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Current Application of Controlled Degradation Processes in Polymer Modification and Functionalization

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ABSTRACT: Ecological concerns over the accumulation of polymeric waste material and the demand for functionalized polymers in specialty applications have promoted extensive research on different controlled degradation processes and their use. The production of functionalized or modified polymers by conventional synthetic routes is expensive and time consuming. However, advances in degradation technology have become an enabling factor in the production of modified polymers and their functionalization. Mild irradiation, ozonization, and enzymatic routes are among the processes that have been explored for polymer modification. Biopolymers, such as chitosan, hyaluronic acids, and polyhydroxyalkanoates, are known to be suitable for a diverse number of applications, ranging from biomedical to organic-electronics. At the same time, their high molecular weight, crystallinity, and shelf degradability limit their utility. Controlled degradation processes can be used to prepare these types of polymers with reasonably low molecular weights and to generate radical species that help to stabilize these polymers or to initiate further beneficial reactions. In this article, we review the application of controlled degradation processes for polymer modification and functionalization. © 2013 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 000: 000–000, 2013

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INTRODUCTION

Polymers are being increasingly used for more and more diverse purposes; they are particularly important in food, cosmetics, and biomedical applications.[1–3] The rise in the utilization of polymers has health and (often negative) ecological implications, especially from biomedical and environmental perspectives. The demand for the control of the precise delivery targets for therapeutic drugs and the capability of polymeric drug carriers to release their drugs on an independent timescale is growing; polymeric waste disposal can cause severe environmental pollution when they are poorly degradable materials. Both of these warrant an intense research exploration into controlled degradation processes for polymer functionalization and modification. The recent momentum in the use of biodegradable polymers over nondegradable ones is among the measures taken toward environmental friendliness and an increase in the sophistication of biomedical applications. However, at present, most of these biodegradable polymers lack many of the attributes of their nondegradable counterparts. These issues are further compounded by the fact that the production of tailor-made or functionalized biodegradable polymers may be costly because of difficult synthetic steps that are often required for their production. Although several approaches to the development of simpler and more cost-effective means to improve the quality of these biodegradable polymers, including dual biosynthesis[4] and blending,[5] have been reported, additional options need to be explored. In view of this, researchers have turned to the use of the opposite route of degradation processes to either improve the degradability of these important polymers or to customize the process for the production of specialty polymers for niche applications. Among recently reported methods have been the use of high-energy radiation,[6] ozonization,[7] ultrasonic irradiation,[8] microwave irradiation,[9] oxidation,[10,11] biodegradation,[12] and photodegradation.[13]

In this article, we review current research approaches in the application of controlled degradation processes as alternative and viable routes toward enhanced polymer degradation, modification, and functionalization. In most cases, the mechanisms and biochemistry of the degradation process are also presented.

USE OF BIODEGRADATION AND ORGANOMODIFIERS

Biodegradation is known to be an effective method of completely removing degradable polymers and their constituents