Characterization of Surface Microstructures on Bio-Based PLA Fabricated with Nano-Imprint Lithography

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Abstract : In the present study, the formation of structures in poly(lactic acid) (PLA) has been investigated with respect to producing areas of regular, superficial features with dimensions comparable to those of cells or biological macromolecules. Nanoimprint lithography, a method of pattern replication in polymers, has been used for the production of features ranging from tens of micrometers, covering areas up to 1 cm^2, down to hundreds of nanometers. Both micro- and nano-structures were faithfully replicated. Potentially, PLA has wide uses within biomedical fields, from implantable medical devices, including screws and pins, to membrane applications, such as wound covers, and even as an injectable polymer for, for example, lipoatrophy. The possibility of fabricating structured PLA surfaces, with structures of the dimensions associated with cells or biological macro- molecules, is of interest in fields such as cellular engineering. Imprint-based technologies have demonstrated the ability to selectively imprint polymer films over large areas resulting in 3D imprints over flat, curved or pre-patterned surfaces. Here, we compare nano-patterned with nano-patterned by nanoimprint lithography (NIL) PLA film. A silicon nanostructured stamp (provided by Nanotypos company) having positive and negative protrusions was used to pattern PLA films by means of thermal NIL. The polymer film was heated from 40°C to 60°C above its Tg and embossed with a pressure of 60 bars for 3 min. The stamp and substrate were demolded at room temperature. Scanning electron microscope (SEM) images showed good replication fidelity of the replicated Si stamp. Contact-angle measurements suggested that positive microstructuring of the polymer (where features protrude from the polymer surface) produced a more hydrophilic surface than negative micro-structuring. The ability to structure the surface of the poly(lactic acid), allied to the polymer's post-processing transparency and proven biocompatibility. Films produced in this were also shown to enhance the aligned attachment behavior and proliferation of Wharton's Jelly Mesenchymal Stem cells, leading to the observed growth contact guidance. The bacterial attachment patterns of some bacteria, highlighted that the nano-patterned PLA structure can reduce the propensity for the bacteria to attach to the surface, with a greater bactericidal being demonstrated activity against the Staphylococcus aureus cells. These biocompatible, micro- and nanopatterned PLA surfaces could be useful for polymer– cell interaction experiments at dimensions at, or below, that of individual cells. Indeed, post-fabrication modification of the microstructured PLA surface, with materials such as collagen (which can further reduce the hydrophobicity of the surface), will extend the range of applications, possibly through the use of PLA's inherent biodegradability. Further study is being undertaken to examine whether these structures promote cell growth on the polymer surface.

Keywords : poly(lactic acid), nano-imprint lithography, anti-bacterial properties, PLA
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