Polyurethane types, synthesis and applications – a review


Polyurethanes (PUs) are a class of versatile materials with great potential for use in different applications, especially based on their structure–property relationships. Their specific mechanical, physical, biological, and chemical properties are attracting significant research attention to tailoring PUs for use in different applications. Enhancement of the properties and performance of PU-based materials may be achieved through changes to the production process or the raw materials used in their fabrication or via the use of advanced characterization techniques. Clearly, modification of the raw materials and production process through proper methods can produce PUs that are suitable for varied specific applications. The present study aims to shed light on the chemistry, types, and synthesis of different kinds of PUs. Some of the important research studies relating to PUs, including their synthesis method, characterization techniques, and research findings, are comprehensively discussed. Herein, recent advances in new types of PUs and their synthesis for various applications are also presented. Furthermore, information is provided on the environmental friendliness of the PUs, with a specific emphasis on their recyclability and recoverability.

1. Introduction

Polyurethanes (PUs) are a special group of polymeric materials that are in many ways different from most of the other plastic types. They can be incorporated into many different items, such as paints, liquid coatings, elastomers, insulators, elastic fibres, foams, integral skins, etc. Several forms in which PUs appear today are mere improvements in the invention of the German professor (Professor Dr Otto Bayer) and his co-workers. Fig. 1 illustrates the most important types of PUs and some common examples of their uses. The invention of the diisocyanate polyaddition technique by these researchers led to the creation of the PU industry in 1937, with PU produced through the reaction between diisocyanate and polyester diol.

PU was first developed as an alternative for rubber during World War II. The versatility of this material as well as its suitability to replace other scarce materials led to its incorporation in several applications. For instance, PU coatings were specifically used for impregnating paper and producing garments that were resistant to mustard gas and corrosion. They were also used as chemically-resistant coatings for wood, masonry, and metal, and as high gloss finishes for airplanes. The early industrial production of PU coatings began with different formulations for specific purposes. By the mid-1950s, PU coatings were commonly found in elastomers, coatings, rigid foams and adhesives. Towards the later part of the 1950s, comfortable and convenient cushions made from flexible foams were commercially available. Additionally, the development of flexible foams from cheap polyether polyols led to several automotive and upholstery applications that are still relevant today. Continuous improvements in processing techniques, additives types and in the formulations have contributed to these materials being used in a wide range of applications.

Currently, PUs are one of the most common, versatile and researched materials in the world. These materials combine the durability and toughness of metals with the elasticity of rubber, making them suitable to replace metals, plastics and rubber in several engineered products. They have been widely applied in biomedical applications, building and construction applications, automotive, textiles and in several other industries due to their superior properties in terms of hardness, elongation, strength and modulus.

The urethane group is the major repeating unit in PUs, and is produced from the reaction between alcohol (–OH) and isocyanate (NCO); albeit PUs also contain other groups, such as ethers, esters, urea and some aromatic compounds. Due to the wide variety of sources from which PUs can be synthesized and given their wide range of specific applications, they can be