iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** V **Month of publication:** May 2020

DOI: http://doi.org/10.22214/ijraset.2020.5066

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue V May 2020- Available at www.ijraset.com

Remodeling Life and Living - A Review of Advanced Polymeric Materials

Dr. Mousumi Bhattacharjee James
Assistant Professor, Department of Humanities and Applied Sciences, New Horizon Institute of Technology and Management, Mumbai University, Maharashtra, India

Abstract: Advanced polymers have occupied centerstage in material science extending conglomerated benefits leveraging multifaced industrial applications. Polymers have been expansively discussed and investigated, for the understanding and the perusal of research work of scientists world-wide. Peer research groups who conducted studies on the various concepts, about the structural and functional aspects of this fascinating class of materials, substantiated through their relevant and consistent research work that polymers will continue to benefit life and living in multiple ways. Smart polymers have given an entirely new dimension to polymer science. SMPs or shape memory polymers, are a class of stimuli responsive polymers which respond to even slight changes in environment. Their dynamic behavior responding to their exposure to biological systems has added newer dimensions to biomedical science. This paper reviews various aspects of polymers and how they constantly continue to transform life and lifestyle of mankind refreshing the ways of living. With each passing day newer developments on polymers are being recorded. Conclusively it can be inferred that mankind is surely benefitting with lives transformed and lifestyles refurbished dawning in better life for all.
Keywords: Polymers, Technology, material-science, Biocompatible, Macromolecules, Research.

I. INTRODUCTION

The versatility of polymers has been firmly established, discussed and researched at various global scientific learning and investigative platforms. The multifaceted profile of polymers has been expansively discussed and elaborated, for the understanding and the perusal of research work of scientists and researchers world-wide. Many peer groups who investigated and studied the various concepts, about the structural and functional aspects of this wondrous class of materials, substantiated through relevant and consistent research work, in the same field but through various different facets.

The history of polymers though dates back to the last century and a half, polymers or plastics initially meant anything which could be reshaped. The word " polymer" was derived from the Greek word *poly* meaning "many" and *meres* meaning "parts". This later was defined and redefined as macromolecules, arranged in repeating units, consisting of many parts or long chains of molecules, consisting of numerous small molecules called monomers that are linked together to form long chains and so on.

The commonest natural polymer is cellulose which makes up the cell wall of plants.

Continuous and consistent research world-wide on this subject led to the invention and development of an array of polymers, initiated by the invention of the first synthetic polymer by Leo Baekeland in 1907, this macromolecule which had no molecule from nature came to be known as Bakelite.

The era during world war II saw a surge in the plastic industry which was necessitated by certain material requirements for war such as nylon for parachutes, ropes, helmet liners, body armor etc. This upsurge in invention and development of various polymers and investigating their applications, never saw a decline till date.

This phenomenon of research on polymers on a massive scale probably was the origin and inception of Polymer Science as an entirely separate field of study.

Eventually all culminated to a notion that polymers are truly versatile in nature due to their structural and functional virtues and hence they are being studied, researched and are center of many deliberations on the global platform. The multiple benefits extended by polymers being light weight, corrosion resistant, easily recyclable, with various color options, chemical resistant, economical, easily moldable and so on, has made it evident that this wondrous material has consistently been transforming our lives in various ways.

This paper reviews the various fields and how different polymers have been continually influenced and altered the societal lifestyle ushering all towards not only a more refined, sophisticated and noteworthy living but at the same time also promising a capital change in living spirits, for the present generation over what the global population had earlier experienced.

II. BACKGROUND

To quote author Susan Freinkel, " In product after product, market after market, plastics challenged traditional materials and won, taking the place of steels in cars, paper and glass in packaging and wood in furniture" [1]. The first example of polymer science dates back to 1830's when Henri Braconnot , Christian Schonbein and others synthesized celluloid and cellulose acetate from the natural polymer cellulose. Much later in 1907Leo Baekeland invented the first fully synthetic polymer Bakelite which holds significant utility till date in many applications due to its insulating property. After this there was no looking back, the surge in discovery of newer polymers continued.

Today polymers have occupied centerstage in multiple manufacturing domains like textiles, paints, automobiles, aerospace, building constructions, pharmaceuticals and medical equipment, electronics etc. to name a few. A major important arena where polymers have established their supremacy is medicine and healthcare. The biocompatible nature of polymers has led to adopting them for multiple healthcare needs.

