Closing remarks

A conclusion is the place where you got tired of thinking. (Martin Fischer)

. . . A well known quote. . . but it does not apply to the topic of polyurethanes ☺.

Conclusions on polyurethane research are like circles as they end where they begin. The topic is inexhaustible. Progress in polyurethane development is being made continuously. Polyurethane research is as organized as a spider silk, where the most difficult part, the construction of the first thread (on which the rest of the web is hanging) was made decades ago. But the wheel-shaped webs, their bridges, are built continuously by every novel valuable contribution to polyurethane research while the whole web is extended by progress of research continuously expanding.

The world of polyurethanes is enormous, and so it is the literature that has been dedicated to these materials over the past seventy years. Academia and industry have equally brought contributions of very high merit to the development of polyurethanes. Thus, obviously it is impossible to write a book about polyurethanes where to include all the valuable works that have been reported in this field.

Therefore in this book I only referred to *particular* aspects, regarding the synthesis and characterization model and novel polyurethane elastomers.

The objective of this book was to review, evaluate and improve understanding of the relationship between molecular/supramolecular architecture, and nm-scale and macroscopic mechanical properties of this uniquely versatile family of polyurethanes categorized in engineering elastomers. The study included numerous conventional block polyurethane elastomers, based on several diisocyanates, macrodiols and chain extenders.

The book reviews aspects from the up-to-date literature focus on these topics. In addition, in order to widen the range of structures achievable beyond those normally available, in this book I also included recent developments that have been made by us, by producing polymers based on the diisocyanate of variable geometry, 4,4'-dibenzyl diisocyanate (DBDI) (only available from Romania), that allows the variation of hard domain crystallinity as a key structural variable. The conformational mobility of DBDI causes an unusually wide range of mechanical, physical and chemical properties, associated with the possibility of pronounced phase separation

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into a domain - matrix morphology, and with a high tendency to crystallization and self-association by hydrogen bonding, which is not available with the conventional diisocyanates in traditional melt-cast polyurethanes. The mechanical performance of such elastomers has been shown to be strongly affected by the higher-ordered structure of hard segments on the macromolecular chain.

In the present book, materials derived from the diisocyanate DBDI were mainly compared with the conventional diisocyanate 4,4'-diphenylmethane diisocyanate (MDI), as one of the most representative and commonly used aromatic diisocyanates.

A key feature of the work described in this book, has been to focus on materials synthesized in the Romanian laboratory, under known and controlled conditions with known reactants. I consider this is a much more promising route to doing good science than working with commercial materials where the exact synthesis conditions and composition are likely to be unknown. Science is feasible when the variables and their combinations are distinct and clear. We are tending toward the condition of science and aspiring to do it.

What it has not been done in this book:

(1) – the block copolyurethanes, consisting of isocyanate hard segments, macrodiol soft segments and chain extenders, represent an extraordinarily versatile family of polymers, where a wide variety of physical properties may be achieved via variations in chemical composition and synthesis route. However *our* research described in this book had to be limited mainly to the comparison between the novel DBDI materials and conventional materials obtained with hard segments of MDI. Further developments by also including other diisocyanates, macrodiols and chain extenders will be reported in another book to be published in year 2013;

(2) As shown in the present book, in recent years, we have made a series of studies of different aspects of the mechanical behaviour of these materials, aimed at improving our understanding of the way macroscopic properties of these materials depend on chemical structure and nm-scale physical structure. However, in view of the difficulty of knowing in detail the physical processes active on the nm scale of elastomers, there still is an urgent need for more comprehensive information on the sensitivity of the inelasticity to structural detail on the nm scale. There have been many attempts to explain the inelastic features and to capture them in constitutive models, with some success at the phenomenological level. But, somewhat inevitably in view of the difficulty of knowing in detail the physical processes active on the nm scale, much of previous work in this area has been speculative in terms of providing a physical interpretation. For progress to be possible, there is an urgent need for more comprehensive information on the sensitivity of the inelasticity to structural detail on the nm scale.

(3) Further work is planned, to exploit a series of novel partially or fully deuterated polyurethane elastomers recently made by us, in obtaining a better understanding of the relation between mechanical properties and the nature and degree of phase separation that occurs in these polymers. The ongoing research in this area will be included in our further book.

(4) Due to the limited length of the book, particular aspects like thermal investigation as revealed by thermogravimetry or thermomechanical analyses had to be limited to only a few examples of DBDI based polymers.

(5) Similarly, due to the same reason, in the present book I had to refer only to few aspects regarding the synthesis and characterization of polyurethane ureas. I have mainly focused on polyurethanes extended with diols because our most recent works are dedicated to the investigation of polyurethanes with diols. Further works on the chemistry, morphology and mechanical performance of polyurethane ureas based on isocyanates of variable geometries will be included in our second book.

(6) Some people write beautifully and effortlessly while others feel like they are sweating out each word. But over time authors with both writing styles make successful contributions to science. For myself it has not been quite easy to write this book as a non-native English speaker. I often felt that *inspiration* is what is the tail for a cat. You cannot catch it, but it follows you if you ignore it ☺.

As always, a conclusion is a chance to have a final say, to summarize thoughts, to demonstrate the importance of the ideas developed in the book so to give the readers an overall view. This is what I attempted to do here in the hope readers have enjoyed this book, but while I am also aware that, as Leonardo da Vinci said, for readers *"it is easier to resist at the beginning than at the end."* ☺

I hope this book will inspire you to take action as well and continue to embark on further study in the so challenging field of polyurethanes. Our mobility is such that we can ask questions and answering them. Our curiosity and willingness are insatiable. Our mind is in constant turmoil, solving problems, accumulating knowledge within a short range of time. Our chances and our ideas turn our daily life into a mosaic of intense moments, where the joy of doing valuable research plays a key role. The future of polyurethanes fundamental research and industry will be driven by the continued innovation in both the chemistry and the polymer physics of these highly versatile materials.

However, as Paul Valery said, *"the trouble with our times is that the future is not what it used to be"*.

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