Biodegradable Shape Memory Polymers- A Mini Review

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Abstract

The use of degradable polymers in medicine was rapidly expanding from the last decade. The introduction of biodegradable polymers with shape memory effect has come into existence very recently. Biodegradable shape memory polymers are promising materials for the design of biomedical scaffolds which will allow degradation and tissue repair with minimal intervention. On comparing to shape memory alloys and ceramics, the development of degradable shape memory polymers will evade the limitations of subsequent surgical procedures for implant extraction. This paper glances over the general aspects of the different types of stimuli that will activate the shape memory effect and also addresses the applications of biodegradable SMP’s as medical devices.

Keywords: Stimuli; Stents; Bone graft; Artificial disc; Biodegradable polymers

Introduction

Shape memory biodegradable polymer was a new class of smart materials which have become increasingly important among research community and has been explored in various applications including cardiovascular, robotic, dental and so on. Around 70% of patents on biodegradable SMP’s were focused on applications in biomedicine such as cardiology, orthopedics and hematology. The shape memory polymers can be defined as the materials that can be programmed into a temporary shape, and upon applications of external stimulus return to a permanent shape [1]. It may adopt one (dual-shape), two (triple-shape) or several (multi-shape) stable temporary shapes and recover to their permanent shape by applying trigger such as heat, light, temperature, pH etc [2]. The schematic representation of dimensional changes of polymeric systems upon different stimuli and their resulting response were shown in Figure 1. In this review we have explored the biomedical application of degradable shape memory polymers [3]. For evaluating the suitability of shape memory polymers in biomedical field the following factors should be considered as follows: trigger mechanism, biocompatibility, mechanical properties and the performance of shape memory effect [4]. The schematic representation of the basic design consideration in biomedical field was shown in Figure 2.

Biodegradable SMP’s in Biomedical Application

Potential application of biodegradable shape memory polymers were successfully explored in drug delivery, wound healing, tissue engineering, endovascular clot removal and biomedical devices as stents, catheters etc. For biodegradable SMP’s, the switching temperature should be close or slightly above body temperature. The replacement of non-degradable SMP’s by biodegradable one will provide a new pathway that reduce the risk of side effects and improve the quality of life. The use of metallic stents as scaffold will have the limitation of in-stent restenosis and thrombosis [5]. This metal stents are prone to re-narrowing of the artery after 6 months, however the incorporation of degradable shape memory polymeric stents will eliminates the requirement of secondary operation as the removal of stent material was not needed. One of the first reported biodegradable SMP’s stent was Igaki-Tamai stent (made of Poly-L-lactic acid) and have been shown to be effective in the coronaries [6]. The PLLA stent fully degraded within 3 years and also supports long-term safety of the stent. Some other examples of degradable polymeric stents include polyvinyl alcohol (PVA), polyethylene glycol (PEG) and Polylactic acid (PLA). Sonawane et al. [7] developed bio-absorbable polymeric stent using...
the combination of PLA, PLGA and reported the stent as good compatibility with blood. Another interesting biocompatible shape memory drug-eluting stent reported in recent year was cross linked polyethylene glycol (PEG)-PCL copolymer network which have the melting temperature close to body temperature sustainably release mitomycin C and curcumin after shape memory performance [8]. Xia et al. [9] reported potential drug-
eluting stent using cross-linked poly (ε-caprolactone) (cPCL) and poly (sebacic anhydride) (PSA). Biodegradable shape memory stent based on chitosan films was reported by Chen et al. [10] that can be placed in artery with minimal surgical invasion. In another study Chen [11] and his coworkers reported genipin-cross linked chitosan polymeric stent

Figure 1: Schematic representation of dimensional changes of polymeric systems upon different stimuli and their resulting response [3].

Figure 2: Schematic representation of the basic design consideration in biomedical field [4].

When applying non degradable polyurethane based SMP graft for segmental bone defects it should integrated with post surgery after 12 weeks providing torsional stability comparable to an allograft. Whereas on switching to degradable SMP’s for bone defects will results in fast healing of grafted bone and also the post surgery should be avoided on employing degradable SMP’s [12]. Xu et al. [13] developed biodegradable amorphous SMP using polyhedral oligomeric silsesquioxane (POSS) nanoparticle core and 8 poly (DL-lactide) (PDLA) arms. This POSS-SMP nanocomposites, with cortical bone like moduli was implanted for male rats and examined after one year of implantation. Xu et al. [13] and his coworkers reported this degradable polymeric scaffold was a potential candidate for tissue repair and no pathologic abnormalities were detected after 1 year. Biodegradable SMP’s as 2D and 3D scaffolds were reported in recent years for tissue engineering application [14]. The primary motto of tissue engineering is the regeneration of new tissues that will act as a substitute to maintain and improve the functions of tissue [15]. These manmade bio-mimetic degradable polymers with shape memory effect will support the development of tissues and their growth. The accordion-like striped actuators made of liquid crystal polymer films with shape memory effect was developed by De Haan et al. [16] which would be used in medical systems and microrobotics.

Chronic recording of brain activity was anchored using epoxy based materials which is non-degradable in nature. When it was switched over by degradable shape memory polymers, it was more compatible with the brain tissues thereby reducing trauma and facilitates the removal of probe once the brain monitoring was completed [17]. Zhang et al. [18] has developed artificial
spinal disc using biodegradable SMP containing polyethylene glycol (PEG) and poly (lactic acid) or poly (lactic-co-glycolic acids). This artificial spinal disc looks as softer material which was manipulated easily and installed. After recovering its shape in between the vertebrates, the disc would stiffen for enhance weight-bearing performance.

**Conclusion**

The application of biodegradable polymers with shape memory effect may usher in an era of simple, low cost biocompatible smart materials that expanded the scope and clinical utility of these materials. The majority of applications were in pilot developmental stages and hence these degradable biocompatible materials with dynamic properties were explored more in future that may helps in diverse application in this material world.

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