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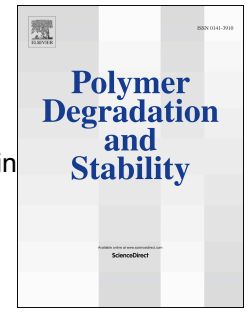

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Oxidation Reactions in Kink Banded Regions of UHMMPE Fiber-Based Laminates Used in Body Armor: A Mechanistic Study

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Abstract

This work demonstrates the synergy between the thermo-mechanical and humidity induced degradation as well as the oxidation reactions in the kink-banded areas of ultra-high molar mass polyethylene (UHMMPE) fiber-based laminates used in body armor. For aged materials, the energy-dispersive X-ray spectroscopy (EDS) and Fourier transform infrared spectroscopy (FTIR) results reveal high concentrations of oxygen containing products, and the EPR results demonstrate the presence of the peroxyl radicals ($RO_2^{\bullet}$) in the kink-banded areas. After one year of dark ambient storage, very long-lived $RO_2^{\bullet}$ radicals were observed primarily in the samples exposed to ageing conditions of elevated temperatures, humidity, and mechanical stress. The total percentage of crystallinity, as measured by differential scanning calorimetry, of the kink-banded fibers was unchanged, indicating that the degradation occurs primarily in the amorphous region, and may also involve recrystallization processes of the degraded chains. However, the most abundant orthorhombic crystalline phase decreases from 77 % to 70 %. This decrease in the orthorhombic structure leads to more diffusion of oxygen into the kink-banded region, enhancing the oxidation processes. No changes are observed in the monoclinic phase of the kinked fibers, which remained constant and constituted ~2 % of the total crystallinity.

Keywords: UHMMPE fibers, kink bands, body armor, free radicals, oxidation, degradation

1. Introduction

Modern body armors are commonly designed using flexible, ballistic-resistant fabrics made from high strength polymers such as ultra-high molar mass polyethylene (UHMMPE). This polymer can be processed via gel spinning into fibers with high tensile strength-to-weight ratios