Polymers – Molecules, Materials and Mathematics

It is a delight to write a small introductory contribution for this way-marking book. Its pages direct our gaze over the territory we have crossed in the plastic materials revolution, then turns it towards the more veiled future of possibility and potential. At every point the story connects the molecules themselves with the chemists making them, and the laboratories in which they were first synthesised and measured. We connect the processes, the pioneering materials engineers and scientists with the fibres, films and mouldings that we now use every minute of our days. It's an honest account that assesses both the great advantages of plastic materials, and the challenges they present to our pressing need for a sustainable materials economy. Like all science and technology, it's a story of people, places and a global community - and this is the ultimate reason to be hopeful. The international community of science brings together a love of curiosity, of truth, and of boundless technical competence. It's a winning combination.

From a personal perspective, working on polymers with academic teams and our industrial collaborators for the last thirty years has been an enormously enriching experience. Few other fields can boast of such an integrated community of researchers, so connected and mutually diffusive. There is a great secret about working with industry, for the university researcher, that seems continually to escape the comprehension of government, who repeatedly chant the myth of a linear progression of ideas from universities into the 'applied' world of industry. This does happen of course, albeit in a much more complex and nonlinear way. But the main motivation for an academic to work with industrial scientists is that they are so good at what they do, think in different ways, and come up with such fascinating problems. Phenomena that unlock deep fundamental science questions frequently arise in industrial contexts. One reason for this is simply that the commercial imperative drives industrial scientists along pathways of complexity far beyond the point where their academic colleagues' courage would have failed. Sir Sam Edwards of Cambridge University taught many of us this truth, which holds as strongly for the theoretical physicist as for the polymer chemist. Who would have guessed, for example, that the mathematical physics for a polymer corresponded to the trajectory of a quantum particle in imaginary time (it's true!)? Earlier in his career in Manchester, with the experience of quantum field theory behind him, and looking for new problems, Edwards decided to cross the road to the Chemistry department and tracked down Henry Gee. It turned out that no one really understood the size of a polymer coil in solution…

It is this reciprocal exchange of ideas and people that drives the most radical innovation, and surely will during the rest of this century. If polymers have dominated the materials revolution in the last generation, then they surely must in the next as well, though the social and technological challenges are shifting. Polymers and plastics have provided lighter, stronger materials for transport, coatings, and electronics. They have, through advanced packaging, opened the way for long-distance transport of foods, pharmaceuticals and more. High performance aerospace, medical products and new high energy-density batteries rely on them. Yet if we have navigated these challenges of moving to a global materials economy using oil-based feedstock in a previous phase, then the next goal must be to meet the urgent requirement of sustainability, on the basis of a renewable and cyclic economy. A strong encouragement is that we know this to be possible, since biology has already achieved it – and also with polymeric materials as the molecular structures of choice. The molecular design and detail of living structures is exquisite, of course, compared with even the finest grades of polyolefins from the most bespoke catalysts, but we learn continually. Adding the discipline of biology to those of engineering, chemistry and physics looks like the next move in the continuous polymer materials revolution.

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