The history of using natural polymers in medicine which goes back thousands of years, as the usage of coconut shells to help injured skulls, and wood and ivory as false teeth, have been often heard of. Then during the Second World War, surgeons came across the benefits of using man-made 'biocompatible' plastics after observing that fragments of Perspex in pilots' eyes as a result of cockpit damage did not cause an adverse reaction from the body. The invention of newer materials is a result of demand for superior manufactured products. The new age industry has upgraded benchmarks, and this leads to advanced research. With the invention of newer polymer molecules, the era of usage of these macromolecules in various walks of life continued to storm and dominate the various industrial arenas with its wide array of material benefits to qualify for being superior basic starting material for various applications.

III. POLYMERS EXTENDING OUTSTANDING MATERIAL BENEFITS

Polymers are macro molecules made up of many repeating units bonded by covalent bonds. The smallest repeating unit of a polymer is called a monomer. Polymers can be natural and synthetic based on their origin. Polymers have established outstanding material benefits like excellent mechanical strength, resilience, corrosion resistance, insulating property, color, transparency and low cost. These facts have facilitated interwoven identities of polymers in almost all facets of manufacturing practices. The increase in life expectancy and altered lifestyles of the society has escalated the demand for superior materials and advanced technology. Polymers by virtue of being available in great variations, have multitudes of members, macromolecular, versatile properties and much more, they have been able to match the expectations for maximum manufacturing practices. Since time immemorial human beings have relied on polymers for various needs, starting from the era of natural polymers or rubbers moving to semi synthetic and then fully synthetic polymers.

Manufacturers in multiple fields like automotive, aerospace, electronics to name a few are now banking on polymers with their preferences over metals, as unlike with metals engineers can reduce processing cycle times and increase durability in demanding environments while using polymers. Additionally, the key benefits of replacing metals with polymers include, significant weight reductions, faster installation and superior mechanical properties.

A study explored the potential of polymers extensively by making comparisons to prove their versatility, social benefits for safety, health, energy saving, and material conservation [2]. They concluded on a positive note predicting potential applications of polymers over the next twenty years.

A book discusses how friction and wear resistance is enhanced in polymeric composite materials as a result of functional fillers and reinforcements[3]. A recent book states that the combination of the components of polymer composites result in unique benefits of mechanical, tensile and thermal properties not possible to obtain from any single material[4]. Most natural polymers are water-soluble and possess some common biological and physiological properties, such as being suitable as soft tissues and organs, compatible for cell encapsulation and transplantation, and easy to handle and reshape.

They comply in multiple ways as suitable materials in organ printing as they are biocompatible, nontoxic, no or low immunological reaction, bio printable using 3D bioprinters, biostable or cross linkable with adequate mechanical properties, biodegradable, suturable with host vascular and nerve networks, permeable for nutrients and gases, bio storable before printing and sterilizable. Synthetic polymers too like polylactic acid (PLA), poly glycolic acid(PGA), Polycaprolactone (PCL), Polyethylene glycol (PEG), Polyurethane (PU), Poly methyl methacrylate (PMMA), Polyethylene glycol acrylate (PEGA) have been successfully used in this wondrous technology along with natural polymers like collagen, gelatin, alginate, fibrinogen, starch, hyaluronan, chitosan, silk, dextran, agar (or agarose), and matrigel.

IV. ADVANCED POLYMERS TRANSFORMING LIFE AND LIVING

Though all polymers which have been consistently used over decades extending the same benefits are till date occupying centerstage of manufacturing practices, but off late the advanced polymers per say smart polymers or shape memory polymers have completely changed industrial research experience and outcomes to a great extent of scientific awe.

The conventional polymers, though still known for their versatility, but are known for their use as static structural parts in various machines and operations whereas advanced polymers with contemporary properties display exceptional benefits. Smart polymers are stimuli responsive polymers which respond to even slight changes in environment.

Their dynamic behavior responding to their exposure to biological systems has added newer dimensions to biomedical science. As discussed in a chapter on smart polymers in a bookstated that smart polymers displayed features similar to biological intelligence. Within smart polymers there are SCPs or Shape Change Polymers, sol hydrogels for which, after their fabrication, the shape change can only occur between a fixed number of equilibrium shapes such as swelling and deswelling[5]. On the other hand, Shape Memory Polymers or SMPs are a class of stimuli responsive polymers. Another important class of polymers are known as self-healing polymers.

V. SMART POLYMERS IN BIOMEDICINE AND BIOTECHNOLOGY

Smart polymers have given an entirely new dimension to the healthcare research arena. Smart polymers are stimuli responsive polymers which respond to even slight change in their environment in an intense manner. In the field of biotechnology and biomedicine researchers have studied the characteristic properties of natural polymers and their behaviors in the biological system. Using such imperative information further synthetic polymers are developed which can mimic these in the biological system. Regarding this the most important property of the material is the exceptional capability to change shape upon application of external stimulus, obtaining shape memory materials[5]. A study enumerates how researchers have been benefited by smart polymers for the development of newer drug delivery systems [6].

