastic Biodegradable Plastic Bags Biodegradable Plastic Bottles Biodegradable Plastic Manufacture Producing Biodegradable Plastic Starch Based Biodegradable Plastics Biodegradable Plastic Packaging Bio Based Biodegradable Plastics Biobased and Biodegradable Plastic Biodegradable Polymers Biodegradable Polymers Plastic Biodegradable Polymer Materials Synthetic Biodegradable Polymers Biodegradable Polymers Production of Biodegradable Polymers Degradation of Biodegradable Polymers Starch Based Bio Plastics Biodegradable Polyesters Polyester Based Bio Degradable Polymers Polyhydroxyalkanoates PHBH Polyesters PLA Polyesters Degradation Mechanism Coated Paper Agricultural Mulch Film Shopping Bags Plastic Sorting and Reprocessing Biopolymer Industry Industrial Biopolymer Fiber Reinforced Composites Natural Polymers Environmentally Degradable Polymers Production of Environmentally Degradation Polymers Synthetic Biodegradable Polymers as Medical Devices Natural and Synthetic Biodegradable Polymers Degradation of Commercial Biodegradable Commercial Biodegradable Material Biobased Packaging Materials for Food Industry Bio Food Packaging Compostable Packaging Bio Based Materials Production of Biobased Products Plastics from Potato Waste Biodegradable Plastics from Potato Waste Carbohydrate Based Polymers Synthesis of Carbohydrate Based Polymers Synthesis and Polymerization of Anhydro Sugars Polymerization of Anhydro Sugar Fungal Degradation of Carbohydrate Linked Polystyrenes Polyester Film Manufacturing PET Film Polyester Film Casting Drawing Slitting and Winding Coating Production of Multilayer Co Injection Co Injection Molding Injection Blow Molding Injection and Co Injection Preform NPCS Niir Process Technology Books Business Consultancy Business Consultant Project Identification and Selection Preparation of Project Profiles Startup Business Guidance Business Guidance to Clients Startup Project Startup Ideas Project For Startups Startup Project Plan Business Start Up Business Plan for Startup Business Great Opportunity For Startup Small Start Up Business Project Best Small and Cottage Scale Industries Startup India Stand Up India Small Scale Industries New Small Scale Ideas for Bioplastics and Biodegradable Plastics Industry Biodegradable Polymers Business Ideas you can start on your own Indian Biodegradable Polymers Industry Small Scale Biodegradable Plastics Industry Guide to Starting and Operating Small Business Business Ideas for Biodegradable Plastics How to Start Biodegradable Plastics Business Starting Biodegradable Polymers Industry Start your own Biodegradable Plastics Business Biodegradable Plastics Business Plan Business Plan for Biodegradable

Plastics Small Scale Industries in India Biodegradable Polymers Based Small Business Ideas in India Small Scale Industry you can start on your own Business Plan for Small Scale Industries Set Up Biodegradable Plastics Profitable Small Scale Manufacturing How to Start Small Business in India Free Manufacturing Business Plans *Biodegradable Polymers in Clinical Use and Clinical Development* Abraham J. Domb, Neeraj Kumar, 2011-05-12 This book focuses on biodegradable polymers that are already in clinical use or under clinical development Synthetic and natural polymers will be included This excludes polymers that have been investigated and did not reach clinical development The purpose of this book is to provide updated status of the polymers that are clinical use and those that are now being developed for clinical use and hopefully will reach the clinic during the next 5 years The book provides information that of interest to academics and practicing researchers including chemists biologists and bioengineers and users physicians pharmacists Biodegradable polymers for industrial applications Ray Smith, 2005-05-17 The vast majority of plastic products are made from petroleum based synthetic polymers that do not degrade in a landfill or in a compost like environment Therefore the disposal of these products poses a serious environmental problem An environmentally conscious alternative is to design synthesize polymers that are biodegradable Biodegradable polymers for industrial applications introduces the subject in part one by outlining the classification and development of biodegradable polymers with individual chapters on polyhydroxyalkanoates polyesteramides and thermoplastic starch biodegradable polymers and others The second part explores the materials available for the production of biodegradable polymers Polymers derived from sugars natural fibres renewable forest resources poly lactic acid and protein nanoparticle composites will be looked at in detail in this section Part three looks at the properties and mechanisms of degradation prefacing the subject with a chapter on current standards The final part explores opportunities for industrial applications with chapters on packing agriculture and biodegradable polycaprolactone foams in supercritical carbon dioxide Biodegradable polymers for industrial applications explores the fundamental concepts concerning the development of biodegradable polymers degradable polymers from sustainable sources degradation and properties and industrial applications It is an authoritative book that will be invaluable for academics researchers and policy makers in the industry *Advances in Biodegradable Polymers* G. F. Moore, S. M. Saunders, 1998-02 In this report the factors which influence biodegradation are first explained Methods of testing and evaluating biodegradation are then described and compared The principles relative costs and practical applications of specific tests are outlined together with the position with respect to recognised standards The range of biodegradable polymers and polymer blends is then described including natural and synthetic products An additional indexed section containing several hundred abstracts from the Rapra Polymer Library database provides useful references for further reading **Biodegradable Polymers** Chih-Chang Chu, 2015 These 2 volume books strive to provide to our readers the most up to date core information available in the published literature as well as our yet to be published studies with ample illustrations total 416 on biodegradable polymers

