Preparation and characterization of polyethylene fiber for carbon fiber production
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The objective of this study was to create a carbon fiber precursor from polyethylene fibers. Polyethylene is a low-cost plastic that has moderate strength and is amenable to thermal processing by proper functionalization. A stretchable, relatively low-crystallinity grade of fiber was drawn to achieve higher molecular orientation. Starting with this was advantageous because a higher polyethylene fiber orientation results in carbon fibers of greater strength. We determined the thermo-mechanical properties of the polyethylene fibers using a dynamic mechanical analyzer (DMA) and a thermo-mechanical analyzer (TMA). The DMA was used to perform tensile tests of the polyethylene fibers as a function of temperature. The resulting stress-strain curves were used to calculate elastic modulus, yield stress, yield strain and maximum stress. We obtained shrinkage force measurements using the TMA, which provides information regarding the amount of tension the polyethylene fiber exerts when heated and stretched. In the shrinkage force test, a constant strain is applied to the sample as the temperature is ramped up at a constant rate. Polyethylene fibers of differing compositions and draw ratios were compared using data from the DMA and TMA to find the conditions that yielded the highest modulus and yield strength. These tests were then used to determine the best polyethylene fiber stabilization and heat treatment conditions to produce carbon fiber. The resulting carbon fiber was tensile tested using a single-filament tensile testing technique. The peak stress and elastic modulus were calculated from the tensile test data. We found that carbon fibers made from drawn polyethylene fibers had a higher elastic modulus, compared to carbon fibers from undrawn polyethylene fibers. This work shows the viability of using polyethylene in the production of carbon fiber, which would substantially decrease the cost of carbon fiber, thus enabling its widespread adoption.