Smart polymers are taking center stage for research and industrial applications due to their amazing ability to undergo large reversible, physical or chemical changes in response to small changes in the environmental conditions such as pH, temperature, dual- stimuli, light and phase transition. They are hence being utilized as assuring means for targeted drug delivery, enhanced drug delivery, gene therapy, actuator stimuli and protein folders. A study on various Smart Memory Polymers unfolds the names of certain SMPs and their utility in the field of healthcare[7]. This paper unfolds the SMPs and Biodegradable Shape Memory Polymers (BSMPs) which generally contain hydrolytically or enzymatically sensitive bonds which has functional groups such as groups commonly present in SMPs include esters, amides, carbamates (urethanes), carbonates, and ureas. BSMPs derived from aliphatic polyesters, like poly(ε-caprolactone) (PCL), poly(lactide) (PLA), and their copolymers are often utilized for medical applications due to their biodegradability moreover their use is well established.

An article discusses how novel biomimetic 4D printed tissue scaffolds were obtained with biocompatible naturally derived smart polymers [8]. This work will surely augment the future design and development of novel and functional biomedical scaffolds with advanced 4D printing technology and highly biocompatible smart biomaterials. Polymers have been consistently used for in the field of artificial organs.

A study published by the Japanese Society for Artificial Organs 2008, put forth that materials for artificial organs fall into three categories that is (1) control of physiochemical properties on the material surface (2) modifying material surface utilizing biomolecules (3) constructing biomimetic membrane surfaces[9]. Further the same study discussed artificial hearts designed using polyurethane, artificial kidneys using cellulose and polysulfone, and membrane oxygenators with porous polypropylene and discussed at length polymeric membrane materials in use for artificial organ manufacture. Another recent paper outlines that both natural and synthetic polymers are of utility in producing a branched vascular, neural or lymphatic network with anti-suture capabilities[10].

The technologies for organ manufacturing which initiated in 2000, as solid freeform manufacturing (SFM), known by rapid prototyping (RP) technologies started being utilized in tissue engineering for scaffold manufacturing. Sequentially in 2010 and 2014, the related technologies were named as additive manufacturing (AM) and 3D printing. All these technologies use natural and synthetic polymers as they have inherent properties which suit the process as well as the human system. In a review on advanced polymers for three-Dimensional (3D) organ Bioprinting, it has been appropriately stated that this technology of 3D and 4D organ printing which promise commercial profit at the same time can solve the mortality issues of organ transplants, organ shortages, drug screening, and pathological analysis.[11].

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue V May 2020- Available at www.ijraset.com

The review outlines the challenges and perspectives for comprehensive and fast manufacturing of organs, such as the liver, heart, kidney, lung, breast, and brain utilizing polymers. Smart polymers are exceptionally favorable materials for controlled drug delivery systems for drug variants having short half-life, narrow therapeutic window, liable to gastric and hepatic degradation, and drugs that are therapeutically active at low plasma concentrations. These delivery systems face challenges associated with their development that are related to drug stability, drug release kinetics and the conditions under which the system is delivered to the body. Smart polymers lead to highly precise delivery of drugs to a specific tissue or organ. In healthcare this awesome class of materials have positively affected mortality and morbidity rates, promising longer and healthier lifespan for mankind.

VI. POLYMER IN CONSTRUCTION, TEXTILES, AUTOMOTIVE AND ALLIED INDUSTRIES

Polymers have been successfully used in constructions by virtue of high strength or modulus to weight ratios (light weight but comparatively stiff and strong), toughness, mechanical strength, resilience, resistance to corrosion, lack of conductivity (heat and electrical), color, transparency, processing, and cost effectiveness. Moreover, they are strong yet lightweight, easily maneuverable and transportable . They are durable, knock-and scratch resistant with excellent resistance to weathering. They are easy to install and offer an array of possibilities in design achieved by extrusion, bending and molding. They are available in multiple color variants[12].

In textiles synthetic polymers have shaped a completely new dimension to this colossal industry which by virtue of nature has huge significance to the lifestyle of mankind. Synthetic polymers have been successfully used as fibers for the textile industry for the past couple of decades. Natural organic fibers such as cotton, linen and wool are easily attacked by microorganisms on the contrary most synthetic fabrics are not susceptible to biodeterioration [13].