Much of the information used in this book is from the authors own research activities over the past several decades These 2 volume books contain a compilation of new developments in the creation and use of biodegradable polymers including the relatively new polymers designed from the ground up i e designing new monomers the modification of existing biodegradable polymers to achieve particular new goals and functions new fabrication methods for better efficiency purity and yields new engineering methods to formulate existing biodegradable polymers into new physical forms and new applications of existing or new biodegradable polymers in biomedical and environmental arenas These 2 volume books contain a total of 28 chapters grouped under 2 volumes Volume 1 has a total of 14 chapters and 2 sections Section I Basic degradation study and phenomenon 6 chapters and Section II Biomedical and environmental applications 8 chapters Volume 2 has also 14 chapters and focuses on newly designed biodegradable polymers and their formulation into different physical forms The chapters in both volumes have both new original articles and information and review articles with updated and new information Although the bulk of the chapters in this book 90% deal with issues in biomedical fields which are far more challenging demanding and costly to resolve two chapters deal with use of biodegradable materials for environmental impacts The books are designed for material and polymer scientists and engineers and biomedical engineers in both universities and in industries with an interest in the biomedical field Biomaterial scientists and engineers biomedical engineers and even medical professionals who have used implantable polymeric based medical devices for their practice will find these books coverage of the latest developments and challenges useful either as a comprehensive review or an up to date report of the developments in the field of biodegradable polymers The contributors include both academic scientists and research scientists in industry from 10 different countries in North USA and South America Brazil Argentina Asia China Korea Singapore and Europe Germany Italy Spain Portugal Therefore these 2 volume books are truly internationally as well as multidisciplinary oriented covering science and engineering without borders Handbook of Biopolymers and Biodegradable Plastics Sina

Ebnesajjad,2012-12-31 Biopolymers and Biodegradable Plastics are a hot issue across the Plastics industry and for many of the industry sectors that use plastic from packaging to medical devices and from the construction industry to the automotive sector This book brings together a number of key biopolymer and biodegradable plastics topics in one place for a broad audience of engineers and scientists especially those designing with biopolymers and biodegradable plastics or evaluating the options for switching from traditional plastics to biopolymers Topics covered include preparation fabrication applications and recycling including biodegradability and compostability Applications in key areas such as films coatings controlled release and tissue engineering are discussed Dr Ebnesajjad provides readers with an in depth reference for the plastics industry material suppliers and processors bio polymer producers bio polymer processors and fabricators and for industry sectors utilizing biopolymers automotive packaging construction wind turbine manufacturers film manufacturers adhesive and coating industries medical device manufacturers biomedical engineers and the recycling industry Essential information

