Morphology and biodegradation of poly (3-hydroxybutirate) films studied by atomic force microscopy

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Poly(3-hydroxybutyrate) (PHB), a natural polyester of the polyhydroxyalkanoates family, is the most well-known microbial polyester used as a promising biodegradable material. Being biodegradable and biocompatible simultaneously, it has attracted researchers as a medical material and a novel environment friendly thermoplastic.

PHB is a semicrystalline polymer, and thus it forms various structures, such as lamellae and spherulites. The semicrystalline morphology and geometry (size of lamellae, their shape, twisting, orientation etc.) of the polymer strongly influences its biodegradation and transport. Understanding factors that influence (and determine) PHB morphology should help to control the biomedical properties of PHB products.

In the current work biodegradation of PHB films by pancreatic lipase was studied by atomic-force microscopy (AFM). During biodegradation three types of changes were observed on the surfaces of the films: appearance of new lamellae, disappearance of lamellae and disintegration of lamellae into shorter fragments. These changes were observed on the surface contacting with glass substrate during film preparation. Presumably, glass substrate slows the crystallization in the thin (~10 nm) interfacial polymer layer, i.e. increases the fraction of amorphous component. To address the problem of the crystallization in the interfacial layer we studied ultrathin PHB films. They were prepared on mica by spin-coating and examined by temperature controlled AFM.

The morphology of ultrathin PHB films depends on deposition conditions. By increasing the polymer concentration and/or decreasing substrate rotation speed we can change the dominant morphology as follows: clean substrate; amorphous layer or drops; seaweed-like crystals; two-dimensional spherulites.

The amorphous component can be represented by either single droplets or continuous layer. At room temperature ultrathin amorphous PHB is metastable and crystallizes easily. Crystallization can be followed by AFM in real time. If the amorphous layer has contacts with crystalline seeds, it crystallizes completely during the experiment (1-2 hours) at room temperature. However the amorphous drops separated from crystalline seeds by bare substrate can be stable for 1-2 days. If the substrate temperature rises, the crystallization rate increases and the crystallization of drops can be imaged easily. The appropriate temperature was found to be 85° C. Thus, it has been shown that the crystallization rate and morphology features depend on the temperature and conditions of PHB film preparation.