They are strong, soft, flexible, available in multiple color variants, lightweight and much more. By virtue of these and many more properties they have captured centerstage of the textile industry. Smart polymers which are materials that exhibit noticeable changes in their properties in response to environmental stimulation.

Exceptional attributes can be extended to textiles by integrating smart polymers into them. Smart polymers vis a vis thermal, moisture and light-responsive polymers, and thermal- and pH-responsive hydrogels, have been integrated to textiles to achieve textile smart functionalities for obtaining advanced textiles.

The properties include aesthetic appeal, comfort, drug release, fantasy design (color changing), wound monitoring, smart wetting properties, and protection against extreme environmental variations [14]. A review explored Shape Memory Polymers (SMPs) and their applications to smart, particularly textile products[15].

Polymers have extended exceptional benefits to the automotive industry in the last twenty years, and their applications are experiencing exponential growth. The wide applications of polymeric materials in vehicles dictate the appearance of the automobiles, their functioning, economy and low fuel consumption. The application of polymeric materials aids adequate freedom in design, at the same time also enables economical solutions for the automotive parts. A study in the past concluded that biodegradable composites which were already being used in commercial applications in the automotive industry, for requirements of interior parts and having the potential to be used in specific high consumption components. Polylactic acid wasrecommended as the most promising material in terms of mechanical performance [16].

VII. CONCLUSION

The interdisciplinary nature of Polymer Science though emerging from chemistry, is now extending boundaries into multi-faceted engineering applications and has made it a field of unmitigated importance. The material benefits of polymers have been reckoned by researchers in multiple engineering applications.

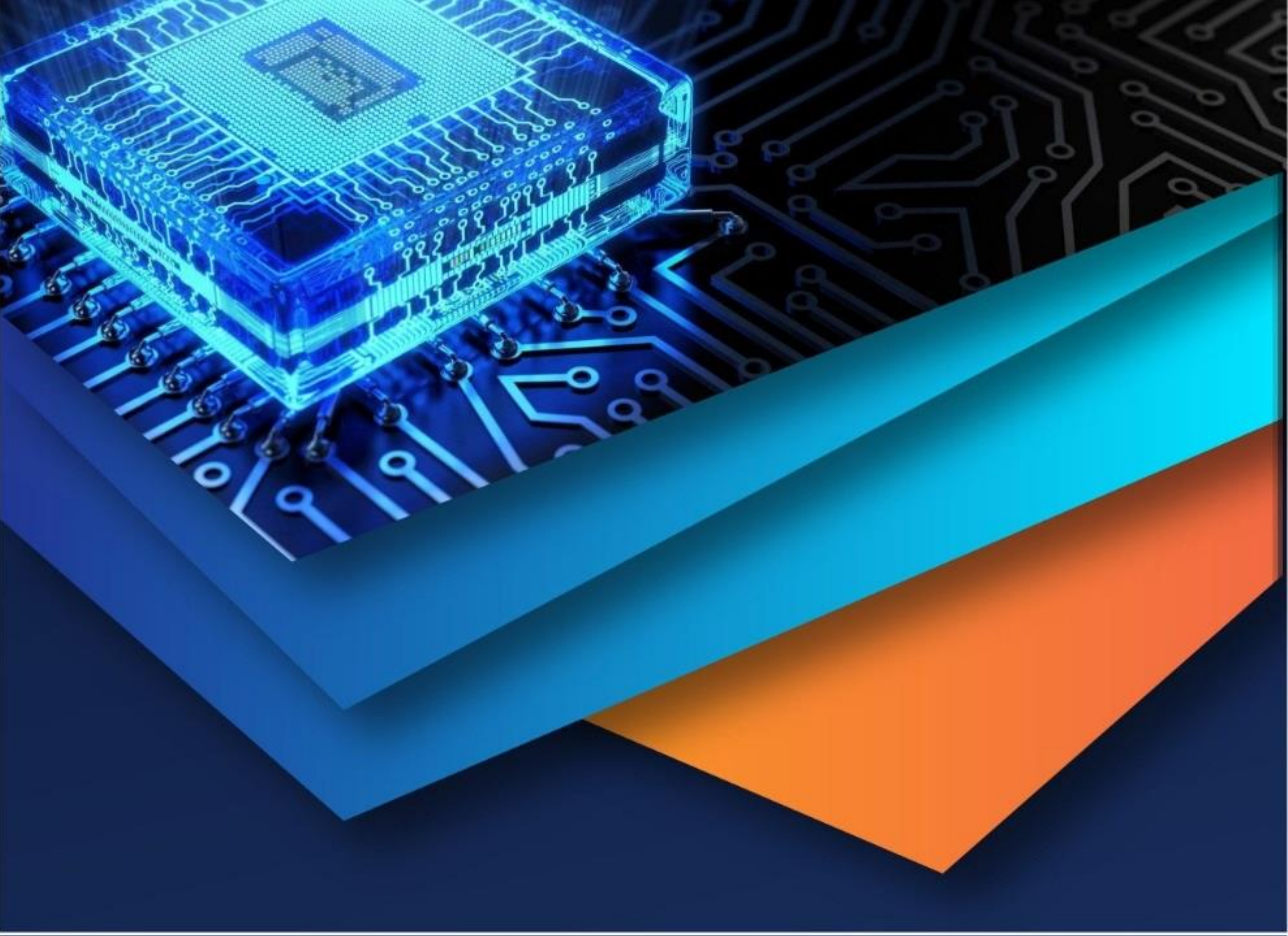
With the onset of the age of shape memory polymers (SMPs) and other advanced smart polymers, unbelievable experiences have been extended to research. This in turn is benefiting the commodity markets enhancing the demand for polymers, furthering investigative and developmental studies in this arena of polymer science. With each passing day newer developments on polymers are being recorded. Conclusively it can be inferred that mankind is surely benefitting with lives transformed and lifestyles refurbished dawning in better life for all.