and practical guidance for engineers and scientists working with bioplastics or evaluating a migration to bioplastics Includes key published material on biopolymers updated specifically for this Handbook and new material including coverage of PLA and Tissue Engineering Scaffolds Coverage of materials and applications together in one handbook enables engineers and scientists to make informed design decisions Biodegradable Polymers and Plastics Emo Chiellini, Roberto Solaro, 2012-12-06 Synthetic and semi synthetic polymeric materials were originally developed for their durability and resistance to all forms of degradation including biodegradation Such materials are currently widely accepted because of their ease of processability and amenability to provide a large variety of cost effective items that help to enhance the comfort and quality of life in the modern industrial society However this widespread utilization of plastics has contributed to a serious plastic waste burden and the expectation for the 21st century is for an increased demand for polymeric material This volume focuses on a more rational utilization of resources in the fabrication consumption and disposal of plastic items specifically Environmentally Degradable Polymeric Materials EDPs Water soluble Swellable Biodegradable Polymers EDPs from Renewable Resources Biopolymers Bioresorbable Materials for Biomedical Applications Biorelated Polymers Standards and Regulations on EDPs **Biodegradable Polymers** Manjari Sharma, 2021-04-15 This book is about development of biodegradable polymers alternatives which are required to save our reserves of fossil fuels and to save our mother earth from further environmental degradation This book deals with the family of biodegradable polymers which have to be prepared with a novel idea of studying polymers with a Cradle to Grave approach It touches upon basic materials which can be potential materials to prepare biodegradable polymers with their basic structures properties behaviour and limitations known till date This book will help students in understanding various characterization techniques which can be used for the study of identification of functional group structural properties thermal behaviour crystallographic nature mechanical properties and morphological properties through FTIR ATR for physico chemical properties DSC TGA for thermal studies XRD for crystallographic studies SEM for morphological studies It also provides an overview of various testing methods to analyse biodegradability including standard guideline for evaluation of biodegradation and compostability of polymer material through ASTM ISO EN standard methods Note T F does not sell or distribute the Hardback in India Pakistan Nepal Bhutan Bangladesh and Sri Lanka *Biodegradable Polymers. Volume 1* Chih-Chang Chu, 2015 These 2 volume books strive to provide to our readers the most up to date core information available in the published literature as well as our yet to be published studies with ample illustrations total 416 on biodegradable polymers Much of the information used in this book is from the authors own research activities over the past several decades These 2 volume books contain a compilation of new developments in the creation and use of biodegradable polymers including the relatively new polymers designed from the ground up i e designing new monomers the modification of existing biodegradable polymers to achieve particular new goals and functions new fabrication methods for better efficiency purity and yields new engineering methods to formulate existing

biodegradable polymers into new physical forms and new applications of existing or new biodegradable polymers in biomedical and environmental arenas These 2 volume books contain a total of 28 chapters grouped under 2 volumes Volume 1 has a total of 14 chapters and 2 sections Section I Basic degradation study and phenomenon 6 chapters and Section II Biomedical and environmental applications 8 chapters Volume 2 has also 14 chapters and focuses on newly designed biodegradable polymers and their formulation into different physical forms The chapters in both volumes have both new original articles and information and review articles with updated and new information Although the bulk of the chapters in this book 90% deal with issues in biomedical fields which are far more challenging demanding and costly to resolve two chapters deal with use of biodegradable materials for environmental impacts The books are designed for material and polymer scientists and engineers and biomedical engineers in both universities and in industries with an interest in the biomedical field Biomaterial scientists and engineers biomedical engineers and even medical professionals who have used implantable polymeric based medical devices for their practice will find these books coverage of the latest developments and challenges useful either as a comprehensive review or an up to date report of the developments in the field of biodegradable polymers The contributors include both academic scientists and research scientists in industry from 10 different countries in North USA and South America Brazil Argentina Asia China Korea Singapore and Europe Germany Italy Spain Portugal Therefore these 2 volume books are truly internationally as well as multidisciplinary oriented covering science and engineering without borders

Biodegradable Polymers and Their Emerging Applications Sampa Saha, Chandrani Sarkar, 2023-08-07 Bio degradable polymers are rapidly emerging as a sustainable alternative to traditional petroleum based plastics and polymers However the synthesis and processing of such polymers present unique challenges and opportunities In this comprehensive volume Dr Saha and her team provide an in depth exploration of the synthesis and processing of bio degradable polymers and their emerging applications in various sectors from drug delivery to food packaging Covering a wide range of topics including synthesis modification processing techniques and few of their advanced applications in emerging areas this book provides a comprehensive overview of the field The authors also delve into cutting edge research on the synthesis properties and applications of bio degradable polymers in various fields such as agricultural food preservation biomedical arena energy storage and other advanced application areas This volume is an essential resource for scientists engineers and policymakers interested in the future of sustainable materials Whether you are a researcher looking to expand your knowledge of biodegradable polymer synthesis and processing or a policymaker interested in the potential of biodegradable polymers to reduce our reliance on fossil fuels this book is an invaluable guide to the field

Handbook of Biodegradable Polymers Andreas Lendlein, Adam Sisson, 2011-09-19 A comprehensive overview of biodegradable polymers covering everything from synthesis characterization and degradation mechanisms while also introducing useful applications such as drug delivery systems and biomaterial based regenerative therapies An introductory section deals with such

fundamentals as basic chemical reactions during degradation the complexity of biological environments and experimental methods for monitoring degradation processes The result is a reliable reference source for those wanting to learn more about this important class of polymer materials as well as scientists in the field seeking a deeper insight **Synthetic**

