Polyhydrohxyamide (PHA) Fibers and Films

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Research Objective: To make high performance PHA fibers and films exhibiting excellent mechanical properties and flame resistance. The materials are precursors to PBO and convert to PBO during cyclization reactions.

Approach: Aromatic polybenzoxazoles (PBOs) have attracted considerable attention because of their excellent thermal stability, outstanding mechanical properties, and resistance to most chemicals. However, PBO polymers have the disadvantage of very poor solubility and no observable melting point, which makes them impossible to process in anything but strong acids, e.g. PPA or MSA . These drawbacks have been the driving force behind this investigation of polyhydroxyamides, (PHAs), which are polymer precursors to PBO. At normal temperatures, PHAs themselves have good mechanical properties that are similar to Kapton and most polyimides. When heated, the precursor polymers can be cyclized to PBOs and absorb large amounts of heat during the cyclization reaction. In addition, they release a small molecule such as water during the cyclization reaction which acts as a flame suppressor. Derivatives of the polymers may release phosphorus or fluorine compounds depending on their structure. The cyclization reaction does not take place until temperatures over 200 °C are reached. The precursor polymer is stable and does not undergo hydrolytic instabilities.

Accomplishment Description: PHA solutions of 8 % in N, N-dimethyl acetamide (DMAc) with a high inherent viscosity of 2.28 dL/g have been synthesized from 3,3'-dihydroxybenzidine and isophthaloyl chloride. Fiber could be spun from these solutions using the dry jet-wet spinning equipment as shown in Scheme 1 using alcohol mixtures as the coagulant. The maximum strength and initial modulus of the unoriented PHA fiber was 127 MPa and 10.6 GPa, respectively. After cyclization annealing, these unoriented properties increased to 369 MPa and 29G Pa, respectively. PHA film was also made from this solution by spin coating. The maximum strength and initial modulus of the films were 134MPa and 3.3 GPa, respectively. After cold drawing and annealing, they increased to 368MPa and 12.9 GPa, respectively.

Significance: High strength and modulus PHA fibers and films have been obtained. Measurements on flammability via heat release on the FAA's microcalorimeter indicate they have flammability properties similar to PBO. These materials have the potential to be used as highly flame resistant fibers, coatings, and perhaps as electrical insulation/thermal barrier materials in high performance applications.

Expected Results: High quality PHA and PBO fibers can be obtained by drawing during spinning and by controlling other conditions such as the coagulant and air gap. It is our intent to optimize this process and to also investigate dry spinning. These materials will likely be scaled up to larger quantities to further investigate their utility and to obtain more detailed information on their flammability and high temperature performance.

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