VIII. ACKNOWEGEMENT

I would like to take this opportunity to extend my gratitude to New Horizon Institute of Technology and Management, Thane, under Mumbai University for providing the platform for my work.

REFERENCES

[1] Plastics: A Toxic Love Story (New York: Henry Holt, 2011), p. 4.
[2] Anthony L. Andrady and Mike A. Neal, Applications and societal benefits of plastics, Phil. Trans. R. Soc. B (2009) 364, 1977–1984.
[3] X.Q. Pei, K. Friedrich, in Reference Module in Materials Science and Materials Engineering, 2016.
[4] Rozyanty Rahman, Syed Zhafer Firdaus Syed Putra, Mechanical and Physical Testing of Biocomposites, Fibre-Reinforced Composites and Hybrid Composites, 2019.
[5] L.Peponi M.P. ArrietaA. Mujica-Garcia D. López, Modification of Polymer Properties, 2017.
[6] Apoorva Mahajan, Geeta Aggarwal “Smart Polymers: Innovations in Novel Drug Deliver”, Int. J. Drug Dev. & Res., July-Sept 2011, 3(3):16-30.
[7] Gregory I. Peterson, Andrey V. Dobrynin, and Matthew L. Becker, Biodegradable Shape Memory Polymers in Medicine, Adv. Healthcare Mater. 2017, 6, 1700694.
[8] Shida Miao, PhD,1 Wei Zhu,Nathan J. Castro,1 JinsongLeng, and Lijie Grace Zhang, Shida Miao, PhD,1 Wei Zhu, Nathan J. Castro, PhD,1 JinsongLeng, PhD,2 and Lijie Grace Zhang, Four-Dimensional Printing Hierarchy Scaffolds with Highly Biocompatible Smart Polymers for Tissue, Engineering Applications TISSUE ENGINEERING: Part C Volume 22, Number 10, 2016.
[9] Kawakami H, Polymeric membrane materials for artificial organs, J Artif Organs. 2008;11(4):177-81.
[10] Xiaohong Wang, Bioartificial Organ Manufacturing Technologies, Cell Transplantation 2019, Vol. 28(1) 5–17.
[11] Advanced Polymers for Three-Dimensional (3D) Organ Bioprinting, Xiaohong Wang, Micromachines, MDPI, 25 November 2019.
[12] Mousumi Bhattacharjee James , Polymers in Civil Engineering: Review of alternative materials for superior performance, Journal of Applied Science and Computations, Vol VI, Issue V, May 2019, pp1770-73.
[13] Jadwiga Szostak-Kotowa, Biodeterioration of textiles, International Biodeterioration & Biodegradation, Volume 53, Issue 3, April 2004, Pages 165-170.
[14] J.HuJ.Lu, Smart polymers for textile applications, Woodhead Publishing Limited, 2014, Pages 437-475.
[15] Hu, JL Ding, XM Tao, XM Yu, JM, Shape memory polymers and their applications to smart textile products, Journal of Dong Hua University (English Edition) 2002, v. 19, no. 3, p. 89-93.
[16] A. M. Cunha, A. R. Campos1,C. Cristova˜o , C. Vila , V. Santos and J. C. Parajo, Sustainable materials in automotive applications, Plastics, Rubber and Composites 2006 VOL 35 NO 6/7 pp 233-241.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)