Biodegradable Polymers Bernhard Rieger, Andreas Künkel, Geoffrey W. Coates, Robert Reichardt, Eckhard Dinjus, Thomas A. Zevaco, 2012-01-21 Salen Metal Complexes as Catalysts for the Synthesis of Polycarbonates from Cyclic Ethers and Carbon Dioxide by Donald J Darensbourg Material Properties of Poly Propylene Carbonates by Gerrit A Luinstra and Endres Borchardt Poly 3 Hydroxybutyrate from Carbon Monoxide by Robert Reichardt and Bernhard Rieger Ecoflex and Ecovio Biodegradable Performance Enabling Plastics by K O Siegenthaler A K nkel G Skupin and M Yamamoto Biodegradability of Poly Vinyl Acetate and Related Polymers by Manfred Amann and Oliver Minge Recent Developments in Ring Opening Polymerization of Lactones by P Lecomte and C J r me Recent Developments in Metal Catalyzed Ring Opening Polymerization of Lactides and Glycolides Preparation of Polylactides Polyglycolide and Poly lactide co glycolide by Saikat Dutta Wen Chou Hung Bor Hunn Huang and Chu Chieh Lin Bionolle Polybutylenesuccinate by Yasushi Ichikawa Tatsuya Mizukoshi Polyurethanes from Renewable Resources by David A Babb *Biofiller-Reinforced Biodegradable Polymer Composites* R. Jumaidin, S. M. Sapuan, H. Ismail, 2020-10-27 Presenting a comprehensive overview of the field Biofiller Reinforced Biodegradable Polymer Composites examines biodegradable composites derived from biofiller and biodegradable polymers while providing critical information for efficient use of biocomposites developed from natural resources Discusses advanced techniques for the use of both biofiller and biodegradable polymers as the matrix for composites Highlights application of both natural fiber and natural matrix for composites in the development of environmentally friendly and sustainable materials Introduces the basics of biocomposites the processing and characteristics of new composite materials and new combinations of composites such as soy protein and nanocellulose Elaborates on the introduction of new materials to develop biodegradable polymers This book has been written for researchers advanced students and professional engineers and materials scientists working in the area of bio based polymers natural fiber composites and biocomposites Degradable Polymers G. Scott, D. Gilead, 2012-12-06 Few scientific developments in recent years have captured the popular imagination like the subject of biodegradable plastics The reasons for this are complex and lie deep in the human subconscious Discarded plastics are an intrusion on the sea shore and in the countryside The fact that nature s litter abounds in the sea and on land is acceptable because it is biodegradable even though it may take many years to be bioassimilated into the ecosystem Plastics litter is not seen to be biodegradable and is aesthetically unacceptable because it does not blend into the natural environment To the environmentally aware but often scientifically naive biodegradation is seen to be the ecologically acceptable solution to the problem of plastic packaging waste and litter and some packaging manufacturers have exploited the green consumer with exaggerated claims to environmentally friendly biodegradable packaging materials The principles

underlying environmental degradation are not understood even by some manufacturers of biodegradable materials and the claims made for them have been categorized as deceptive by USA legislative authorities This has set back the acceptance of plastics with controlled biodegradability as part of the overall waste and litter control strategy At the opposite end of the commercial spectrum the polymer manufacturing industries through their trade associations have been at pains to discount the role of degradable materials in waste and litter management This negative campaign has concentrated on the supposed incompatibility of degradable plastics with aspects of waste management strategy notably materials recycling

