Is the future of plastics green?

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Since the pioneering advances of Hermann Staudinger, who introduced the concept of macromolecules in 1920, plastics have become an indispensable part of our daily lives and economy. Their attractive cost/performance ratio in conjunction with their exceptional versatility in terms of tailored property profiles, applications, processing, flexible choice of raw materials, and recycling is unmatched by other materials. The annual world plastics production has surged from 15 million tons in 1965 to around 350 million tons today and is projected to exceed 1.4 billion tons in fifty years fueled by the urgent need for plastics by the rapidly growing world population. According to the Ellen Mc Arthur Foundation, plastic packaging accounts for more than 26% of the total volume of plastics used worldwide, but less than 14% of this packaging waste is recycled world-wide today. We must abandon linear economy with its throw-away spirit and move to circular economy with high resource and energy efficiency, eco-friendly processes and products, effective recycling and product-stewardship systems. Indeed, the future of plastics is going to be sustainable and green meaning that we must apply the principles of green chemistry as stated by Paul Anastas and John C. Warner in 1998. Green polymers are not synonymous to biopolymers. In ideal way polyolefins meet the demands of green chemistry. They are the clear leaders in terms of world-scale production and life cycle assessment. Produced by solvent-free, environmentally benign catalytic olefin polymerization, polyolefins are well-established as highly versatile, cost-, resource-, eco- and energy-efficient lightweight materials. Olefin monomers are available from fossil resources like oil and gas but also from renewable resources like sugar cane and algae and even carbon dioxide conversion to hydrocarbons appears to be industrially feasible. As hydrocarbons polyolefins possess oil-like high energy content. Upon thermolysis high molar mass hydrocarbon polymers are readily converted back into low molar hydrocarbon oil and gas useful as raw material and energy source. In future, chemcycling exploiting hydrocarbon polymer wastes represents a viable option for circular economy. However, in numerous engineering applications polyolefins require reinforcement with alien fibers and fillers which impair recycling. In terms of sustainability it is highly desirable to develop all-hydrocarbon composites (All-HC) in which matrix and reinforcement are made of the same hydrocarbon polymer. Today All-HC are fabricated by specialized processing techniques like hot compaction of stretched tapes, fiber lamination, or melt extrusion through convergent dies. Ethylene polymerization on multisite catalysts affords All-HC processable by conventional injection molding. During polymerization nanophase separation of ultrahigh molar mass polyethylene (UHMWPE) prevents massive entanglement and enables injection molding of polyethylene with high UHMWPE content. During molding flow-induced 1D crystallization produces ultra-strong, extended-chain UHMWPE nanostructures with diameter of <100 nm resembling nanofibers which nucleate HDPE crystallization to form shish-kebab-like reinforcing phases. Self-reinforced polyethylene exhibits an exceptional combination of simultaneously improved stiffness, strength, toughness and abrasion resistance without impairing sustainability. For the first time, material recycling of All-HC wastes by melt processing is feasible. The development of All-HC closes the gap existing between easy-to-process commodity HDPE and high-performance UHMWPE requiring special processing.