What Are Core Polymer Chemistry and Physics?

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From the clothes we wear, the computers we use, to the airplanes we fly in, polymers have completely changed how mankind lives. It is perhaps true that from the first second one opens one's eyes after birth to her/his final breath, there is a scarce chance in consciousness that she/he is able to avert her/his eyes from surrounding polymer materials. It is difficult to imagine our modern world without polymers.

Over the past ~80 years, polymers have, from a mere concept, developed into a very lively research field, and from there to a multibillion dollar industry. In the process, there have been both inventions of new chemistry and unearthing of fundamental physics, all of which have filled volumes of textbooks. The fruitfulness of the field is perhaps best represented by the fact that it is estimated that over 70% of all chemistry graduates' careers are sooner or later related to polymers. And in China alone, there are currently over 30 000 people who are studying, teaching, and researching in polymer-related fields.

After its rapid developments in the 1950–1970s, the polymer field has gradually matured and, as with many mature scientific disciplines, we researchers are faced with the inevitable and daunting question of "what should we do next?" Over the past 20 years, answers have been supplied by polymer researchers, especially those employed in academic institutes, in the form of repackaging existing polymer science into new fields with "new" names, such as "nano-", "soft matter", "self-assembly", "supramolecules", and so on.

There is nothing inherently wrong with the migration of polymer researchers to new research areas (e.g., into bio- and food-related problems) because knowledge and expertise in macromolecules can be used to advance other areas by approaching their problems from different angles. However, it would be a false claim that these polymer scientists are still working on core polymer chemistry and physics. It should be especially alarming if most polymer researchers are driven into other fields by factors such as funding, "fashion", "impact factors", and publications.

The trend of deviation from core polymer chemistry and physics is evident if we examine the subfield trends of manuscripts published in polymer journals. The publication records of *Macromolecular Chemistry and Physics* over the last decade show that two very active subfields—the self-assembly of block copolymers and "living" free-radical polymerization—account for close to 40% of all its article publications in recent years (compare this with only around 15%–20% in the early 2000s), as shown in Figure 1, where the overlap between the two subfields has been addressed in the calculation. The examination

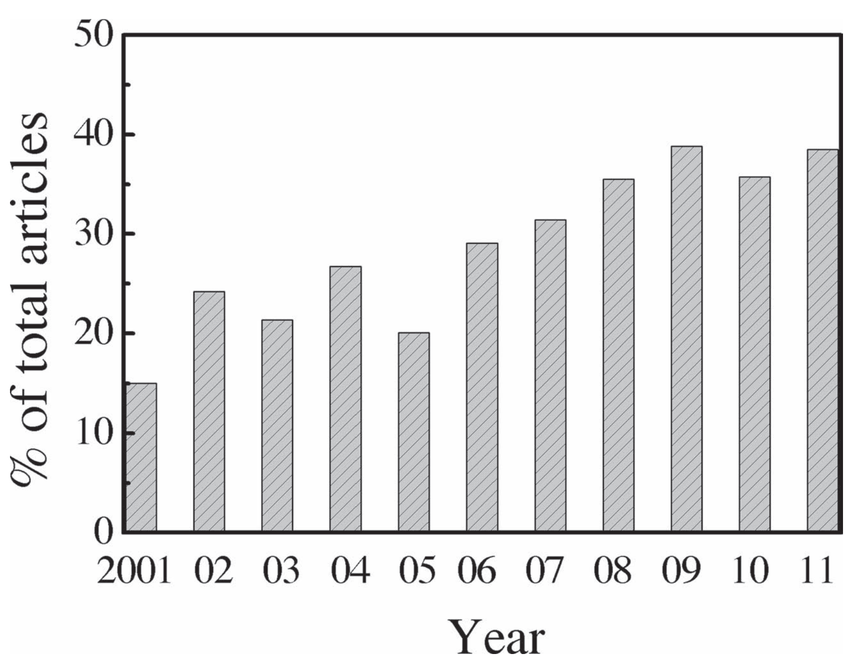

Figure 1. Percentage of articles related to topics of assembly, block copolymer, ATRP, RAFT, and LRP in *Macromolecular Chemistry and Physics* (statistics source: ISI database).