Biodegradable Polymers Margarita del Rosario Salazar Sánchez, José Fernando Solanilla Duque, Aidé Sáenz-Galindo, Raúl Rodríguez-Herrera, 2023 The book on biodegradable polymer science dwells on the basic concepts of biodegradable polymer science describing the techniques standards and analysis to be performed to characterize biodegradable polymeric materials highlighting that it is important to further develop and or innovate processes considering the environment All applications are shown from a sustainability and sustainability approach it is important to highlight that biodegradability has a great burden when it involves substituting modifying and or designing existing processes in harmful and polluting processes The book concludes with a reflection on the development of biodegradable polymers in different fields Biodegradable Polymers. Volume 2 Chih-Chang Chu, 2015 These 2 volume books strive to provide to our readers the most up to date core information available in the published literature as well as our yet to be published studies with ample illustrations total 416 on biodegradable polymers Much of the information used in this book is from the authors own research activities over the past several decades These 2 volume books contain a compilation of new developments in the creation and use of biodegradable polymers including the relatively new polymers designed from the ground up i e designing new monomers the modification of existing biodegradable polymers to achieve particular new goals and functions new fabrication methods for better efficiency purity and yields new engineering methods to formulate existing biodegradable polymers into new physical forms and new applications of existing or new biodegradable polymers in biomedical and environmental arenas These 2 volume books contain a total of 28 chapters grouped under 2 volumes Volume 1 has a total of 14 chapters and 2 sections Section I Basic degradation study and phenomenon 6 chapters and Section II Biomedical and environmental applications 8 chapters Volume 2 has also 14 chapters and focuses on newly designed biodegradable polymers and their formulation into different physical forms The chapters in both volumes have both new original articles and information and review articles with updated and new information Although the bulk of the chapters in this book 90% deal with issues in biomedical fields which are far more challenging demanding and costly to resolve two chapters deal with use of biodegradable materials for environmental impacts The books are designed for material and polymer scientists and engineers and biomedical engineers in both universities and in industries with an interest in the biomedical field Biomaterial scientists and engineers biomedical engineers and even medical professionals who have used implantable polymeric based medical devices for their practice will

find these books coverage of the latest developments and challenges useful either as a comprehensive review or an up to date report of the developments in the field of biodegradable polymers The contributors include both academic scientists and research scientists in industry from 10 different countries in North USA and South America Brazil Argentina Asia China Korea Singapore and Europe Germany Italy Spain Portugal Therefore these 2 volume books are truly internationally as well as multidisciplinary oriented covering science and engineering without borders *Synthetic Biodegradable Polymer*

Scaffolds Anthony Atala, David J. Mooney, 2013-11-11 This body of work represents the first volume of a book series covering the field of tissue engineering Tissue engineering which refers to a category of therapeutic or diagnostic products and processes which are based upon a combination of living cells and biomaterials was defined as a field only a few years ago 1988 Tissue engineering is an inherently interdisciplinary field combining bioengineering life sciences and clinical sciences The definition of this area of work as the field of tissue engineering brought together scientists from multiple backgrounds who already were working toward the achievement of similar goals Why a book series exclusively devoted to tissue engineering The field of tissue engineering is heterogeneous The cells involved in tissue engineering can be autologous allogeneic or xenogeneic The biomaterials utilized can be either naturally occurring synthetic or a combination of both The application of the technology can be either for acute or permanent purposes An attempt to cover the field of tissue engineering in a single volume with the degree of detail necessary for individuals with different scientific backgrounds and disciplines would be a difficult task to accomplish particularly when this field is just emerging and changing rapidly Therefore addressing different technologies within the field of tissue engineering in a comprehensive manner is the main mission of this series of volumes A stellar group of scientists has been brought together to form the editorial board of the series **Biodegradable Polymers in Pharmacy and Medicine. Classification, Chemical Structure, Principles of Biodegradation and Use** Jan Gajdziok, Roman Gonč, David Vetchý, 2016-09-13 Document from the year 2016 in the subject

Medicine Pharmacology Pharmacy course Pharmaceutical technology language English abstract The aim of this book is to provide a brief but comprehensive overview on the issue of biodegradable polymers The introduction chapter is followed by a description of the general characteristics of biodegradable polymers and pathways of their degradation in the human body Particular pitfalls and specifics of their various biomedical and pharmaceutical applications especially in the field of pharmaceutical technology are described in order to define the ideal carrier polymer system for specific types of therapy Finally the work presents the classification of these polymers based on the type of degradation mechanism This section also includes the chemical structure of particular polymer molecules their chemical or bio synthesis and the description of their uses in specific biomedical and pharmaceutical applications The book could be used as a textbook for students of medical and pharmaceutical sciences as well as by researchers in this field or industrial area In the past few decades biodegradable polymers have reached significant importance in fields of biomedical and pharmaceutical applications They have become

preferred candidates for the manufacture of therapeutic forms for instance orthopaedics devices temporary bone screws and spins three dimensional scaffolds for tissue engineering or drug delivery systems for sustained and targeted release Each of these applications requires material with specific physical biological and chemical properties as well as specific degradation profile These polymers natural or synthetic undergo hydrolytic or enzymatic degradation which both have some advantages and disadvantages Most widely used polymer materials in biomedical applications are listed including their structure and degradation pathways

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