

Preface

The possibility of long-chain molecules was established at the start of the twentieth century through the pioneering work of Hermann Staudinger (1920), who was awarded the Nobel Prize in Chemistry in 1953 “for his discoveries in the field of macromolecular chemistry.” Much of the twentieth century was dominated by the ingenious work of synthetic organic chemists in producing polymers with particular chemical configurations and molecular lengths. The first to dominate the field were Giulio Natta and Karl Ziegler whose work led to the commercial production of stereoregular alpha olefins such as polypropylene (Natta 1967). The contribution of Karl Ziegler was the discovery of the first titanium-based catalysts. Giulio Natta used such catalysis to prepare stereoregular polymers from propylene. Both were awarded the Nobel Prize in Chemistry in 1963.

Other developments have built on these early steps. In the 1950s, scientists at Phillips Petroleum discovered that chromium catalysts are very effective for the low temperature polymerization of ethylene, which launched major industrial technologies. A little later, Ziegler discovered that the combination of titanium chloride and ethyl aluminum sesquichloride gave comparable activities for the production of polyethylene. Natta used crystalline α -titanium chloride in combination with triethyl aluminum to produce the first isotactic polypropylene. In the 1960s, BASF developed a gas phase, a mechanically stirred polymerization process for making polypropylene which led to the UNIPOL process, which was commercialized by Union Carbide to produce polyethylene. Later in the 1970s, magnesium chloride was discovered to greatly enhance the activity of the Ti-based catalysts. These catalysts are so active that the residual Ti is no longer removed from the product. They enabled the commercialization of linear low-density polyethylene (LLDPE) resins and allowed the development of noncrystalline copolymers. These developments and similar research have transformed plastics from an oddity only suited to Hula-Hoops into a major technological materials industry with a total global demand of over 200 million tonnes.

Functional polymers appeared in the second half of the twentieth century. Although polyaniline was first described in the mid-nineteenth century by Henry Letheby and polypyrrole derivatives were reported to be electrically conducting in 1963 by B.A. Bolto et al. (1963), substantial progress was not made with intrinsically conducting polymers until the pioneering work of Hideki Shirakawa, Alan J. Heeger, and Alan MacDiarmid who reported similar high conductivity in oxidized iodine-doped polyacetylene in 1977 (Shirakawa 1977). For this research, they were awarded the 2000 Nobel Prize in Chemistry “for the discovery and development of conductive polymers.”

Liquid crystal polymers and elastomers (Donald et al. 2006), dendrimers (Hawker and Fréchet 1990), and block copolymers (Szwarc 1956) also appeared in the second half of the twentieth century. Today we can select polymers with many different properties and functions. Of particular current note is the development of photovoltaic devices which are beginning to show considerable promise. However, in the field of photovoltaics, researchers have found that it is not just the ingenuity of the molecule makers that delivers the efficiency but also controlling the morphology. Controlling the morphology is a major tool in polymer science and engineering. It enables chemically the same material such as polyethylene to be exploited to produce low-cost plastic bags as well as bulletproof vests.

This book sets out to embrace this control of morphology recognizing from the outset that the different scales of structure are connected. As Natta discovered the precise positioning of the methyl group in polypropylene leads to a high crystallinity and without precise positioning to a poor quality amorphous polymer used in roofing membranes, others have identified that the control of that crystallization process leads to clear packaging material which constitutes about half of the 60 million tonnes of polypropylene-based materials used in 2013.

Like the scales of structure, the contributors to this book are all interconnected in a myriad of ways. At the core, connecting many is the highly successful Reading Polymer Physics Group, later morphing into the Polymer Science Centre at the University of Reading. It was there that Alison Hodge, Robert Olley, and David Bassett optimized the permanganic etching process for revealing the morphology of semicrystalline polymers (Olley 1979). The advent of time-resolving X-ray scattering at synchrotron-based beamlines (Keates et al. 1994) has greatly added to the ability to follow in real time the development of structure and morphology during processing. Not all good things go on forever, and the University brought the curtain down on polymer physics at Reading in 2010 with the closure of the Department of Physics. With every closing door, another opens and so please check out controlling morphology during 3D printing in Chap. 7. The future is direct digital manufacturing as Mr. McGuire¹ might say.

¹Mr. McGuire (played by Walter Brooke) is a character in the motion picture “The Graduate” who said in the movie “Plastics,” followed by “There’s a great future in plastics,” to the graduate Ben Braddock played by Dustin Hoffman, which is one of all-time top 100 quotes judged by the American Film Institute.

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