

“Optimization of the properties of adhesive joints of polylactic acid (PLA) biodegradable polymers with natural adhesives by using atmospheric plasma technologies”

ABSTRACT

The main deal in the development and research of new biodegradable or ecological materials, are the current environmental policies, and the consumer awareness regard to the use and consumption of low environmental impact materials or environment respectful materials. One of the main sources of waste generation is the product packaging, especially food packaging. New consumer trends of current society produce a great amount of waste which has to be correctly arranged in order to produce the least possible environmental impact. It is obvious that plastics are an important part of this kind of waste and due to their petrochemical nature, they are very difficult and expensive to recycle, mainly because of their problems of source separation. For this reason, polymeric materials are occupying nowadays important lines of investigation, due to the interest in substituting materials from petrochemical nature by polymeric materials of natural origin or biopolymers. On the one hand, we face the problem of reducing source materials coming from fossil residues; on the other hand, the simplicity of waste elimination or biodegradability.

Polylactic acid (PLA) is one of the most demanded polymers of this kind because it's applications have increased significantly in the industrial sector. In many cases, this kind of applications requires adhesion or glued, depending on the product design. Due to the inherently low humectability of this kind of biopolymer, the adhesive joints show very low strength.

This problem justifies the research on superficial modification processes, which improve its low humectability. There are different physical and chemical processes related with superficial modification. In general, chemical processes usually cause waste, because they use chemical products which attack the polymeric surface. That waste is harmful to the environment due to its nature. For this reason, processes which do not produce waste are more interesting. Dealing with this topic, processes based on plasma technology are optimal, since both they are environmentally correct, and only modify the surface that we are going to treat without modifying the general behaviour of bulk material.

In this work we want to improve the adhesion strength of polylactic acid (PLA) biodegradable polymers with natural adhesives, using an atmospheric plasma process. The analysis of the effects on PLA surface is made by quantifying the variation of humectability in an experimental way; after that, the PLA substrate was treated with different speeds and distances nozzle-substrate. Study of the mechanisms of plasma surface modification were made to check the efficacy of the atmospheric plasma process, by X-Ray Photoelectron Spectroscopy (XPS) and Fourier transform infrared spectroscopy with Attenuated Total Reflectance (FTIR-ATR) in order to observe the chemical activation on the surface. Next, the physic modification of the surface's material was quantified by the Atomic Force Microscopy technique (AFM) and the Scanning Electron Microscopy technique (SEM). The experimental results allow us to analyse an interesting improvement of the resistance of the PLA/PLA adhesive joints. Furthermore, optimal work ranges are defined in order to use the atmospheric plasma; as well as the evaluation of the durability of atmospheric plasma effects on the treated PLA surface.

The results of this work show that the best results of PLA treated with atmospheric plasma were reached using conditions of slow speed treatment (100-300 mm/s) below the nozzle that produces the plasma and low nozzle-substrate distances, around 10 mm. As it was checked in the XPS results, the surface activation is the main mechanism in the treatment of the PLA surface, due to the insertion of polar species. These species vary along ageing, causing a negative influence in the substrate humectability. Apart from chemical changes, some physical changes also occur due to the material is removed; this fact improves the PLA substrate adhesion properties. The atmospheric plasma treatment is a suitable method to improve the PLA surface adhesive properties; moreover, it is very interesting from an industrial point of view, due to its easy establishment and flexibility in a continuum production process, and because it is a very environmentally respectful technology.