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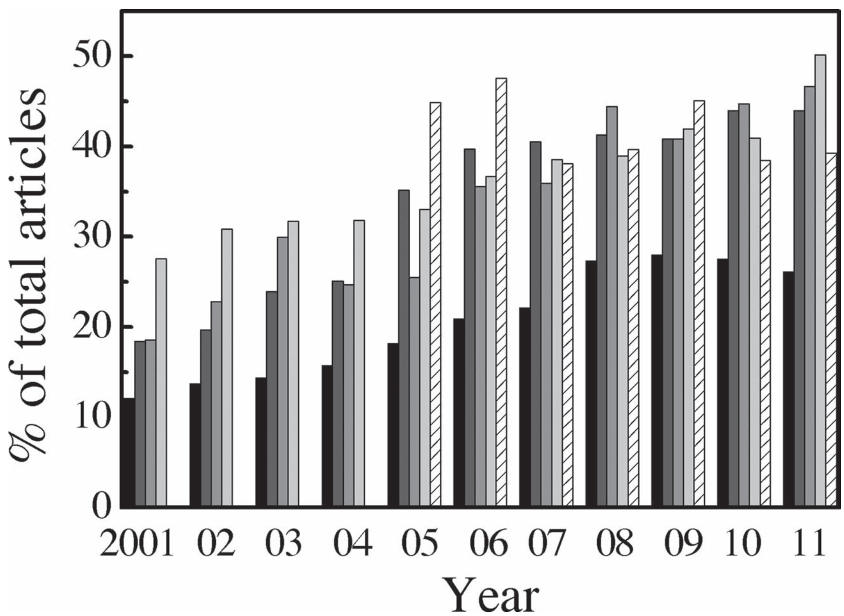

Figure 2. Percentage of articles related to topics of assembly, block copolymer, ATRP, RAFT, and LRP in five other polymer-related journals (statistics source: ISI database).

of publication records of five other polymer-related journals shows a similar trend (Figure 2, journal names are suppressed). The absolute percentage varies among different journals because of their different scopes, but these figures are all doubled in the last decade except for one journal that has a high number since its circulation in 2005.

These two aforementioned sub-fields are without question very important developments in polymer science over the last two decades. It is still extremely important and difficult to assemble and develop block copolymers into useful materials for real applications or to search for new catalysts and procedures to make "living" free-radical polymerization large-scale industrial processes. However, the directions which many researchers in these sub-fields have embarked on do not touch on core polymer chemistry or physics. Many researchers have simply used different block polymers to repeatedly make various, occasionally exotic structures or used "living" free-radical polymerization to prepare different kinds of polymers that neither have any intellectual value nor tackle any specific practical problem.

In my opinion, the polymer community has gradually lost its focus and identity in recent years, with this being particularly true in China. A brief examination of polymer history shows what are the cores of polymer chemistry and physics. Polymer chemistry has traditionally been centered on developing new catalysts and polymerization reactions, from Ziegler–Natta to metallocene catalysts for polyolefins, from conventional free-radical to recent "living" free-radical polymerization, and from solution or bulk to dispersion or suspension reactions. On the other hand, polymer physics has always revolved around problems in polymer processes and correlations between chemical structure and physical properties by applying and inventing many experimental methodologies including ultracentrifuge, X-ray, neutron and laser light scattering, UV–Infrared and Raman spectroscopy, size-exclusion chromatography, osmotic analysis, viscoelastic, dielectric, and mechanical measurements.

Nowadays, it is much easier for polymer chemists to make polymers with different compositions, conformations, and topologies using already existing polymerization methods because many monomers are commercially available. If no further questions are asked about the relevance of these synthesized polymers to scientific or practical problems, then there is little actual science. With widely available instruments, it has become facile for polymer physicists to characterize a range of physical properties of a given polymer material and then to present the findings in the form of a "scientific" paper, which in actuality bears greater resemblance to a technical report. To illustrate this point, I refer to the fact that only in a few polymer papers nowadays authors do actually report the absolute molar masses of the polymers used. Since it is known that polymer properties are closely related to the average chain length and its distribution, this suggests that only few people are doing quantitative research nowadays. This situation is particularly serious in China, where many polymer laboratories have bought laser light scattering spectrometers over the past 20 years but only few of them have been used to characterize a polymer's absolute molar mass. The simple reason for this is because it is time-consuming to characterize this parameter, which conflicts with the need for researchers to hurriedly publish their "papers" in "high impact" journals to please their chairmen, deans, and administrators.

So what are core polymer chemistry and physics? In my opinion, aside from making existing catalysts and polymerization conditions optimal, polymer chemists should focus on developing new catalysts, new synthetic methods, and new polymerization processes. These are not easy tasks, but if change and progress are to take place in polymer chemistry, there is really no choice. An area that should be of particular interest to polymer chemists is that of biocatalysts and biosynthesis because of the inevitable exhaustion of crude oils and natural gases on which the modern polymer industry has been built. But in order to venture along that direction, polymer chemists will have to learn molecular, cell, structural, and microbiology. For polymer physics, the focus should still lie in the development of novel methodologies to solve remaining fundamental problems that are related to polymer processes by concentrating on correlations between polymer properties and chain structures as well as process conditions. By understanding these better, we can then improve the properties of those existing polymer materials and extend their applications to new areas. Only in this way, polymer researchers can distinguish themselves from the researchers of other fields.

In summary, polymers are real materials with real problems and applications. Polymer research should be problem-driven and its results should either have intellectual value, thus ending up on a bookshelf, or commercial value, thereby ending up in a shop. There should really be nothing in between.

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