Sustainable Coloration of Poly(lactic acid)

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Introduction

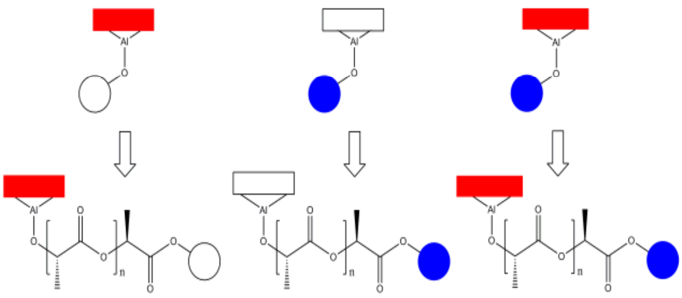
The use of polyesters in textiles applications is constantly increasing – poly(ethylene terephthalate), PET, accounts for over 45% of world textile consumption. However, with the continuing depletion of petrochemical feedstocks, coupled with the non-degradable nature of PET, it has become necessary to develop renewable, degradable polymers for a sustainable future. Poly(lactic acid), PLA, is a linear, aliphatic polyester derived from completely renewable resources and is completely compostable *via* a hydrolysis mechanism.

In order to be a commercially viable material for textiles applications, coloration of PLA is an important consideration. Based on the disperse dyeing of polyesters, the conventional process presents several problems, both environmental and technical. From an environmental view, a huge amount of time, water and energy are used in the dyeing step, along with a number of auxiliary chemicals, which, along with unreacted dye, must be processed before release into the general water stream. From a technical view, the optimum dyeing conditions of pH 4.5 and 130°C lead to significant degradation of the PLA fibre. For future large-scale commercial applications, a coloration process which removes these problems is required.

The DyeCat process combines the polymerisation and coloration processes into a single step, eliminating the wet dyeing process and the technical and environmental issues associated with it. An overview of the process and some important results are presented below.

The DyeCat Approach

The DyeCat approach is based around an aluminium catalyst. By incorporating a dye into the catalyst structure, coloration can be effected during the polymerisation process.



Dye as ligand — Dye as initiator — Combined approach

Polymerisation Results

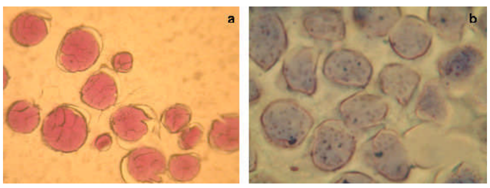
All approaches have been investigated and coloured PLA produced. The most successful approach is the use of a coloured initiator, and the majority of work has been carried out using this method. A variety of coloured PLA has been produced, exhibiting molecular weights in the range 170000-340000 with PDI 1.2-1.6.

Polymer Processing

DyeCat PLA has been successfully melt-spun into fibre. Due to homogeneous coloration, observed colour strength is higher than that obtained through aqueous dyeing, which results in non-homogeneous distribution and dye aggregation. Tensile and other properties compare favourably with typical commercial PLA.

DyeCat PLA subjected to an ISO 106:C06/C2 (60°C) wash fastness test, has shown much greater wash fastness properties than aqueous dyed samples. No staining of the adjacent multifibre fabric (GS5) was observed and UV/VIS showed no colorant in the wash liquor.

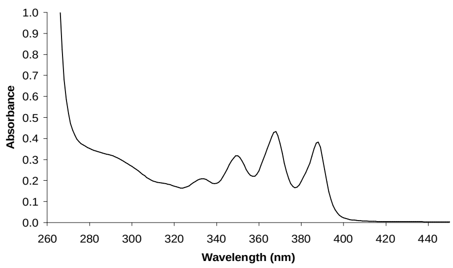
Melt-spun DyeCat PLA



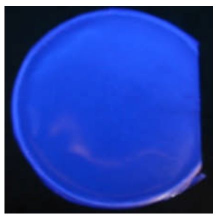
Optical microscopy images of cross-sections through: a) DyeCat PLA, b) Conventionally dyed PLA

Additional Functionality

As PLA is an aliphatic polyester, it has limited absorbance in the UV region, severely limiting its applications in areas where UV protection is required. By incorporating a UV absorbing moiety into the catalyst, significant UV absorbance may be introduced to PLA, as can be seen in the UV/Vis trace below. Fluorescence may also be introduced by the same method, as is also shown below.



UV/Vis trace of UV absorbing DyeCat PLA



Fluorescent DyeCat PLA photographed under short wave UV light

Summary

The DyeCat process has significant environmental and technical advantages when compared to the current practices of PLA fibre preparation, dyeing and finishing. There is no waste dye and no subsequent treatment of waste effluent. Homogeneous coloration leads to a more intense colour than obtained through conventional dyeing and no leaching of colour is observed.

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